An Examination of Slip-and-Fall Safety Assessment, Standards and Auditing

The author examines the history and development of assessment standards for auditing hard-surface floors for slip-and-fall safety.

>> By Brent Johnson

With the growth in popularity of hard-surface flooring and coatings, globalization, advancement in technologies, floor failure and slip-and-fall costs soaring into the billions, the importance of following industry and trade standards of care prudent to the related industries has become critical.

With this significant growth and fast-paced evolution, now more than ever, as related-industry professionals, we owe it to our clients and end users to pause and review this evolutionary process, evaluate how these changes have affected the inter-industry relationships, and identify the new challenges we face moving forward.

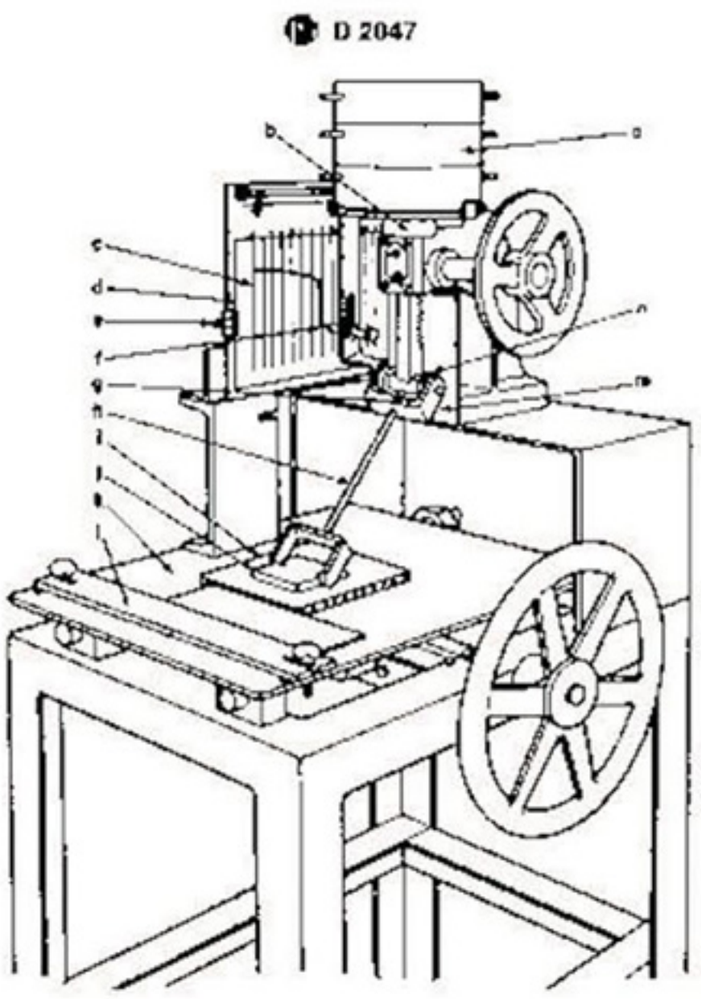
All one has to do is attend shows such as Surfaces and World of Concrete, held in Las Vegas, to realize how fast technology and growth have affected all hard-surface floors. No longer can we rest on our laurels of "doing it this way for thirty years," as materials are no longer made or made the same way. With popularity comes a cost to health and safety, as slip-and-fall incidents on hard-surface floors continue to soar. As a result, hard-surface walkway audits and hard-surface inspections have taken on added importance.

The ADA and Slip-and-Fall Safety

The 1990 Americans with Disabilities Act (ADA), and the subsequent U.S. Access Board "Bulletin #4: Ground and Floor Surfaces," issued in August 2003 (www.access-board.gov), established the foundation for industry practices relating to slip-and-fall. According to "Slip Resistance and the ADA: Separating the Facts From the Marketing," an article by Christopher Capobianco, in *The Flooring Contractor*, Winter 2007, "The ADA Accessibility Guidelines (ADAAG) requires only that newly constructed or altered ground and floor surfaces of accessible routes on sites and in building and facilities be stable, firm and slip-

resistant. Although the Appendix to ADAAG contains advisory recommendations for slip resistance values derived from Board-sponsored research, and in A4.5.1 suggested some values but without a defined test procedure, these recommendations cannot be applied."

After many provocative discussions among materially interested parties, subject-matter experts and interindustry-related ASTM committees and ANSI standard-writing bodies such as the Institute of Inspection Cleaning and Restoration Certification (IICRC), the Tile Council of North America (TCNA) and the National Floor Safety Institute (NFSI), some have or are in the process of publishing standards and other publications related to hard-surface floor testing and performance. Floor covering and coatings, substrate/subfloor suitability, cleaning and maintenance, chemical walkway treatments, mat testing and installation are some of the subjects covered by these organizations' publications and standards. When used properly, these publications can reduce the possibility of slips and falls, decrease exposure to possible litigation and help protect the health, safety and welfare of built-environment occupants.



The James Machine

The History of Slip-and-Fall Testing

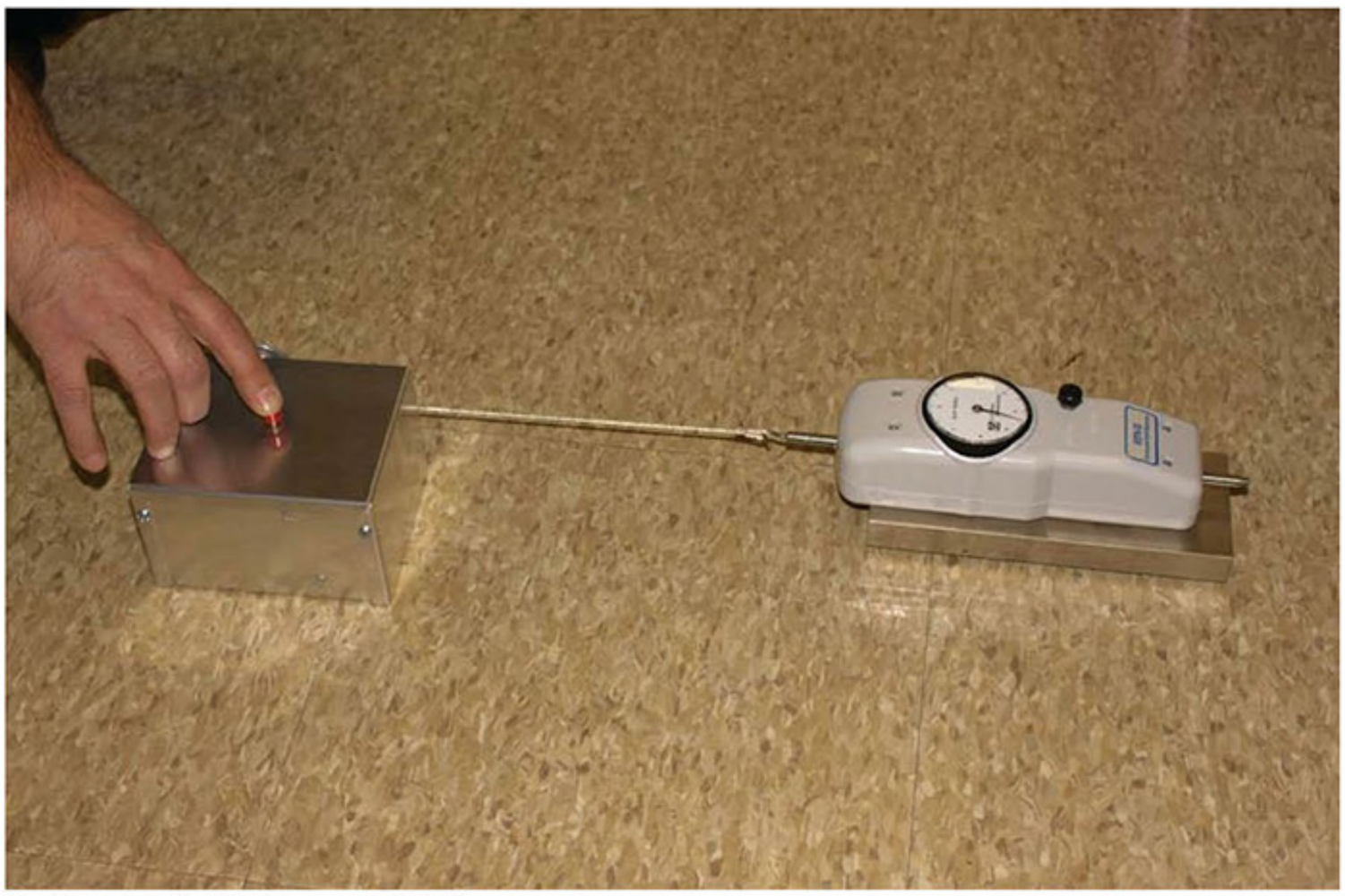
Slips and falls have plagued not just modern man but have been documented as far back as Leonardo da Vinci (1452-1519). I still recall the thrill in the science teacher's face when he demonstrated how, by pulling masses of varying sizes and shapes across different surfaces with a fish scale, he was performing the same experiment on coefficient of friction (COF) that da Vinci did way back in the 16th century. While the basic physical laws involved in the measurement of COF have and will always remain the same, interpretations and applications for those laws have been greatly expanded in modern times. In particular, the use of COF to document the available traction of walking surfaces to increase pedestrian safety continues to develop.

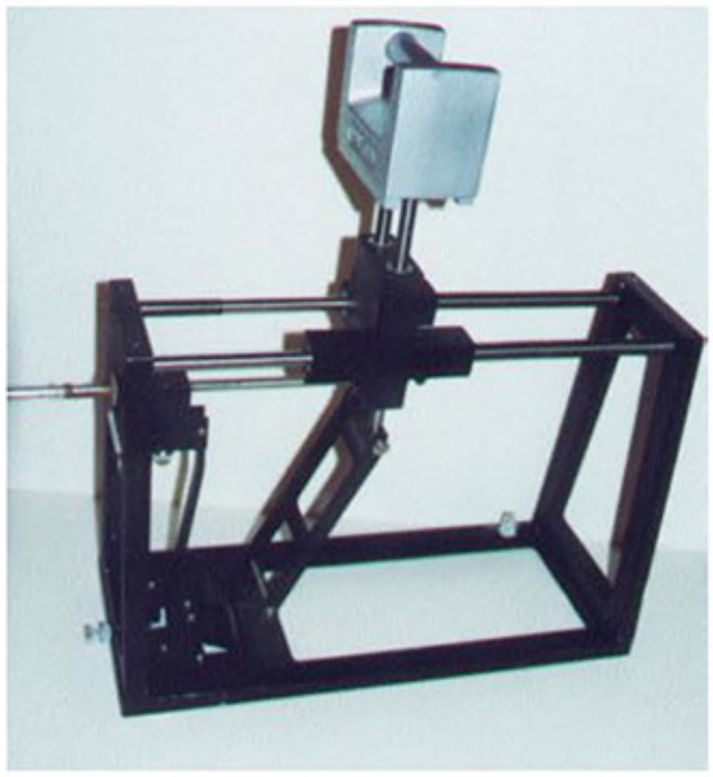
Although Leonardo da Vinci was ahead of his time, the application of measuring the *static* coefficient of friction (SCOF) to prevent slips and falls, did not start maturing until the 1930s, when Sidney James, in collaboration with Underwriters Laboratories (UL), developed the "James Machine." At that time the vast majority of footwear soles were comprised of leather and the prevalent walking surface was waxed, thus the development of a testing standard using this machine only incorporated these two parameters. While the research performed by UL in its day was groundbreaking, its usefulness became limited with the development of various types of footwear soles and modern coatings and finish technologies. In addition, the test had to be performed in a laboratory environment and it only tested for SCOF in a dry state.

Because the James Machine is a large, stationary testing device that is impractical for field testing, the necessity of on-site testing gave rise to multiple portable devices being developed to measure the COF of walking surfaces. This testing methodology is much more practical, as it tests the walkway surface under the actual conditions it is being used and maintained, providing real-time useable information to the end user.

The early tribometers were direct offshoots of the da Vinci invention and while some were cloaked in different exteriors, they were still drag-sled devices patterned after their ancestor. One of the earliest innovations was the "Topaka" or "Bean Bag" tester, as it became known. This device used a motorized reel to give a consistent speed to the pull of the scale attached to a bean bag with a known mass. While portable, it needed an electric cord, limiting its usability in the field.

The next innovation was the Horizontal Pull Slipmeter (HPS) developed at the Liberty Mutual Research Center. This device used a battery-operated reel for a consistent pull speed and replaceable


Horizontal Pull Slipmeter (HPS)



Brungraber English XL

BOT-3000

Neolite sensors for the surface contact. This was an improvement over the bean bag, as the Neolite was more reproducible and consistent. Additionally, this device used a dial instead of a scale that measured a "slip index," not the COF. The HPS device has an ASTM standard associated with it, the ASTM F609.

Another portable device with an ASTM standard attached is the ASTM C-1028 (recently withdrawn by the ASTM C21 committee). This device was developed for testing in the ceramic tile industry. While it is a portable drag sled, it weighs 50 pounds, rendering it cumbersome for field-test purposes.

Three very portable devices that received widespread use that are not drag-sled devices are the Brungraber MK II, MK III and the English XL. These devices use an articulated strut over a Neolite sensor. The Brungraber MK II is powered by a ten pound mass and gravity, while the MK III is spring driven and the English XL is powered by a disposable CO_2 cartridge. These devices had national standards associated with them, however, the standards were withdrawn in 2006.

With the advent of the miniaturization of computer technology, smaller automated portable devices were able to more accurately measure COF. The American Slip Meter is a human-pulled device that contains a PC board and displays the SCOF results digitally. The BOT-3000, manufactured by Regan Scientific Instruments, not only displays its results digitally, it is self propelled and can measure dry SCOF, wet SCOF as well as wet *dynamic* coefficient of friction (DCOF), taking the human error of pulling the device completely out of the equation.

Commonalities and Differences of Static and Dynamic COF

While all of these devices use a slightly different testing method, they all do essentially the same thing: measure the COF, in other words, the available traction of a walkway. Some measure "slip resistance index," some SCOF and some dynamic or kinetic COF. Since all current ANSI and ASTM national standards that deal with walkway testing call for the measurement of COF, the "slip resistant index" devices cannot be taken into consideration in regards to these national standards.

It is critical to understand the commonalities and differences between *static* COF and *dynamic* COF and *wet* measurement and *dry* measurement. Each of these methods yields information about an important aspect of the walking surface. Just as a medical professional takes into consideration different aspects of a person to determine their overall health, so the auditor takes into consideration the different attributes of a walkway surface in order to determine its overall performance. For example, only considering the measurement of DCOF and not taking into account SCOF, leaves valuable information out of the equation. Worse, this limited testing could leave the installation contractor, cleaner, end user or owner of a walkway with an exposure to a slip and fall and possibly litigation. Therefore the discussion continues among industries that, in conjunction with the appropriate testing standard, it is critical that the walkway COF audit be comprehensive and evaluate both dynamic and static COF when indicated.

Static COF measurement has been the most common walkway performance measure in the U.S. According to *ANSI/NFSI B101.1-2009 Test Method For Measuring Wet SCOF of Common Hard-Surface Floor Materials*, "SCOF is the ratio of the horizontal component of force applied to a body that just overcomes the resistance to motion (slipping) of the vertical component for the weight of the object or force applied in the vertical direction." In practical terms, SCOF can be described as the "slip potential" of the walkway surface. For this reason,

SCOF is an extremely important indicator for slip prevention and should be considered in the evaluation of the available traction of a walking surface. Dr. Fred M. Johnson, former chairman of the Physics Department at California State University-Fullerton states, "It is the SCOF and not the dynamic COF nor the Slip Resistance Index that is relevant for walking safety."[1]

Under normal human ambulation, the moment when a person's heel strikes the floor surface is the time that the heel must decide if there is enough available traction to keep from slipping forward. "The heel strike phase is typically the most critical phase with respect to slips because of the forward momentum of the pedestrian's body mass. This generally results in a forward slide of the lead foot if a slip occurs." (Redfern et al., 2001).[2] At the point of heel strike, the heel is in a static state and its traction demand is at its highest. If the available traction or SCOF is not sufficiently high, the heel will overcome the resistance of the surface and slip forward. The person may at that time have a noticeable slip, or it may be small enough that it is not even noticed. If the available traction is adequate, the stride will continue. Because this process is repeated with every stride and heel strike, the SCOF of a walking surface is an important attribute of the surface to know when trying to maintain walkways in a high-traction state.

The *dynamic* COF of a walking surface is different yet equally important. However, for this aspect to come into play, the available traction as measured by the SCOF must be insufficient to propagate a normal stride and a slip has to occur. According to *ANSI/NFSI B101.3-2012 Test Method For Measuring Wet DCOF of Common Hard-Surface Floor Materials*, DCOF is defined as "The ratio of the horizontal component of force applied to a body required to overcome resistance to movement when the body is already in motion divided by the vertical component of the weight of the body or force applied to the surface where movement occurs." In practical terms, the DCOF measures the "slide potential" of a walking surface.

At the moment the SCOF is insufficient to maintain traction and a slip occurs, the importance of a high DCOF, or low slide potential of a walking surface, becomes evident. When the traction demand overcomes the SCOF and a heel begins to slide, if the DCOF is high, the person may just feel a small slide. We have all had the feeling of "Oh, I almost slipped" after we have caught ourselves. However, if the DCOF is low, the heel will continue its forward slide, sometimes quickly and violently enough that the person may suffer severe injuries from the ensuing fall. This "slide potential" is the reason that the DCOF is also a critical component of walkway performance.

The ANSI/NFSI Testing Protocols

Current national testing standards take both of these factors into consideration. The *ANSI/NFSI B101.1-2009 Test Method For Measuring Wet SCOF of Common Hard-Surface Floor Materials* is the most recently published standard for measuring the SCOF of walking surfaces. The *ANSI/NFSI B101.3-2012 Test Method For Measuring Wet DCOF of Common Hard-Surface Floor Materials* is the most recently published standard for testing the DCOF of walking surfaces. These two standards, in conjunction with the *ANSI/NFSI B101.0-2012 Walkway Surface Auditing Procedure for the Measurement of Walkway Slip Resistance*, provide business owners and interested parties procedures for testing walking surfaces in public and private facilities. The ranges outlined in these standards give useful meaning to the readings acquired during the testing procedures.

The *ANSI B101.3-2012* standard was developed to harmonize with that of Europe's ISO/DIS 10545-17, BGR 181, and DIN 51130, 51131 and 51097 standards. Instead of a pass/fail number, the *ANSI/NFSI B101.1* and *B101.3* standards provide ranges that indicate risk categories. These ranges are: 1) low traction, 2) moderate or acceptable traction and 3) high traction. The break point between each of the ranges is an action limit that indicates that remediation should be undertaken to raise the COF and reduce the risk of a slip and fall. It is up to the user of the standard to decide the amount of risk they are willing to tolerate. For some users, the "moderate/acceptable" range is a sufficient level of risk; for others, only the "high traction" range will satisfy their risk tolerance. Each user is free to decide the level of risk they are willing to tolerate.

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Other related standards still in common use today include the *ASTM D2047* standard for testing floor finishes. This standard still uses the James Machine with a dry leather sensor. Floor finish manufacturers still use this standard today because it is designed especially for their industry. Also, for work facilities' walkways, the *ANSI/ASSE 1264.2 Walking and Working Surfaces* standard, which suggests a 0.5 dry SCOF be maintained, is widely used. This standard encompasses many other facets of facility safety and is widely used in the safety engineering field to test and promote safety.

The ANSI A137.1 Testing Protocol

The September/October 2013 www.tile-magazine.com, quoting a TCNA technical bulletin, states, "Starting early in 2014, with the ASTM C1028 method for measuring COF headed for obsolescence, many ceramic tile manufacturers will only report their tile's COF per the new DCOF AcuTest℠. And, the ceramic tile standard (ANSI A137.1) now specifies a required COF of ≥0.42 for level interior tiles that will be walked on when wet."

This new test method can be found in section 9.6 of *ANSI A137.1-2012*. In this section, the procedure for DCOF testing outlines the method for Quality Control DCOF testing for the ceramic tile manufacturer. Following is the purpose and scope quoted from the A137.1:

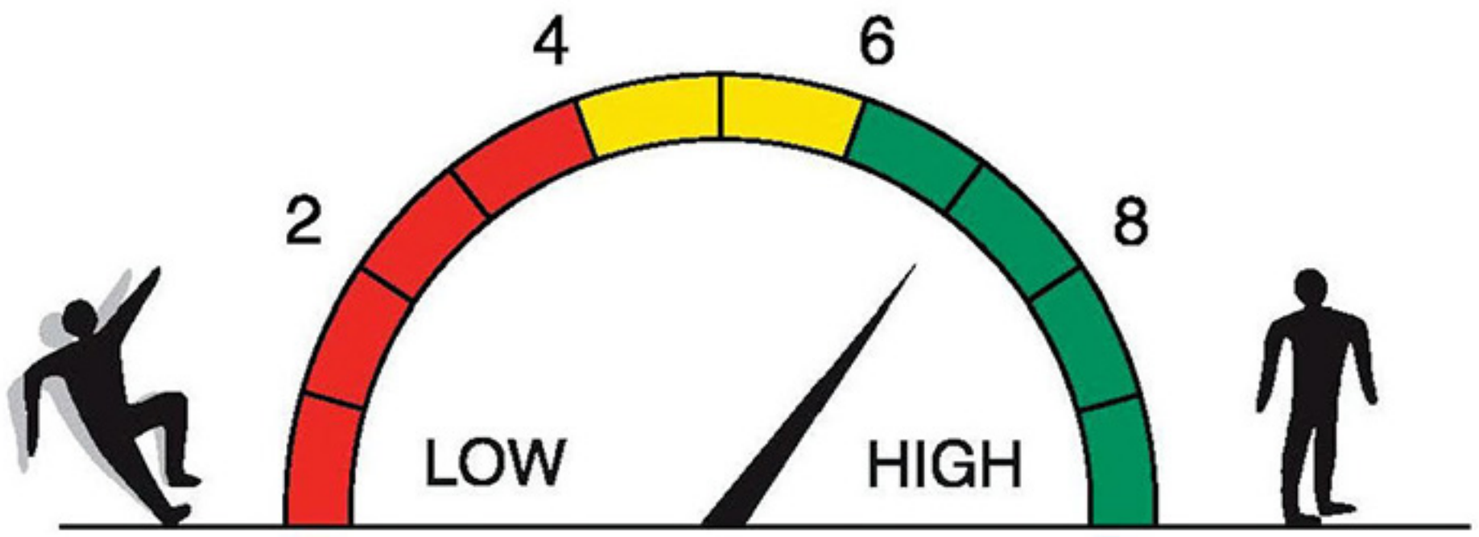
1.0 Purpose

> These specifications serve as a reference standard for buyers and specifiers of Standard Grade and Second Grade ceramic tile, Decorative Tile, and Specialty Tile. These specifications are also a guide to producers in maintaining quality control of the manufacture of such ceramic tile.

2.0 Scope

> These Specifications describe the normally available sizes and shapes of ceramic tile: the physical properties of Standard Grade and Second Grade Ceramic Tile, Decorative tile and Specialty Tile; the basis for acceptance and methods of testing prior to installation; the marking and certification of ceramic tile; and the definitions of terms employed in these specifications.

Currently, there is controversy within the industry concerning the use of the ANSI A137.1 for field testing. Neither the Purpose nor the Scope of the ANSI A137.1 reference its use for field testing, which for many, including the author, indicates it is not appropriate for field testing of installed tile. Others disagree. Certainly it is the case that the ANSI A137.1 standard is not the same as the ANSI/NFSI B101.3-2012 or DIN 51130 standards. Unlike the ANSI/NFSI B101.3-2012 standard, which provides for the use of a wide range of tribometers, the ANSI A137.1 mandates the use of a single tribometer (BOT-3000). Also, the ANSI A137.1 calls for a different test foot sanding procedure, and reduced the level of liquid surfactant by half that of the ANSI/NFSI B101.3-2012 standard. Therefore, results as generated under the ANSI A137.1 test procedure should not be compared to the ANSI/NFSI B101.3-2012, ISO, BGR or DIN standards.



SCOF Traction Scale

The SCOF Traction Scale

The ANSI/NFSI B101.5

The ANSI committee on the prevention of slips, trips and falls has just received approval for the publication of the *ANSI/NFSI B101.5* packaging standard for uninstalled tile. This packaging standard uses a "gas gauge" type designation to enable the public to better make decisions when choosing tile for a particular area. The gauge diagram uses a "red, yellow, green" designation with a printed pointer to indicate the "High, Moderate or Low" traction range of the tile. With this easy-to-associate-and-remember information, the consumer can now make tile choices informed of the available traction of the particular tile they are considering.

While the COF of the walking surface is not the only determining factor in the occurrence of slips and falls, it is one of the few aspects — along with maintenance and environment — that is under direct control of the specifier, business owner or user of the standard.

Pedestrians slip and fall for myriad reasons. Footwear is a major contributing factor, as is the age and physical condition of the person. However, these are not under the control of the user of these standards. Therefore, in regards to COF, in order to significantly reduce the risk of slips and falls in and outside a facility, the walking surface must have sufficient available traction to meet the demands of the walking public. Likewise, it is also important to follow applicable industry and trade standards of care for cleaning, maintenance and installation.

Specifiers and business owners can utilize these standards to demonstrate due diligence to their clients, customers and employees. Inspection and auditing services, maintenance service companies, general contractors and safety managers can use these standards to document the fact that the various services they provide can confirm compliance with applicable national stan-

dards. In the end, this not only will help protect from unwarranted litigation, but also provides the necessary tools for this value-added service, to demonstrate to their clientele their work is not only *status quo*, but superior.

Many cases of litigation in the event of a slip and fall seek to prove that the walkways were kept in an unsafe manner. By retaining a third-party walkway auditor, companies can document their walkways are in compliance with the current national standards. This documentation can produce an evidentiary trail of due diligence and demonstrates an increased level of care.

Building Service Contractors (BSCs) can also use walkway auditing as a value-added service. This not only allows them to protect themselves, but to offer additional services by providing either independent third-party testing or having a direct employee become a qualified walkway auditor. Each of the *ANSI B101* standards outlines the minimum qualifications of a walkway auditor. Section 4 of the *ANSI B101.1* and *ANSI B101.3* describes these qualifications as having met the minimum standards of a nationally recognized training course. An example of a nationally accredited course is offered by the National Floor Safety Institute (NFSI). This course consists of four days of instruction that includes best practices for cleaning, matting, appropriate flooring, identification of hazards and practical tribometry. Courses such as this prepare someone to observe hazards and conduct the appropriate COF tests using the proper methods and standards.

For those wishing to have their walkways audited, it is imperative to require appropriate training. For example, recently a general contractor was required to have the walkway surfaces tested to the *ANSI/NFSI B101.1-2009* standard upon completion of the project. Not knowing who to call, the project manager looked online and hired an engineering firm, believing they would know what to do. The engineering firm conducted what the project manager believed to be the proper tests and he accepted the report from the firm. However, the report stated the COF did not comply with the plan specifications and they were responsible to redo the walking surfaces until they were in compliance.

The project manager did not believe the surfaces were out of compliance, so he pursued the matter with another third-party auditing company. The second company consulted with the general contractor and discovered the original testing firm had not performed the proper tests, nor had they used the proper standard or testing device. Because of the improper procedures and citing of irrelevant standards, it was discovered that the readings they produced were inaccurate and meaningless. The second company employed certified walkway auditors, knowledgeable in standards and proper methods, so their tests were performed with the correct methodology and the readings were found in compliance. The improper use of testing methodologies could have cost this contractor hundreds of thousands of dollars, because an unknowledgeable and untrained person used the wrong testing methodologies and applicable standards.

BSCs are not immune to litigation where slips and falls are concerned. In one case, an employee in an older high-rise building slipped, fell and sadly became a quadriplegic due to her injuries. The owners of the building settled immediately; however, the BSC also named in the suit claimed that they were not negligent and refused to settle. A trained walkway auditor was retained by the plaintiff's counsel. Because of proper training and experience, the auditor was not only able to document that the walkways were not in compliance, but that the BSC was not performing the floor maintenance the occupants were paying for. For this reason, after the auditor's report was produced, the BSC settled out of court. Had the BSC been using the services of a trained auditor, they would have known there was a problem, been able to correct it, and been able to produce documentation that the work was being done and the walkways were in compliance. Had the walkways been in compliance with the national standards, the risk of a slip and fall would have been reduced and the incident may not have taken place, sadly leaving a human life changed forever. Lesson learned. By uti-

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lizing the services of an outside company or training internally in accordance with the related and applicable industry standards, this and future slips and falls could be prevented from taking place.

Unfortunately, there are some unscrupulous businesses that still prey on business owners trying to do the right thing by keeping their floors in compliance. One such con stems from the claim for many years that both OSHA and ADA require a COF of 0.60 on level surfaces and a 0.80 on ramps. The ADA originally included this as part of their appendix, but it was quickly removed as it caused much confusion. While the requirement of having a COF of 0.60 and 0.80 is not excessive, the ADA neglected to include details such as if it was a wet or dry test and if the tests were to be performed as static or dynamic COF. Because these testing details were omitted in the original appendix, the requirements were quickly withdrawn.

OSHA, on the other hand, has never had a COF requirement, but requires that walkways be kept clean and dry. The ADA requirements today are for walkways to be "firm, stable and slip resistant." Unfortunately, none of these terms are defined and may be interpreted differently by different ADA inspectors. Because of this ambiguity, it happened that a particular construction project was not accepted by an ADA inspector, since the walkway surface was deemed not "slip resistant." In this case, the contractor hired a certified auditor to conduct COF tests to national standards. When the tests indicated the surface was "High Traction" per the national standard, the ADA inspector accepted the report and passed the construction.

The same experience can be said of OSHA. A particular heavy equipment manufacturer decided to upgrade the floor-covering surface in several parts of its facility and chose to polish the concrete surface. Because many associate a shiny surface with a slippery surface, one employee immediately complained to OSHA that the surface was low traction. The plant and the contractor immediately contracted with a certified third-party auditor to test the available traction of the surface. The walkway tested "High Traction" on both the static and dynamic ranges. The plant safety manager submitted the report to OSHA and the file was closed. The plant now regularly has walkway audits performed to ensure the traction is still high and the employees are satisfied that the surfaces are not low traction.

In the past, OSHA has indicated that a change in the Code of Federal Regulations (CFR) is being considered. Several years ago, OSHA requested the chairman of the NFSI to testify about the requirements of the ANSI standards and how they could be integrated into OSHA's requirements. However, OSHA has postponed a decision on several occasions since that time. Both OSHA and the ADA would do well to integrate the defined ranges from national consensus standards to eliminate undefined and ambiguous terminology contained in their regulations. This would help business owners in their efforts to comply with federal regulations.

In order to reduce slips and falls, the diligent business owner should maintain their walking surfaces using all best practices, including but not limited to using certified hard-surface maintenance technicians. Additionally, using walkway inspections, performing regular COF audits, and following industry standards of care can help solve problems before they become severe.

This article covered an array of subjects relating to COF and to slip and fall and provided up-to-date information to help the specifiers, business owners and standards users protect the health, safety and welfare of the public from the dangers of slips and falls. But this is only the beginning. Now that we have a more scientific-based and repeatable basis for testing SCOF and DCOF, wet or dry, it's time to explore some of the other contributing factors relating to slips, trips and falls. That comes with understanding from an interrelated industry point of view — including but not limited to design, build, inspection, installation and maintenance industries — how the floor-covering assembly and the mechanisms within the assembly, from foundation to cover, can detrimentally affect barrier-free design.

But that is a subject for another time and will be addressed in the next issue of *The Journal*.

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