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Slip-Sliding Away: Tribometers, Slip Testing, and the Standards

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Introduction

Slips and falls injure and kill a large number of individuals annually. It is an issue in both the workplace and in public spaces, and this trend will likely be increasing. There are steps that can be undertaken to reduce the likelihood of walkway surfaces being a contributing factor to a slip-and-fall incident. One of the keys to making a walkway surface with adequate traction is to actually measure the surface's coefficient of friction and take corrective action if warranted. The device that is used to determine the coefficient of friction is a Tribometer. Unfortunately, there is a lack of uniformity among how various tribometers work, what constitutes a reading for a "safe" walkway surface, and how to apply various/differing standards.

The Slip-and-Fall Problem

The statistics about slips and falls are alarming and easily found via a wide range of sources, including the Bureau of Labor Statistics, National Safety Council, OSHA and the National Floor Safety Institute (NFSI). It is beyond the scope of this document to review these various sources of injury and fatality data. The occurrences of slips and falls are expected, however, to become more prevalent and incur greater costs, mainly due to the aging population.

To combat our ever increasing frequency and severity of slip, trip and fall incidents, a comprehensive effort on the part of safety professionals, building owners, employers, and public officials needs to be undertaken to review, or audit, walkway surfaces and correct hazardous situations. Some of the contributing causes of slip-and-fall incidents are well beyond the control of any of the before mentioned parties and may include: personal gait characteristics, cognitive deficiencies, substance derived impairments, balance deficits, eyesight deficits, clothing, and footwear.

Tribometric testing to determine the slipperiness of flooring and finishes is one aspect of a comprehensive audit and will be addressed in this paper, but other aspects over which there is generally a great deal of control may include: lighting, changes in elevation, floor transitions, cracks and heaves, obstructions, carpet tears or puckers, unmarked or indistinguishable steps, distractions, or visual distortions, to name just a few.

Auditing to Assist in the Prevention of Slips and Falls

As with many aspects of the safety and health field, there are many opinions as to what constitutes an acceptable auditing procedure. At this juncture there is starting to be some coalescence around the required minimum elements of an acceptable auditing report. ANSI A1264 is undergoing revisions to include more robust auditing protocols and potentially sample forms for practitioners to utilize. The B101.1 Standard, Section 6 lists the components that comprise a Test Report and include the types of floors tested, location of the test areas and sites, testing values, surface conditions, test results, and a signature of the auditor. Under development at this time, but not published at the time of this document, is ANSI/NFSI B101.0 Walkway Surface Auditing Procedure for the Measurement of Walkway Slip Resistance, which should provide more detailed guidance on both how to perform the audit and what should be included in the audit report. The National Floor Safety Institute's Walkway Auditor Training Program addresses the form and format of what they feel are the appropriate report elements, and presumably this is what is used as a basis of the new B101.0 standard. It is important to remember, however, that the mechanics of performing a tribometric test on a flooring surface will only address some of the hazards present in a walkway hazard analysis.

Auditor/Tribometrist Certification

Currently there are two certifications that individuals may earn to demonstrate competence in performing walkway audits/tribometric testing. They are as follows:

Certified XL Tribometrist (CXLT): This certification is specific to the English XL Variable Incidence Tribometer and requires successfully passing both a practical hands on test of correct operation of the device and a written exam. The course and certification exam require having a device to utilize and demonstrate proficiency on. The one day course is held by the manufacturer of the devices, Excel Tribometers LLC and costs $640 as of the date of this paper. The certification is good for three years at which time it needs to be re-validated.

Certified Auditor Safety Specialist: This certification is administered by the NFSI and is a four day course that includes a hands-on practical test of various slip meters, identification of flooring materials, and a written test that must be passed, in addition to full attendance at the class to qualify to receive the certification. The certification is good for three years, with a one day recertification class required to renew the credential. The current cost for members is $995 and $1250 for non-members.

It is important for practitioners to consider certification if they intend to utilize tribometric testing in their safety function or practice. The first consideration is that there is an expectation of credibility on the part of the auditors as would be the same with any segment of the safety profession. Being able to not only obtain readings but having the knowledge to interpret them and put them into perspective is vital to maintaining a holistic approach that seeks to reduce risk. The second major area is the actual auditing process, and while the use of the various devices may seem simple and straightforward, they are not. There are many specific steps and procedures to be taken into consideration with operating what are sensitive scientific instruments. For instance, just one small aspect, the preparation of the testing foot is critical, and improper procedures or techniques can lead to erroneous readings. Finally, it is important to recognize that legal precedent and concerned organizations are increasingly specifying that auditors are

competent, and certification programs are an important means of demonstrating this capability.

Tribometers

The concept of measuring the coefficient of friction (COF) dates back to work that Leonardo da Vinci documented in the early 1500's. He experimented with what we now define as static friction using blocks, pulleys and weights and defined the first two laws of friction. In the 1920's the concept of applying the measurement of friction to improving pedestrian safety began with work completed by R.B. Hunter. His work led to the development of one of the first machines to successfully perform tests of floor finishes, the James Machine. Since that time, there have been upwards of 75 different commercially available tribometers for use by practitioners that break down into four general types:

1. Drag Sleds: both motorized and manually operated
2. Articulated Strut
3. Pendulum
4. Variable Incidence Machines

Some practitioners might group articulated strut and variable incidence together, creating three categories. The above categorization doesn't include various homemade devices that have been used over the years and include items such as barbell weights being dragged across surfaces and shoes filled with a weight and pulled with a scale. Safety engineers have even been taught to kick the floor with their shoes to get a "relative" measurement of the floors slipperiness, obviously this and other questionable methods lack any basis in science.

Various devices have engendered loyal users over the years and various conflicting studies have been produced that attempt to validate devices. One of the major issues is the different readings that various devices produce using the same standardized tiles and taking measurements wet and dry. For instance, drag sleds have a residence time on the surface of whatever they are measuring that allows the surfaces to stick together either through adhesion as in dry testing or stiction as in wet testing. This can occur with the testing device's foot or feet being in contact with the surface, or dwell time, for as little as 0.2 seconds. Having the surfaces in adhesion or stiction can both produce results of an artificially high COF. Depending on the size of the foot that is being tested, it can also hydroplane in wet testing, rendering the test results suspect. Drag sleds and other testers that engage the test foot/feet slowly can allow for the contaminant (usually water) to squeeze out from under the tester in such a way as to give unusually high readings for wet tested surfaces. It isn't easy to wade through all of this, but it is important to remember that what is attempting to be measured isn't just an academic exercise to determine a coefficient of friction, but a reading that can be related to human ambulation and some confidence of a safe walkway surface.

The latest effort to provide this validation is: ASTM F2508-11 Standard Practice for Validation and Calibration of Walkway Tribometers Using Reference Surfaces. It tests subjects in a lab differentiated between various walkway surface materials. These materials can be

obtained by the tribometer manufacturers and they can then attempt to validate their devices through a testing regimen that provides a similar differentiation through a lengthy statistical testing process. An important consideration in the selcction of a tribometer is whether the manufacturer is able to demonstrate validation in either a scientific manner or meeting the requirements of a standard like F2508.

Slip Resistance Quantification

The question of what constitutes a safe walkway is, at its core, a difficult problem to quantify and still requires a great deal of experience and judgment to incorporate all the disparate elements that could affect a determination. Within the context of this paper, the determination of an adequate slip resistance, either dry or wet, has entailed a measure of controversy that continues. While there have been many scientific studies and validation experiments that highlight differing aspects of the answer to this question, two approaches will be discussed, representing the major methodologies.

The standard ANSI/ASSE A1264.2-2006 Provision of Slip Resistance on Walking/Working Surfaces details a guideline for slip resistance of 0.5 utilizing a Neolite slider pad and devices that avoid residence time to avoid stiction and adhesion. The reference of 0.5 is found or referenced in a number of sources since the 1940's when Sidney James of Underwriters' Laboratory undertook his study of walking on polished surfaces. The 0.5 had been validated in a number of studies in which the heel strike slipped forward in an uncontrolled manner; hence the predicate of a slip-and-fall is facilitated. The articulated strut and variable incidence tribometers are able to measure this dynamic without the problem of stiction or adhesion. Recognition of a device's biofidelic properties in the validation of this 0.5 threshold is occurring, which requires a device to be able to simultaneously incorporate both normal and tangential forces, thus avoiding the problem of residence time. This approach is called biofidelic because it emulates the actual process of human ambulation and the initiation of a slip-and-fall.

The NFSI in their B101.1-2009 Test Method for Measuring Wet SCOF of Common Hard Surface Floor Materials has taken a different approach. They have looked to the approaches used in Europe and incorporated values around those required to overcome static friction on selected walkway surfaces. Their schema for reporting results is based on a table in Section 5 of the standard outlining characteristics of walkway surfaces. Their ranking method includes:

>= 0.60 as having High Traction
>= 0.40 to < 0.60 as having Moderate Traction
< 0.40 as having Minimal Available Traction

Future work by the B101 committee will include a color coded "gas gauge" to show the walkway surface's characteristics.

While there are proponents of both approaches, the underlying goal must be to utilize a scientifically based approach that can identify a slip-resistant walkway surface for pedestrians, or a surface that needs to be improved. This area will undoubtedly be the focus of additional research, debate, and standards development.

Selected Standards

ASTM International: ASTM

ASTM F2508-11 Standard Practice for Validation and Calibration of Walkway Tribometers Using Reference Surfaces: This standard was approved in March 2011 and looks to validate the actual human propensity for slips and falls of surfaces and contaminents to tribometers. There are rigourous testing criteria involved for surface discernment and repeatability.

ASTM F1637-10 Standard Practice for Safe Walking Surfaces

This standard reviews various potential hazards in walkways including surfaces, sidewalks, short flight stairs, gratings, wheel stops, and speed bumps.

ASTM F1694 - 09 Standard Guide for Composing Walkway Surface Investigation, Evaluation and Incident Report Forms for Slips, Stumbles, Trips, and Falls

This standard develops a terminology, approach, list of critical items, and forms to review incidents.

ASTM F1240 – 01 Standard Guide for Ranking Footwear Bottom Materials on Contaminated Walkway Surfaces According to Slip Resistance Test Results

Highlights shoe characteristics for various worksite applications.

ASTM F802 – 83 Standard Guide for Selection of Certain Walkway Surfaces When Considering Footwear Traction

This standard highlights various attributes of floor surfaces to address contamination.

American National Standards Institute: ANSI

ANSI/ASSE A1264.2-2006 Provision of Slip Resistance on Walking/Working Surfaces

The standard focuses on three interrelated areas; the first is the identification and mitigation of hazardous conditions, the second references test equipment, and the third section references slip guidelines.

ANSI/NFSI B101.1-2009 Test Method for Measuring Wet SCOF of Common Hard Surface Floor Materials

The standard develops a protocol for measuring the SCOF of only certain hard flooring materials but excludes any floor surface that is mechanically polished. This would exclude marble, granite, terrazzo, polished concrete and polished porcelain tile, and severely limits the applicability of the standard to a narrow range of materials.

National Fire Protection Association: NFPA

NFPA 1901 Standard for Automotive Apparatus

Specifies in 15.7.4 a testing methodology and minimum slip resistance for the English XL and Brungraber Mark II tribometers for all surfaces designated for standing, stepping or walking.

NFPA 5000 Building Construction and Safety Code

Specifies that walking surfaces shall be slip resistant and references what they identify as the withdrawn standards: ASTM F 1679 Standard Test Method for the Variable Incidence Tribometer and ASTM F 1677 Standard Test Method for Using a Portable Inclinable Articulate Strut Tester.

Organizations

National Floor Safety Institute: NFSI

The National Floor Safety Institute was founded in 1997 with the mission, "To aid in the prevention of slips, trips-and-falls through education, research, and standards development." At this writing, they have published ANSI/NFSI B101.1, and have developed a suite of standards they intend to publish:

B101.0 Walkway Surface Auditing Procedure for the Measurement of Walkway Slip Resistance

B101.1 Test Method for Measuring Wet SCOF of Common Hard-Surface Floor Materials

B101.2 Test Method for Determining the Impact on Wet Dynamic Coefficient of Friction of Various Chemical or Physical Walkway Surface Treatments

B101.3 Test Method for Measuring Wet DCOF of Common Hard-Surface Floor Materials (Including Action and Limit Thresholds for the Suitable Assessment of the Measured Values)

B101.4 Test Method for Measuring the Wet Barefoot Condition of Flooring Materials or Products

B101.5 Standard Guide for Uniform Labeling Method for Identifying the Wet Static Coefficient of Friction (Traction) of Floor Coverings, Floor Coverings with Coatings, and Treated Floor Coverings

B101.6 Standard Guide for Commercial Entrance Matting in Reducing Slips, Trips, and Falls.

B101.7 Standard Test Method for Lab Measurement of Footwear Outsole Material Slip Resistance

B101.8 A Floor Safety Management Program for Slip, Trip, and Fall Prevention

The NFSI also has a product certification process in which manufacturers can have their products certified or re-certified. These could include a mop/bucket combination, floor mats, gripper tape, floor treatments or floor cleaning machines. They have also undertaken to perform some research on common household type cleaners, some of which make it into commercial or industrial venues, and have ranked their effect on slip resistance.

Each of these standards has a sub-committee that, as published on their website, is comprised of as few as two members and can include manufacturer's representative organizations, consultants, manufacturers, or insurance company representatives. Sub-committee rosters can be viewed on the NFSI website. Committee members have to pay a membership fee of between $495 and $5000 depending on their standing as a manufacturer or other type of member to participate in the standards writing process.

The NFSI has also developed a certification process for tribometers for gaining "approved" or "recognized" status. An established process has been developed that includes the criteria for both designations. To date, only one device has gained the "approved" status, which includes such criteria as hardcopy printouts, digital readout, and determining both the Wet and Dry SCOF. Manufacturers that do not meet the above criteria are allowed to submit for "recognized" status, it is reported. However, the NFSI has stated to these other manufacturers that they do not have the technical expertise to evaluate devices.

OSHA

OSHA requires the use of slip-resistant surfaces in several locations in their standards. This term is largely left undefined.

29 CFR 1910.24(f): "Stair treads."
All treads shall be reasonably slip-resistant and the nosings shall be of non-slip finish. Welded bar grating treads without nosings are acceptable providing the leading edge can be readily identified by personnel descending the stairway and provided the tread is serrated or is of definite non-slip design. Rise height and tread width shall be uniform throughout any flight of stairs including any foundation structure used as one or more treads of the stairs.

A proposed standard for Subpart D does make a reference to a 0.5 requirement for coefficient of friction. However, this standard was never promulgated as a final rule.

The most specific regulation addressing slip-resistance measurement is found in the OSHA construction standards as they relate to steel erection.

29 CFR 1926.754(c)(3): Slip resistance of skeletal structural steel.
Workers shall not be permitted to walk the top surface of any structural steel member installed after July 18, 2006 that has been coated with paint or similar material unless documentation or certification verifies that the coating has achieved a minimum average slip resistance of .50 when measured with an English XL tribometer or equivalent tester on a wetted surface at a testing laboratory is provided. Such documentation or certification shall be based on the appropriate ASTM standard test method conducted by a laboratory capable of performing the test. The results shall be available at the site and to the steel erector. (Appendix B to this subpart references appropriate ASTM standard test methods that may be used to comply with this paragraph (c)(3)).

Americans with Disabilities Act: ADA

Uniform Federal Accessibility Standards and Americans with Disability Act Accessibility Guidelines (ADAAG) specify a minimum COF of 0.6 for level surfaces and 0.8 for ramps, but unfortunately do not specify any methodology around performing the testing.

Conclusion

There has been a wide variety of approaches over the years to study and take accurate

measurements, and address walkway safety to reduce the likelihood of slips and falls. As safety practitioners, there are standards, tribometers and resources available to address potentially hazardous situations in the workplace or public venues. Certification programs can provide the necessary basis of understanding toward applying standards, approaches, devices and reviewing the specific slip measurements and ensuring that an entire walkway environment is considered as part of an investigation. The near-term future will be one of changes as the ANSI/ASSE A1264 committee works to revise the standard and the NFSI works to publish additional standards. Throughout this period, it will be important for safety professionals to stay informed and use sound judgment in the interpretation of standards, devices, and results to avoid – slip sliding away.