C39 Analysis of ASTM F2508 Reference Surfaces Using Logistic-Regression-Based Criteria

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The goal of this presentation is to inform the attendees how to qualify reference surfaces and the implications of the same. ASTM 2508 is a new standard designed to qualify Walkway-Safety Tribometers. This paper uses logistic regression to analyze the quality of the reference surfaces.

This presentation will impact the forensic science community by showing how the nuanced view of the ASTM F2508 reference-surface qualification methodology for tribometers will allow researchers and practitioners to have more than a one-dimensional "handbook" view of tribometric-test variability and reliability. This is essential for an understanding of the relationship between fall hazard and tribometric test results.

Background: The measurement of the available friction between the floor surface and a shoe (or foot) bottom is of significant import in determining pedestrian-ambulation safety. High-school and elementary college physics, for the sake of simplicity, assume the Amontons-Coulomb friction model, where it is axiomatic that friction is solely a function of the materials in contact, and independent of contact pressure, velocity, temperature, and so forth. This model holds reasonably well when the materials are non-resilient, e.g., steel and/or wood. The model is often problematic when one of the surfaces is resilient, like a shoe or foot bottom, and essentially irrelevant when the interface between the materials is lubricated. In that situation, factors other than the materials involved become significant. Importantly, the friction-measuring instrument itself (called a Walkway-Safety Tribometer, or WST) becomes a factor in the measurement. That is, different WSTs, measuring the same surfaces, will give different, sometimes very different, results. This is caused by two factors: (1) on a fundamental level, different WSTs use different friction-generating mechanisms (for example, a drag-sled or articulated-strut tribometer cannot replicate the hydrodynamic, squeeze-film phenomenon that occurs when pedestrians slip on a wet surface); and, (2) assuming that the WST is capable of replicating the appropriate friction mechanism, the parameters (especially pressure/time effects) are different, both between different models of WSTs, and different between a WST and an ambulating pedestrian. Because the ultimate purpose of WST test results is to determine if a walking surface (or shoe bottom) conveys adequate safety, the test of utility for any WST results are how they reflect pedestrian-ambulation traction. The concept that WST tests must ultimately reflect on pedestrian-ambulation safety is called biofidelity. Recognizing this, and troubled by the fact that the then-current ASTM WST standards referenced proprietary instruments, the Board of Directors of the ASTM convened a task group under the guidance of a former ASTM Chairman of the Board to address this issue. From this, ASTM-sponsored research at the University of Southern California examined the relationship between a pedestrian's utilized friction and the results of tribometric tests. The end result was a set of four reference surfaces, which are used to "standardize" the tribometer readings. These four test surfaces consist of (from the most to least slippery): (1) polished granite lubricated by a diluted non-ionic solution); (2) Porcelanosa Ferrokor tile, lubricated by distilled water; (3) Official Vinyl Composition Tile (OVCT), lubricated by distilled water; and, (4) unglazed ceramic tile, lubricated by distilled water. The calibration of tribometers using these tribometric reference surfaces is governed by ASTM standard F2508, which was first approved in 2011.

Because walkway-safety tribometry test results are standardized by these four tribometric reference surfaces, it is useful to be able to answer questions concerning the reference surfaces and their relationship to the tribometers. F2508 requires a WST to discriminate—with statistical significance—between the four reference surfaces. F2508 discrimination is verified with t-tests of the adjacent surfaces: granite vs. Porcelanosa; Porcelanosa vs. OVCT; and OVCT vs. unglazed ceramic. There was interest to see if the quality of the reference surfaces using the Slip-Test Mark II portable inclinable articulated-strut tribometer (the PIAST) and logistic regression, which was chosen as an analysis tool because the PIAST gives dichotomous (slip or no-slip) results could be better assessed.

Experiment: A PIAST was modified by fabricating and installing a mechanism to be able to tilt the mast with an order of magnitude of more accuracy than an unmodified PIAST and installed a platform for a high-precision level (0.1 degree repeatability). For the experiments, the PIAST was shod with two slightly different test feet, both of test liner, but with different siping patterns:[1]

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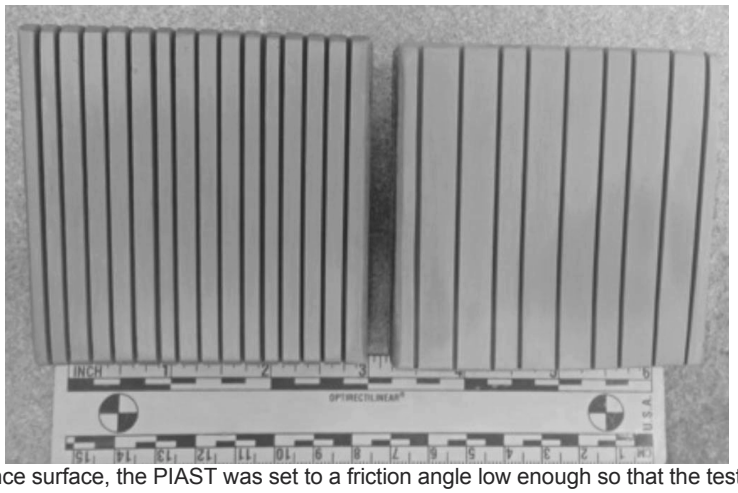
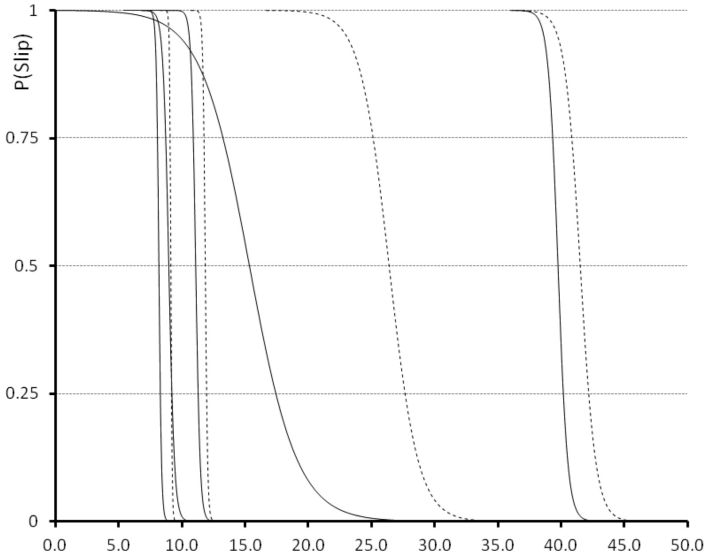


For each reference surface, the PIAST was set to a friction angle low enough so that the test foot would not slip, and the friction angle was slowly increased, typically at a fraction of a degree at a time, taking numerous (typically 25) tests at each friction angle, until slips were observed at 100% of the readings.[2] This was done with each of the two test feet. For each test-foot/reference-surface combination, between 100 and 400 friction tests were taken.

Logistic regression was used to determine the probability of a slip at a given WST setting. Ideally, the WST will always slip at exactly the same value, yielding a step function graph:

$$P(\text{Slip}) = \begin{cases} 1; \ \mu \leq \mu_c \\ 0; \ \mu \geq \mu_c \end{cases}$$

In reality, because slipping is—in walkway-safety tribometry as in real life—a probabilistic event, the curve obtained is s-shaped: a logistic curve. The steeper the curve, the more like a step function, and the more discriminating the reference surface. The P(slip) = 50% point on the curve is the nominal friction value of the test-foot/reference-surface combination. Here are the results:



Discussion: Visually, it is clear that the granite/diluted non-ionic solution (the leftmost three curves) and Porcelanosa/distilled-water (the fourth and fifth from the left) reference surfaces demonstrate excellent discrimination; the behavior is very close to the ideal step function for the slip/no slip condition. The test-foot-to-test-foot differences for these surfaces were also minimal. The ceramic tile (the rightmost two curves) are not quite as discriminating, but as the friction angle for the slip/no slip dichotomy is quite large (above 40°), the relative variation (analogous to the coefficient of variation for a continuous variable) is small. Problematic is the OVCT, the third and fourth curves from the right. They are both quite shallow, indicating poor discrimination; importantly, the two curves for the two test feet are widely separated, indicating that different (but similar) test feet will give disparate results.

Neither of these OVCT flaws necessarily negates the utility of F2508. As far as the lack of discrimination inherent in the OVCT, one can increase the sample size (an operator checking his equipment will typically perform 12

repetitions on each surface; a validation run requires 40 repetitions on each surface) to compensate for the increased relative variation. As far as the separation between the curves, one of the main purposes of F2508 standardization is to allow results from different tribometric instruments to be compared; this can obviously extend to different test feet on the same tribometric instrument, different operators, and so forth.

That said, it is recommended that the ASTM subcommittee that maintains F2508 (ASTM Committee F-13 on Footwear and Pedestrian/Walkway safety's subcommittee 13.1 on traction) seek to revise F2508 by researching and qualifying at least two other reference surfaces to use in the stead of OVCT.[3]

References:

1. In the graph (above), the test foot on the left is represented by the dashed curves. The test foot on the right is represented by the solid curves.
2. The friction angle is the angle of inclination of the PIAST mast. The friction coefficient is the tangent of the friction angle.
3. It is recommended that ceramic reference surfaces both having low variability and in the range of 20° and 30° friction angles be explored.

Forensic Science, Tribometry, F2508

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