

COEFFICIENT OF FRICTION TESTING FOR PAVERS AND SLABS (Last Updated March 2020)

To reduce the risk of slips and falls, there have been an increasing number of specifications calling for a minimum "coefficient of friction" value for the selected paver or slab. The following was developed to help explain what the actual rules are for slip resistance, the recommended testing that needs to be done, and what should be asked for in specifications.

1) <u>TERMINOLOGY</u>

Coefficient of friction (COF) describes the ratio of the force of friction resisting motion between two bodies, and ranges from near zero to greater than one. The coefficient of friction depends on the two materials used; for example, a steel ice skate on ice has a low coefficient of friction, while rubber tires or soled shoes on pavement have a higher coefficient of friction. The COF is also impacted by the presence of a lubricant (water, food spills) between the two surfaces - the following are examples of COF values for both wet and dry conditions to show how the presence of a lubricant can alter the results.

Material Combinations		Coefficient of Friction		
		Clean & Dry Surface	Lubricated Surface	
Rubber (tire or	Asphalt	0.5 – 0.8	0.25 - 0.75	
shoe sole)	Concrete	0.6 - 0.85	0.45 - 0.75	
Steel (skate)	Ice	0.03		
Iron (train wheel)	Iron (train track)	1.0	0.15-0.2	

Static coefficient of friction (SCOF) is a measure of the friction between two items that are motionless, for example a person standing on a pavement. Dynamic coefficient of friction (DCOF), also known as kinetic or sliding coefficient of friction, is a measure of the friction between an item and the surface it is moving across, for example a person walking across the floor. The Tile Council of North America and the Concrete Polishing Association of America typically call for the DCOT, and don't bother with the SCOF, as the consensus is that if the results are positive for DCOT (i.e. someone in motion) then the results will inherently be positive for SCOF (i.e. someone at rest).

2) **REGULATIONS**

a) Ontario Integrated Accessibility Standards

Ontario Regulation 191/11 – Integrated Accessibility Standards is enforced through the 'Accessibility for Ontarians with Disabilities Act, 2005'. The standard requires that surface be, among other things, "slip resistant". From the accompanying Guide to the Integrated Accessibility Standards Regulation, there are two definitions of a slip resistant surface:

- 1. "slip resistant surfaces offer a level of friction that allows people with disabilities, particularly those who use mobility assistive devices, to travel safely in the vehicle".
- 2. "slip resistant surface is one that even when wet provides friction between the surface and a person's footwear, mobility air or mobility assistive device that reduces the risk of slipping".

There is no quantified value provided. Again, from the Guide "a number of factors can contribute to slips and falls, such as moisture, types of footwear or methods of walking. Because of this variation, organizations are responsible for determining the best way to achieve a slip resistant surface".

b) OSHA (Occupational Safety and Health Administration)

The general <u>perception</u> in the industry is that there is an OSHA rule that states the minimum COF needs to be 0.5. In 2003 the Tile Council of America requested that OSHA "provide any perspective or background on how the COF value of 0.5 came to be"; in other words, they wanted to ascertain the details of the perceived requirements. The response was "OSHA, does not have any standard that mandates a particular COF for walking/working surface. While there are devices to measure the COF, no OSHA standard specifically requires the employer to use them".

There is however a non-mandatory appendix in the Notice of Proposed Rulemaking for Walking Working Surfaces that discusses COF. The pertinent portions of the non-mandatory appendix read as follows:

Slip Resistance: A reasonable measure of slip resistance is static coefficient of friction. A COF of 0.5, which is based upon studies by the University of Michigan and reported in the "Work Surface Friction: Definitions, Laboratory and Field Measurements, and a Comprehensive Bibliography", is recommended as a guide to achieve proper slip resistance. A COF of 0.5 is not intended to be an absolute standard value. A higher COF may be necessary for certain work tasks such as carrying objects, pushing or pulling objects, or walking up and down ramps.

In short, the COF of 0.5 is solely a guide, not a rule. So even though the COF of 0.5 is stated within the OSHA documentation, including it as a minimum requirement within a specification will not prove due diligence and protect the owner from potential liability.

c) Access Board of the US Department of Justice

The access board is responsible for establishing guidelines for accessibility of disabled persons. The Board is often quoted as having in 1991 recommended a minimum static coefficient of friction of 0.6 for level floors and 0.8 for ramps. However, the Board in fact states in a May 11, 2011 letter that they never made such a recommendation, but had merely quoted the results of a research project they funded. Further, they stated they are not authorized to establish guidelines for public safety, so even if the recommendation would have been made it could not be enforced.

Within the Americans with Disability Act (ADA), which was issued by the Department of Justice (most recent version in 2010), Section 302 – Floor or Ground Surfaces states "Floor and ground surfaces shall be stable, firm and slip resistant". The associated advisory statement provides the following details "A slip resistant surface provides sufficient frictional counterforce to the forces exerted in walking to permit safe ambulation" – there is no specific method of assessment or numerical value that has to be achieved.

d) National Floor Safety Institute (NFSI)

The mission of the NFSI is to aid in the prevention of slips, trips and falls through, education, research, and standards development.

In 2009, the NFSI issued ANSI/NFSI B101 "to serve as a safety standards intended to provide preventative measures in all manner of pedestrian ambulatory safety in regards to slips, trips and falls". Included is B101.1 "Test Method for Measuring Wet SCOF (static) of Common Hard-Surface Floor Materials" and B101.3 "Test Method for Measuring Wet DCOF (dynamic) of Common Hard Surface Floor Materials".

The results of the testing are measured and categorized into one of three Traction ranges: High, Moderate or Low Traction. Floors with high traction present a low risk of slip and fall, while moderate and low floors present an elevated risk. Testing is done using a BOT-3000 Universal Walkway Tester – Digital Tribometer, which is discussed in more detail below.

The intent of NFSI is to introduce a uniform labeling method to better inform the consumer with the traction level of the flooring product. Green would be high traction, yellow moderate traction and red low traction. It is the opinion of NFSI that this labeling will become a requirement of the insurance underwriters. At the time this document was prepared, the uniform labeling method had not been finalized.

e) Tile Council of North America(TCNA)

The TCNA is a trade association representing manufacturers of ceramic tile, tile installation materials, tile equipment, raw materials and other tile related products.

In 2013, the TCNA issued the Technical Bulletin "Coefficient of Friction and the DCOF AcuTest". The report recommends that the test protocols outlined in ANSI A137.1 be used, which is known as the DCOF AcuTest. DCOF AcuTest is "an evaluation of the COF of a tile surface under known conditions using a standardized sensor prepared to a specific protocol. Measurements are made with the BOT-3000 (or other equivalent tribometer).

f) 2012 International Building Code

The ANSI A137.1 (aka AcuTest) was specified in the 2012 International Building Code as the method of testing wet Ceramic Tile surfaces. Although there is some debate as to whether the same 0.42 DCOF value should apply to marble, hardwood or concrete (primarily argued by the Ceramic Tile industry to create a competitive advantage), the safety industry commonly applies the same DCOF value to these other walking surfaces.

3) TEST METHODS

a) ASTM C-1028

ASTM C-1028-07 "Standard Test Method for Determining the Static Coefficient of Friction of Ceramic Tile and Other Like Surfaces by the Horizontal Dynamometer Pull-Meter Method" involves pulling a 50 lb weight, with one of the materials (say neolite to simulate a rubber sole of a shoe) glued to the bottom, over the surface of the other material (say a paver) and measuring the force required. The test is done in both dry and wet conditions.



ASTM C-1028 is used extensively in the ceramic tile industry as a method of measuring compliance with the perceived OSHA standard (COF of 0.5); however, there are inherent flaws in the testing process. Stiction is a suction (adhesion due to capillary forces caused by surface tension) created by the actual lubricant between the neolite and material – the force required to overcome this stiction can result in false safe reading. Also, the test process only gives a measure of how slippery a surface is when someone is standing still (static coefficient of friction), not walking on it (dynamic coefficient of friction).

For the benefit of the reader, ASTM C-1028 test results for standard pavers (i.e. pavers that have not undergone any special grinding or polishing, or are not sealed) are typically around 0.70 to 0.95 when dry and 0.64 to 0.76 when wet.

b) <u>ASTM E-303</u>

ASTM E-303 "Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester" was developed by the McDonald's Restaurant chain to assess the effects of mild abrasives on wet slip resistance. The objective is to assess changes in the slip resistance over time as it is recognized that the value can change after installation. The test uses a pendulum with a abrasive strip on the end to simulate several thousand passes over the test surface to calculate a Pendulum Test Value (PTV). The most common safety standard for a level floor is a minimum PTV of 36; as a basis of comparison, a PTV of 36 equates to a COF of 0.36.



This test method is most applicable to establishing detailed situation specific standards; for example, assessing the long-term performance of a product adjacent to a swimming pool exposed to chlorinated water and being navigated by bare feet. Per the standard itself "the values measured in accordance with this method do not necessarily agree or directly correlate with those obtained utilizing other methods of determining friction properties" – it is intended to measure relative effects on materials due to manufacturing changes (e.g. polishing) or long term use.

c) ANSI B101.1 and B101.3

As mentioned above, ANSI B101 specifically calls for a BOT-3000 Universal Walkway Tester – Digital Tribometer, which is shown adjacent. The device is about the size of a shoebox and is easily portable. It does not require a high level of user training and is extremely easy to use.



The benefit of the BOT-3000 is it performs the test without human input (except for setup and the pressing of an electronic button) so there is limited risk of human error or subjectivity in interpretation of test results. The instrument also includes many features that help in validating the results, providing courtroom credibility.

The safety standards ANSI specifies for a level floor using the B101.3 dynamic test method are as follows:

- 1. High slip resistance = minimum DCOF of 0.43 (and 0.46 for ramps up to 4.76 degrees)
- 2. Medium slip resistance = a DCOF between 0.3 and 0.42
- 3. Low slip resistance = minimum DCOF of 0.30

Flooring that achieves a high slip resistance is recommended for general use. For flooring in the medium range, the general recommendation is to "monitor the DCOF regularly and maintain cleanliness. Consider traction enhancing products and practices where applicable for intended use". Flooring with low slip resistance is not recommended for general use.

d) ANSI A137.1

According to the ANSI A137.1 standard, level interior spaces expected to be walked upon when wet must have a minimum wet DCOF AcuTest value of 0.42.

However, there is a caveat included that states not all products with a DCOF AcuTest value over 0.42 are suitable for all applications. Types of use, traffic, contaminants, maintenance, expected wear, and manufacturer's guidelines and recommendations are important and must also be considered by the specifier.

4) Research and Test Results

Research at the University of Wuppertal in Germany (known worldwide for their traction studies) studied human subjects walking on force plates to find the relationship between the tangential force and the vertical force needed for reliable traction; this relationship defines the COF. It is commonly found to be between 0.2 and 0.3 depending on the individual. The German researchers then considered many different slippery conditions, different ways people could move on the surface, and accident statistics over many years to recommend to the German national insurance body a minimum wet DCOF of 0.42 for flooring.

The TCNA conducted tests on more than three hundred tile surfaces and found that 0.60 wet SCOF correlated on average with 0.38 wet DCOF. This means that the recommended 0.42 DCOF will actually provide a higher measure of safety over the traditionally used ASTM C1028 wet SCOF value of 0.60.

In 2015, Oaks tested various paver and slab sizes (affects the presence of a chamfer, if any, within the test area), textures (smooth versus embossed), production styles (face mix versus through colour) and finishes (standard versus colour treatment) to assess how changes affected the DCOF. In 2020 additional testing was done on new surfacing options (ground face and shot blasted) being investigated. Testing of how

the degree of texturing affected the DCOF could not be performed as the testing firm was concerned that moderately to highly textured surfaces would damage the BOT-3000. The results are as follows:

Product Details				DCOF Results	
Size	Texture	Production	Finish	Average	Range
4x8	Smooth	Face Mix	None	0.67	0.57 – 0.83
4x8	Smooth	Face Mix	Treated	0.55	0.49 - 0.64
>12x12	Smooth	Through Colour	None	0.54	0.48 – 0.7
>12x12	Embossed	Through Colour	None	0.6	0.54 - 0.71
>12x12	Ground Face	Face Mix	None	0.54	0.53-0.55
>12x12	Shot Blasted	Face Mix	None	0.58	0.55-0.63

Note: for units >12x12, there would be no chamfer within the test area.

In short, all products tested exceeded the recommended minimum DCOF of 0.42. General observations are that:

- 1. Products with chamfers (i.e. smaller paver) or texturing have a higher DCOF.
- 2. Treating the surface with chemicals decreases the DCOF of the product this is likely as a result of the reduced absorption of the material resulting in water beading on the surface.
- 3. Surface treatments such as ground face and shot blasting only create a marginal change in the DCOF.

Please note that the treatment process tested is a liquid additive applied during production such that it is intrinsic to the product, and not a post-curing or on-site applied sealer. Where the latter is being requested by a client to be applied to a paver or slab surface post installation, we recommend that the sealer / paver product combination be tested.

5) Recommendations for Specifications

As noted above, OSHA references the COF of 0.5 solely as a guide, not a rule. Further, the inherent flaws of ASTM C-1028 are causing this standard to fall out of favor. In the end, this is an incorrectly applied guidance standard using a non representative (static conditions) and problematic test method that will not protect the owner from potential liability.

ANSI A137.1 testing using the BOT-3000 is cost effective, and provides rapid and automatically documented wet testing, both static and dynamic, with various available test foot materials. Specifying product that has *a MINIMUM Dynamic Coefficient of Friction of 0.42 as determined in accordance with ANSI A137.1 on a wet surface* would help to reduce the risk of slips and falls. Should the owner want to reduce their potentially liability in the event of a slip and fall claim, a higher DCOF value can be specified.