CONTINUED ASSESSMENT OF VARIOUS CERAMIC TILE FLOOR COVERINGS USING DIFFERENT FRICTION TEST METHODS

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ABSTRACT

ANSI A326.3, *American National Standard Test Method for Measuring Dynamic Coefficient of Friction of Hard Surface Flooring Materials*, was revised in 2021 to include five "product use classifications" (see Table 1, below). Since publication of this standard in February 2022, manufacturers have been making classifications available for their products to meet the standard.

Classification	Reference Category	Criteria
Interior, Dry	ID	≥ 0.42 dry DCOF* (per Section 10.1)
Interior, Wet	IW	≥ 0.42 wet DCOF* (per Section 9.1) or Manufacturer-Declared
Interior, Wet Plus	IW+	Manufacturer-Declared
Exterior, Wet	EW	Manufacturer-Declared
Oils/Greases	O/G	Manufacturer-Declared

Table 1: *Product Use Classification*

The "0.42" wet and dry DCOF criteria are maintained from the 2017-version of A326.3, and have been used by the US ceramic tile industry for over 10 years. The new "manufacturer-declared" requirement (Section 3.4) allows manufacturers to define their own internal product selection criteria—which can be based on results from any friction measurement method. Since manufacturers can define internal threshold values using any methodology, research has been initiated at TCNA to assess various ceramic tile products according to three different friction measurement methods:

1) ANSI A326.3 (wet DCOF testing with a BOT 3000E tribometer)
2) DIN/EN 16165 Annex B ("R"-value testing using a "German" ramp)
3) DIN/EN 16165 Annex C (skid resistance testing using a pendulum device)—with some ASTM E303 results provided for comparative purposes

This research will expand on work presented at the June 2023 IEA Conference in Toronto and include further research conducted at TCNA. Results on approximately 100 products are expected for Qualicer 2024. This work is the first of its kind to compare test results on various ceramic tile products to real-world manufacturer declarations per ANSI A326.3. As such, it is expected to have significant implications on the future development of ANSI A326.3. Further, it is anticipated manufacturers will be able to use the findings from this work to better define their A326.3 declarations and strengthen their understanding of how differing test methods and devices perform on certain products depending on surface characteristics.

INTRODUCTION

When used individually, measurements of surface friction (e.g., dynamic coefficient of friction, pendulum test values, R values obtained from ramp testing) may be mistakenly perceived as the sole indicator of a surface's slipperiness. While such measurements are helpful in assessing the relative traction of a surface, there are many other aspects relating to slip resistance that should be considered—especially by manufacturers, specifiers, and consumers of ceramic tile (and all other types of hard surface flooring). To provide standardized criteria that allows for consideration of different slip resistance-related factors, and to facilitate better communication on where products can be used based on their slip resistance characteristics, ANSI A326.3 *American National Standard Test Method for Measuring Dynamic Coefficient of Friction of Hard Surface Flooring Materials* requires that products be classified into one of more of five "product use classifications."

This unique classification system is based on manufacturer declarations, meaning manufacturers must define their own internal product selection criteria to classify products based on multiple traction-related parameters.

Since there are many friction test methods that can be used as part of an internal selection criteria, research was initiated to assess ceramic tile products using three well-known methods for measuring surface friction: ANSI A326.3 using a BOT 3000E device, DIN/EN 16165[1] Annex B using a variable-angle ramp, and DIN/EN 16165 Annex C using a pendulum device. As of September 2023, nearly 100 products have been collected, 59 of which have been fully assessed using all three test methods. After all collected products have been measured per each method, the results will be analyzed for testing trends and insights depending on declared product use classification, certain surface characteristics, and more.

BACKGROUND

Davidson's 2022 Qualicer submission indicated that dynamic coefficient of friction (DCOF) is often mistakenly portrayed as the sole indicator of a surface's slipperiness.[2] Similar to that concept, values obtained from pendulum and ramp testing are for specific test conditions and do not represent a single, condensed value applicable to all aspects of slip resistance. In most instances, these values alone are not sufficient in determining where products can be installed. However, when paired together, or in consideration with other traction-related factors such as drainage of liquids or presence of three-dimensional patterning/profiling, a more complete picture can be determined regarding product use.

ANSI A326.3[3], which contains a test method for measuring dynamic coefficient of friction (DCOF[4]) of hard surface flooring materials in the laboratory and in the field, requires that products are classified into one or more of five product use classifications shown in **Table 1**.

The unique system is unlike any other in the North American marketplace and requires that manufacturers define internal product selection criteria to classify products based on multiple traction-related parameters.[5] As a result, manufacturers are not limited to using a single measurement criterion, nor are they required to use a specific tribometer device (some of which can produce misleading values depending on the characteristics of the surface being measured[6]).

[1] DIN/EN 16165 is titled *Determination of slip resistance of pedestrian surface – Methods of evaluation* and contains test methods for testing with a variable-angle ramp (barefoot and shod), a pendulum, and a tribometer device.
[2] Davidson, G. (2022, June). *Slip Resistance—Advancements in Product Use Categories for Hard Surface Flooring and Adoption of Standards Into North American Building Codes*. Qualicer 2022, Castelló, Spain.
[3] ANSI A326.3 was initially published in 2017. It was based substantially on criteria previously standardized and published in ANSI A137.1, and includes a test method for measuring wet or dry dynamic coefficient of friction (DCOF) of hard surface flooring materials in the laboratory or field. In 2021, it was updated to provide five product use categories for hard surface flooring products. A copy of ANSI A326.3 can be downloaded for free at https://tcnatile.com/resource-center/dynamic-coefficient-of-friction/.
[4] DCOF, as defined in ANSI A326.3, is the ratio of the force necessary to keep a surface already in motion sliding over another surface divided by the weight (or normal force) of the sliding object. Different contaminants such as dirt, water, soap, oil, or grease can change this value.
[5] For more information on manufacturer declarations, refer to Sections 3.0 and 4.0 of ANSI A326.3.
[6] Surface structure/texture, which can improve traction when walking due to mechanical interlocking, can result in some tribometers testing along the "peaks" of the surface, measuring only certain high points rather than making constant contact across the distance of the measurement. Similarly, grout joints and tile edges may affect results.

Classification	Reference Category	Criteria
Interior, Dry	ID	≥ 0.42 dry DCOF* (per Section 10.1)
Interior, Wet	IW	≥ 0.42 wet DCOF* (per Section 9.1) or Manufacturer-Declared
Interior, Wet Plus	IW+	Manufacturer-Declared
Exterior, Wet	EW	Manufacturer-Declared
Oils/Greases	O/G	Manufacturer-Declared

Table 1: *Product Use Classification*

This concept is like the German work rule ASR A1.5[7] that relates "R" groups[8] obtained per DIN/EN 16165 Annex B to various product use scenarios, with the key difference being the new ANSI A326.3 system does not rely on a single test method and allows for various factors to be considered.

Given the recent development of the product use system, there is ceramic tile manufacturer interest in North America to further develop the understanding of how measurements from commonly used testing devices can be impacted depending on certain surface characteristics. Additionally, there is currently no research available comparing results obtained using popular test methodologies back to the manufacturer-declared A326.3 classifications.

SCOPE OF STUDY

The key objective of this research was to assess various ceramic tile products using three well-known methods for measuring surface friction. The results will be used to look for trends and testing insights in relation to each product's assigned ANSI A326.3 product use classification.

RESEARCH METHODOLOGY

PRODUCT COLLECTION

Beginning in March 2023, various ceramic (non-porcelain), porcelain, and quarry tile products were donated by various manufacturers who sell tile into the North American marketplace. As of September 2023, nearly 100 products had been collected, although it is possible that number will increase prior to the Qualicer 2024 conference. As of September 2023, 59 products had been tested using three different methodologies, described in the following sections of this paper.

[7] ASR A1.5 is a German Technical Rule for Workplaces that relates "R" groups to specific flooring applications.
[8] "R" groups, or "R" values, are derived from the angles at which harnessed, human operators, wearing standardized footwear, "slip" on an increasingly inclined, oil-slicked ramp.

WET DCOF TESTING PER ANSI A326.3

The methodology used for assessing wet DCOF for each tile product was ANSI A326.3 Section 9.0.[9] The test consists of an automated dragsled-type tribometer (BOT 3000E was used for this research), an SBR testfoot, and 0.05% Sodium-Lauryl Sulfate solution (SLS) being used to test a surface for its wet DCOF value in four different test directions. Operator error is limited by use of a validation surface.

SHOD RAMP TESTING PER DIN/EN 16165 ANNEX B

The methodology used for determining the "R" value for each tile product was DIN/EN 16165 Annex B.[9] The test consists of two test persons, wearing standardized work shoes, determining the angle of slip by walking upon a test piece that has been evenly coated with oil. The mean angle of slip obtained from multiple operator tests is used to express the degree of slip resistance as an "R" value.

PENDULUM TESTING PER DIN/EN 16165 ANNEX C

The methodology used for determining the pendulum test value (PTV_{96}) for each tile product was DIN/EN 16165 Annex C.[9] The test requires use of a pendulum friction tester to measure loss of energy as a standard rubber testfoot slides across a test specimen. Slider 96 was the testfoot material utilized and all surfaces were tested in wet, laboratory conditions. The flatness criteria contained in Section C.3.4 were ignored for the purposes of this research, to better understand how certain product surface texture patterns affect results.

There are other pendulum testing standards besides the DIN/EN 16165 Annex C methodology. A method commonly used in the US is ASTM E303 *Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester*. DIN/EN 16165 Annex C requires sensor preparation using P400 paper and pink lapping film; ASTM E303 requires the use of a 60-grade silicon carbide cloth. Work by Bowman, Strautins, and Do[10] showed that slider preparation can significantly impact pendulum results for stone products.

To evaluate this effect on ceramic tiles, ASTM E303 results were obtained on a few products to evaluate the effect of preparing a slider 96 with 60-grade silicon carbide cloth versus P400 paper and pink lapping film.

[9] The same methodology will be used to measure the products that had not been tested as of September 2023.
[10] Bowman, R., Strautins, C., Do, M. (2005). Beware of conflicting stone slip resistance reports. *Discovering Stone*, (7), 26-34.

PRELIMINARY FINDINGS

Product Breakdown

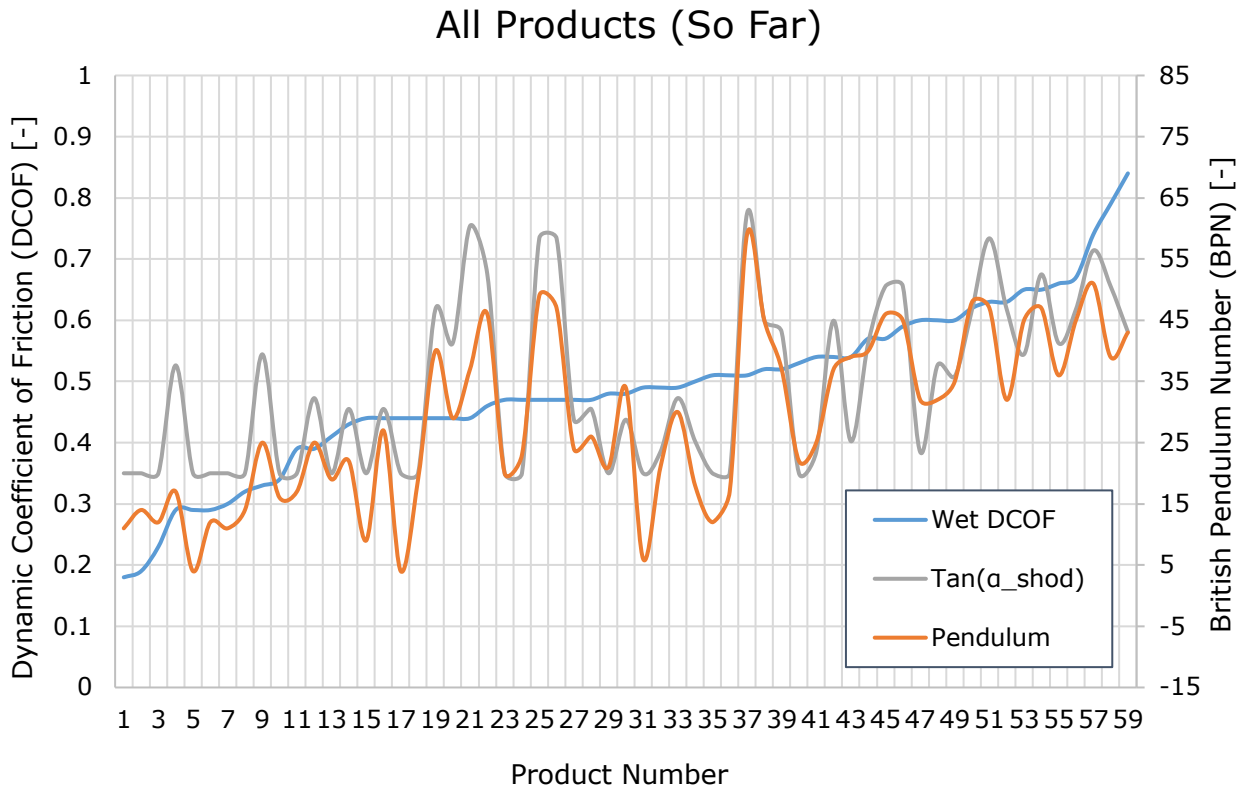
Table 2 shows the breakdown of the A326.3 product use classifications for the 59 products that have been fully assessed using all three methodologies. The 59 tested products cover a wide range of surface texture types. Manufacturer descriptions of product surface textures included, but were not limited to, polished, satin, glazed, gloss, enameled, matte, lappato, honed, unpolished, textured, treaded, and abrasive.

Reference Category	Number of Products Tested
ID	17
IW	20
IW+	7
EW	8
O/G	7

***Table 2**: Breakdown of Tested Products by A326.3 Classification*

PRELIMINARY RESULTS

The wet DCOF, ramp, and pendulum test results for 59 products, as of September 2023, are shown in **Graph 1**.



***Graph 1:** Preliminary Results*

The results are sorted based on wet DCOF values from low to high. The resultant a_{shod} values obtained from DIN/EN 16165 Annex B testing were converted to coefficient of friction values by taking the tangent of the angle.[11,12] The pendulum results are plotted on their own individual y-axis. The results show the preliminary data for all products, regardless of declared A326.3 product use classification and regardless of any defining surface characteristics. Notably, there are multiple areas where the results for all three methods overlap, where the results for all three methods diverge, and where the results for one of the three methods does not line up with the other two.

The DIN/EN 16165 Annex C results in comparison to ASTM E303 results (for ten randomly selected products) are shown in **Table 3**.

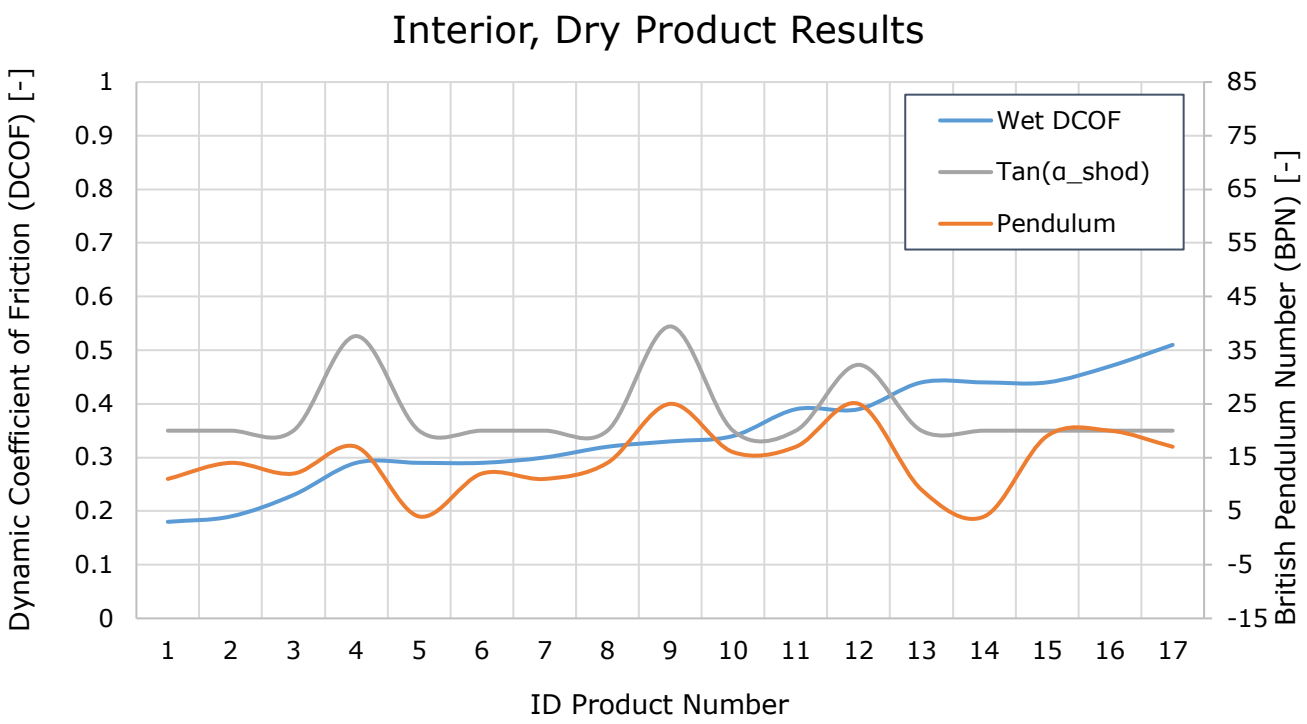
Product Number	DIN/EN 16165 Annex C Result (PTV_{96})	ASTM E303 Average Result (BPN)
4	17	28
8	14	19
11	17	24
14	22	35
33	30	45
34	18	24
44	40	47
45	46	53
48	32	41
56	45	50

***Table 3**: DIN/EN 16165 Annex C vs. ASTM E303 Results*

The **Table 3** results clearly show a similar effect of sensor preparation as demonstrated by Bowman, Strautins, and Do. Using 60 grade silicon carbide cloth for sensor preparation, as opposed to P400 conditioning paper and pink lapping film, produces significantly higher pendulum results on average. If relying on ASTM E303 test results as part of an internal product selection criteria for ANSI A326.3 manufacturer-declared product use classifications, manufacturers should exercise caution—conditioning with 60-grade silicon carbide cloth results in a rougher sensor that may not be able to consistently measure test specimens.

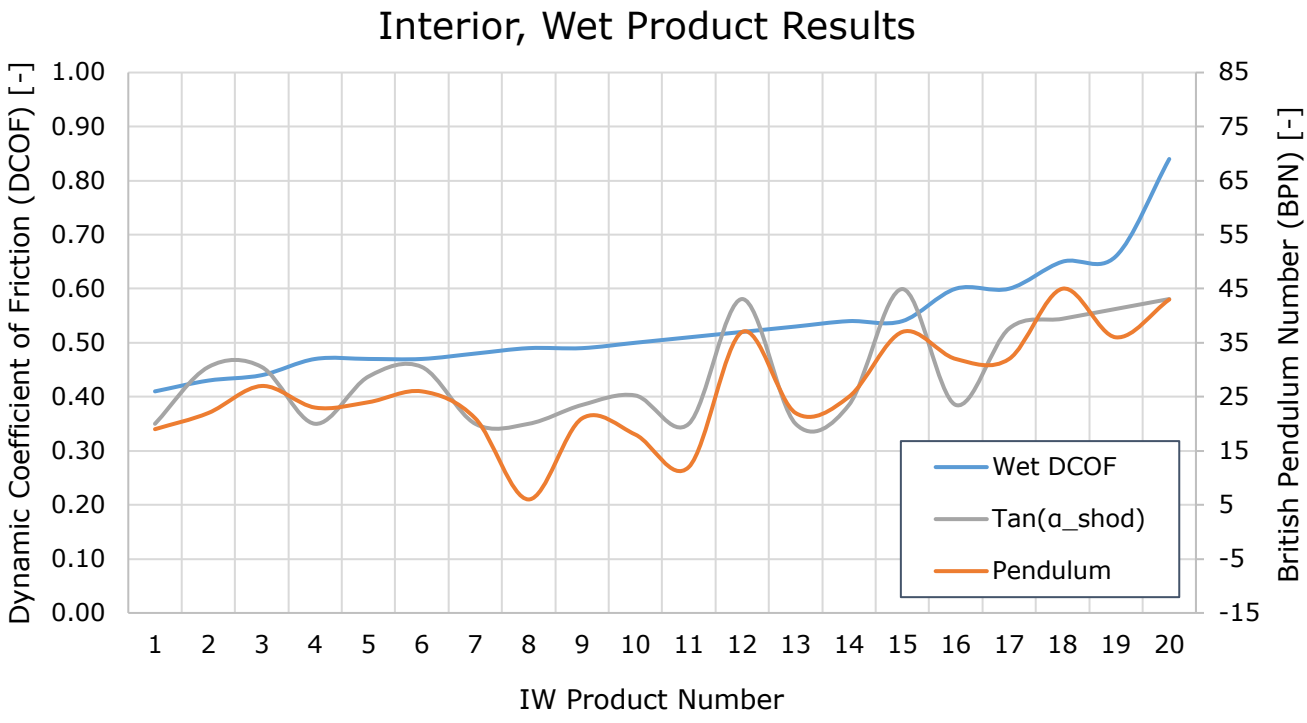
[11] In his work titled *System oriented concept for testing and assessment of the slip resistance of safety, protective and occupational footwear*, Jens Sebald utilized the equation $\alpha = \tan^{-1}(\mu)$ to convert ramp angles to dynamic coefficient of friction.

[12] The $\tan(a_{shod})$ plotline is shifted upwards by 0.35 units on the DCOF axis, for viewing purposes.



***Graph 2**: Interior, Dry (ID) Product Results*

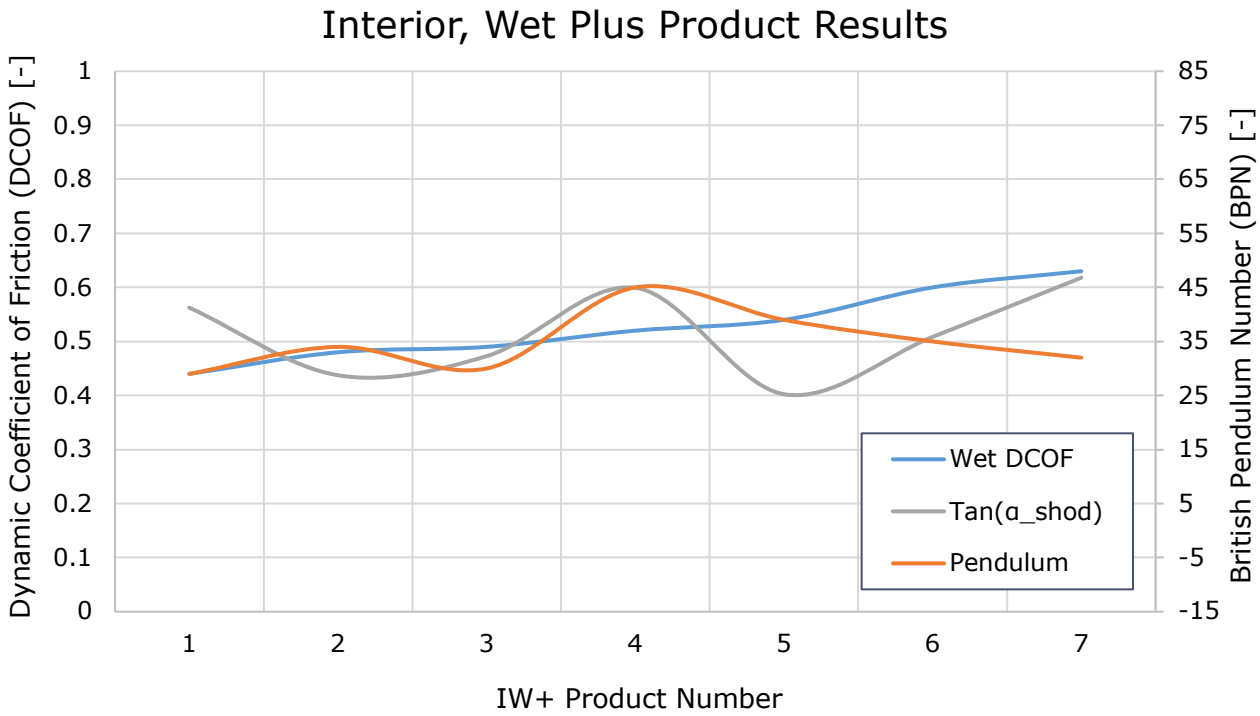
There are some divergences of results for the three test methods used on the ID products. However, these products are intended to be installed in areas where the floor shall be kept dry. While a future area of consideration could be to assess the surface texture of these products, the results for all three methods are relatively low due to mostly polished or otherwise very smooth finishes.



***Graph 3**: Interior, Wet (IW) Product Results*

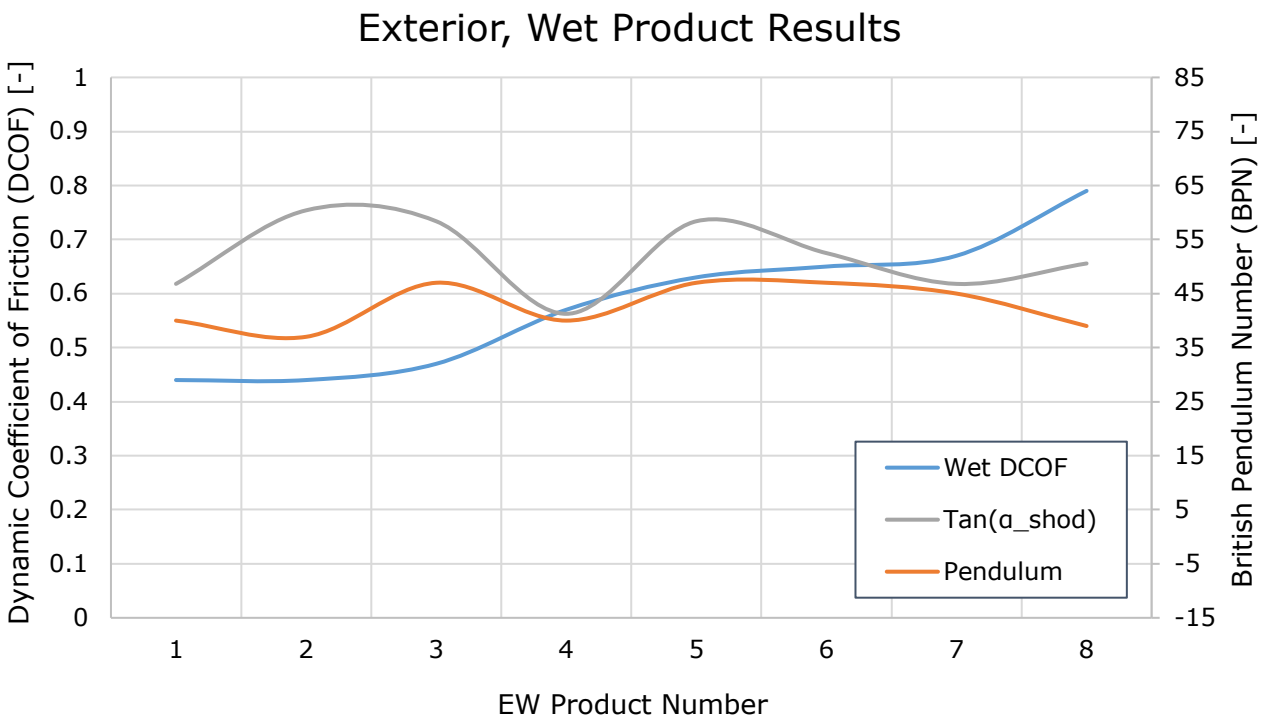
The criteria for IW products are that they must be manufacturer-declared or have a minimum wet DCOF value of 0.42 or greater per ANSI A326.3. If only using the 0.42 criterion, only the first product in **Graph 3** did not meet that criterion. All other products met this criterion, but there are several areas where the ramp and pendulum test results were considerably lower than the DCOF results. There are two key factors that must be considered moving forward with this work:

1) **Product surface texture**: The IW products exhibited a wide range of manufacturer-defined finishes, and qualitative observations yielded a wide range of surface textures amongst the products. However, the role that texture plays in causing variation between test results from the three methods has not yet been assessed in this study. Specific texture-related factors must be assessed moving forward.
2) **Test contaminants**: ANSI A326.3 requires the use of 0.05% SLS solution, DIN/EN 16165 Annex B requires the use of motor oil, and DIN/EN 16165 Annex C requires the use of potable water. An area that will be assessed moving forward is how the results for each method are affected by using each of the different surface contaminants. For example, ramp results using potable water or SLS solution on products not classified as "Oils/Greases" would provide valuable insight into surface traction for products being installed in areas where water-based contaminants are expected.



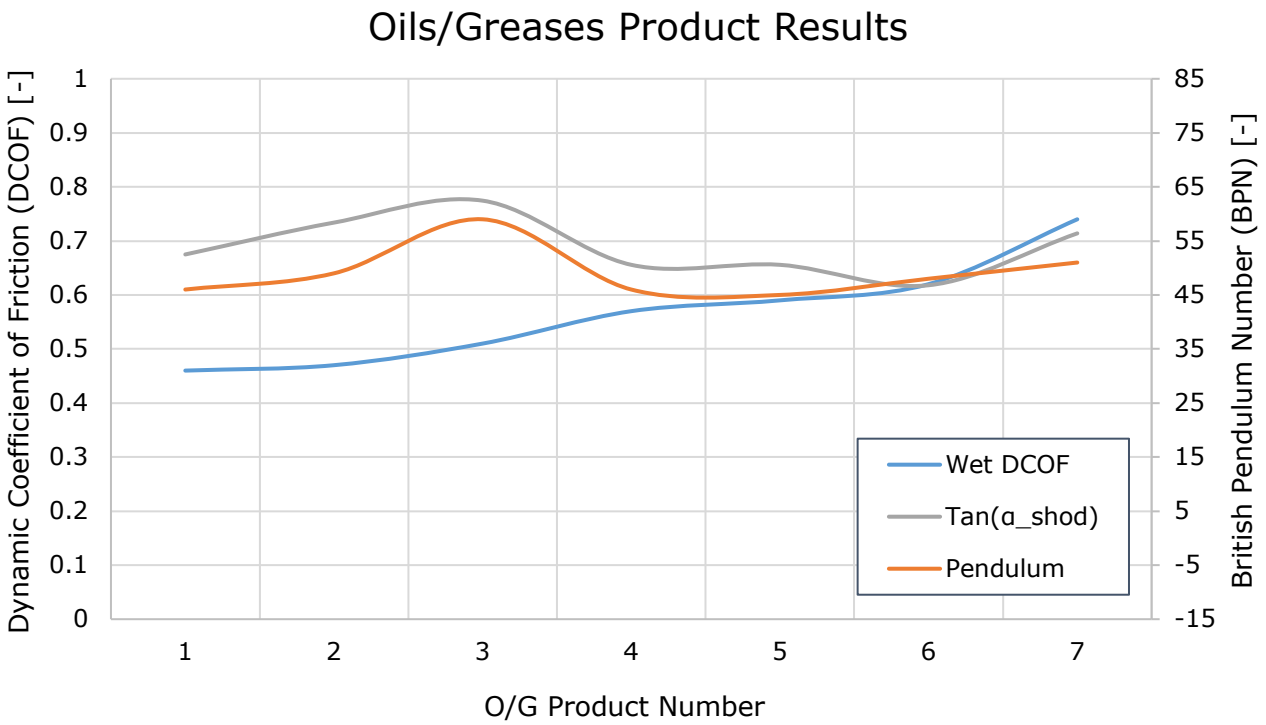
Graph 4: *Interior, Wet Plus (IW+) Product Results*

IW+ products require a manufacturer declaration, meaning the manufacturer is required to define their own internal product selection criteria. Notably, four mosaic tile products have been tested, all of which were classified as IW+. The other three products were manufacturer-designated as having "matte" surface finishes, but the full degree of surface texture varied. In addition to investigating the key factors discussed under **Graph 3**, an investigation into how mosaic edges affect test results using each of the three methods would provide valuable insight.



Graph 5: *Exterior, Wet (EW) Product Results*

EW products require a manufacturer declaration. Most products exhibited a profound degree of intentional or random patterning, and all results were relatively high for each of the three methods. Moving forward, given the observed nature of surface texture, the displacement space test per DIN 51130:2023-03 *Testing of floor coverings – Determination of the displacement space* would provide valuable insight, in addition to further investigation of other texture-related factors.



Graph 6: *Oils/Greases (O/G) Product Results*

O/G products require a manufacturer declaration Most products exhibited a profound degree of intentional or random patterning, or had significant abrasive embedded into the product surface, and all results were relatively high for each of the three methods. Notably, several of the products were quarry tiles, which are regularly installed in areas where the floor will be exposed to oils and greases. Like the EW category, results per DIN 51130 and other texture-related factors should be assessed moving forward.

NEXT STEPS

While the results on the first 59 products tested are insightful, there are many more products to be tested. The number of products remaining could significantly impact the plotlines presented in **Graphs 1 through 6**. Those results are expected to be available for Qualicer 2024, with additional information on physical surface texture characteristics. Once the research is complete, it will be useful in understanding how certain product types perform depending on the measurement method. This information could be used to further define the manufacturer-declared classifications in ANSI A326.3 and help further develop manufacturer understanding of different test methods and how they can be used as part of their internal product selection criteria. This would also be beneficial for specifiers, resulting in better specification of flooring and potentially less accidents as a result.

REFERENCES

[1] American National Standards Institute (ANSI). *American National Standard Test Method for Measuring Dynamic Coefficient of Friction of Hard Surface Flooring Materials*. ANSI A326.3-2021, Anderson, SC: Tile Council of North America.
[2] ASTM International. 2022. *Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester*. ASTM E303-22, West Conshohocken, PA: ASTM International.
[3] Astrachan, Eric (2016). Research Supporting an ANSI American National Standard for Slip Resistance. *Tile Initiative*, 2-9.
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[5] Davidson, Grant. *Assessment of Various Ceramic Tile Floor Coverings Using Different Friction Test Methods*. June 2023. PowerPoint Presentation.
[6] Davidson, Grant. (2022, June). *Slip Resistance—Advancements in Product Use Categories for Hard Surface Flooring and Adoption of Standards Into North American Building Codes*. Qualicer 2022, Castelló, Spain.
[7] German Institute for Standardization (DIN). *Determination of slip resistance of pedestrian surfaces – Methods of evaluation*. DIN EN 16165:2021-12, Berlin: German Institute for Standardization.
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