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Wet Slip Resistance of Plastic Based Material Flooring (PBM Flooring)

John P. Sanders
Clemson University, jpsand@clemson.edu

Grant Davidson
Tile Council of North America

Clemson University
Bishop Materials Laboratory

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John P. Sanders, Ph.D., PE
Director, The Bishop Materials Laboratory, College of Engineering, Computing and Applied Sciences
Research Professor, Department of Materials Science and Engineering

Grant Davidson
Standards Development Engineer, Tile Council of North America

The Bishop Materials Laboratory
102 Clemson Research Blvd
Anderson, SC 29625 USA
TEL: 864.656.1094
www.brickandtile.org

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1.0 Executive Summary

Tile Council of North America Product Performance Testing Laboratory, under the direction of Dr. John Sanders of the Bishop Materials Laboratory at Clemson University, measured the wet Dynamic Coefficient of Friction (DCOF) of 22 plastic based material (PBM[1]) flooring products that manufacturers[2] advertise or claim to be waterproof, water resistant, or depict being used in areas where flooring gets wet.[3] The claims suggest that such PBM products can be used where exposed to water. However, product literature for only five products tested in this report cautioned the products can be potentially slippery when wet, and no measurements of wet DCOF are provided by the product manufacturers for any of the PBM flooring products studied.[4] This research examines whether the tested products are suitable for wet use, or instead should carry a dry use-only caution.

ANSI A326.3, *American National Standard Test Method for Measuring Dynamic Coefficient of Friction of Hard Surface Materials,* was used to measure the wet DCOF of each PBM product. The ANSI A326.3 test method was developed through a broad consensus of stakeholders across the flooring industry and is widely used in the ceramic tile, polished concrete, and stone industries.[5]

The ANSI A326.3 testing showed 16 out of the 22 product specimens tested in this report had an average wet DCOF value below 0.42. Per ANSI A326.3, those 16 specimens are not suitable for

[1] PBM flooring described herein includes, but is not limited to, flooring products recognized in the marketplace as Resilient Floor Coverings, Luxury Vinyl Tile (LVT), Luxury Vinyl Plank (LVP), Wood Polymer Composite (WPC), Stone Polymer Composite (SPC), Clay Polymer Composite (CPC), and Rigid Core Board (RCB).

[2] "Manufacturer" in the context of this report refers to any of the following: actual manufacturer, apparent manufacturer, or primary importer.

[3] At the time testing for this report was conducted, all tested products were advertised or claimed as waterproof, water resistant, or depicted being used in areas where flooring gets wet.

[4] Literature for nine of 22 tested products contained ASTM D2047 (see Section 3.4.1 of this report) dry SCOF values or specifications. Literature for three products contained ASTM C1028 (see Section 3.4.2 of this report) SCOF values or specifications, one of which was specified as a dry test value, and two which did not specify wet or dry test conditions but based on the values reported appear to be dry values. No literature for the 22 products was found providing wet DCOF values or specifications. Refer to Table 6.1.1 for a complete list of COF specifications for the products tested in this report.

[5] At the time ANSI A326.3 was developed by ANSI Accredited Standards Committee (ASC) A108, there were over 60 voting members representing a wide range of stakeholders in the flooring industry. https://web.archive.org/web/20190520173144/https://www.tcnatile.com/industry-issues/dcof-acutest.html.

wet use,[6] although each tested product was advertised as waterproof, water resistant, or was depicted being used in areas where flooring gets wet. In addition, two out of 22 product specimens' DCOF measured below 0.42 when tested parallel to the plank length, but above 0.42 when tested perpendicular to the plank length. These two products exhibited a potentially dangerous level of directionality (See Section 3.6.3) with a significant change in DCOF occurring depending on the direction of measurement. Further, four other products exhibited directionality. In total, 20 of the 22 products tested for this report exhibited either a low level of wet DCOF for products that are advertised for wet applications (18 of 22) or directionality when wet (6 of 22)[7], and should be considered for a dry use-only cautionary statement.

[6] ANSI A326.3 specifies that level, interior surfaces expected to be walked upon when wet must have a wet DCOF test value of greater than or equal to 0.42. See Section 3.0 *Specification* in ANSI A326.3. https://web.archive.org/web/20190520173303/https://www.tcnatile.com/images/pdfs/ANSI_A326.3_1-18.pdf.

[7] Four of the six products exhibiting directionality also are included in the 18 products with DCOF measurements below 0.42.

2.0 Introduction

This report presents a wet Dynamic Coefficient of Friction (DCOF) assessment of a variety of plastic based material (PBM) flooring samples that have been advertised as waterproof, water resistant, or depicted being used in areas where flooring gets wet. This report also includes an assessment as to whether such flooring products when wet warrant a dry use-only caution. Testing was performed by the Tile Council of North America Product Performance Testing Laboratory, under the direction of Dr. John Sanders of the Bishop Materials Laboratory, in the Advanced Materials Research Park at Clemson University.

Thirty-seven flooring products were purchased between October 2018 and March 2019 from retail locations in South Carolina. The PBM flooring products were purchased based on the following criteria: (1) product was easily obtainable,[8] (2) was popular among specialty flooring resellers, designers, and architects,[9] or (3) reflected current or upcoming trends among floor coverings.[10] Twenty-two of the PBM products were selected for wet DCOF testing based on claims of being waterproof, water resistant, or were depicted being used in areas where flooring gets wet.[11] Samples of each product were measured for their wet DCOF value using ANSI A326.3. The test procedure for the ANSI A326.3 method is described in Section 5.2 of this report.

Section 3 details the purpose of this report and provides relevant background information; Section 4 describes the product sampling. Section 5 details how each product was evaluated. Sections 6 and 7 respectively present the testing results and provide a discussion thereof. Section 8 summarizes the conclusions.

[8] Products were available for local pickup in 14 days or less.
[9] Products were advertised as "best sellers" with online retailers or were recommended by local retailers specializing in flooring.
[10] Based on advertisements from online retailers, local retailers specializing in flooring, or observations from Surfaces Trade Show held in Las Vegas, Nevada 2019.
[11] Claims of being waterproof, water resistant, or depicted being used in areas where flooring gets wet were found by the authors in product literature or advertisements and have been archived using an internet archive "Wayback Machine." https://web.archive.org/. If none of these claims were found for a purchased product, then that product was not tested.

3.0 Background

3.1 Purpose of study

Tile Council of North America Product Performance Testing Laboratory, under the direction of Dr. John Sanders of the Bishop Materials Laboratory at Clemson University measured the wet Dynamic Coefficient of Friction (DCOF) of 22 different PBM flooring products, the manufacturers of which advertise or claim the products are waterproof, water resistant, or depict such products being used in areas where flooring gets wet. The claims suggest that these PBM products can be used where exposed to water. This study evaluates the wet DCOF of these flooring products, compares the results to established criteria for hard surface flooring, and discusses whether some PBM products should be considered for a dry use-only cautionary statement.

3.2 Wet Dynamic Coefficient of Friction (DCOF)

The wet Dynamic Coefficient of Friction (DCOF) of a material is defined as 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 under wet conditions.[12] In a laboratory, wet conditions often consist of a combination of deionized water and surfactant (surfactant is added to water in a carefully controlled standardized manner to create a uniform film on a hydrophobic surface and to simulate soapy wet conditions that are sometimes present in slip situations). Surfactants lower the surface tension of water,[13] which helps to simulate the effects of a squeeze film. A squeeze film commonly forms between the bottom of a shoe (or foot, if barefoot) and a wet flooring surface at the time of a slip.[14]

[12] ANSI A326.3, Section 2.0 *Definition of Terms*.
[13] Callister Jr., William D. and David G. Rethwisch (2014). *Materials Science and Engineering: An Introduction, 9th Edition* (p. 41). Hoboken, NJ: John Wiley & Sons, Inc. See definition of "surfactant."
[14] Chen et al., *The slip-resistance effect evaluation of floor roughness under different liquid viscosity*. Procedia Manufacturing 3 (2015) 5007 – 5009.

3.3 Relevance of COF testing

Extensive research explores the relevance of COF testing, particularly concerning human ambulation and slip risk.[15,16,17,18,19] Notably, research by Iraqi, Cham, Redfern, and Beschorner (2018)[20] shows that COF can be used as a predictor of slip risk for same-level ambulation, indicating that available friction can have a significant effect on the potential for slip events while walking. Further, research conducted in Germany establishes a correlation between human ambulation and DCOF and provides a basis for the development of many laboratory and field DCOF test methods. Two of the German studies are described in Sections 3.3.1 and 3.3.2.

3.3.1 Bönig dissertation on DCOF limit values

The research of Dr. Stefan Bönig titled, "Experimental Investigation to Determine the Standardized Limit of the Coefficient of Friction for Slip Resistance During Walking," was published in 1996 and establishes a necessary friction required for walking. This pivotal research was necessary for the determination of DCOF limit values that are calculated to reduce the likelihood of a slip to less than one fatality in a million over 10 years.[21] Conducted at Wuppertal University in Germany, this highly regarded research has been added to the German workplace guidelines for safety, titled "Handbook of Commercial Safety Technology." Bönig utilized force plate measurements, accident statistics, and social acceptability to determine DCOF limit values for different walking conditions. For example, "straight-line walking" has a DCOF limit value of 0.39, "descent of stairs" is 0.41, and "turning while walking" is 0.42. These limit values, along

[15] Beschorner, Kurt E., Devon L. Albert, Mark S. Redfern. *Required coefficient of friction during level walking is predictive of slipping*. Gait & Posture 48 (2016) 256 – 260.
[16] Lockhart, Thurmon E. *Biomechanics of Slips and Falls in the Elderly*. PhD diss., Lubbock, Texas: Texas Tech University, 1997.
[17] Chang, Wen-Ruey, Chien-Chi Chang, Mary F. Lesch, Simon Matz. *Gait adaptation on surfaces with different degrees of slipperiness.* Applied Ergonomics 59 (2017) 333 – 341.
[18] McGorry, Raymond W., Angela DiDomenico, Chien-Chi Chang. *The anatomy of a slip: Kinetic and kinematic characteristics of slip and non-slip matched trials*. Applied Ergonomics 41 (2010) 41 – 46.
[19] Cham, Rakie, Mark S. Redfern. *Changes in gait when anticipating slippery floors.* Gait and Posture 15 (2002) 159 – 171.
[20] Iraqi et al. *Coefficient of friction testing parameters influence the prediction of human slips*. Applied Ergonomics 70 (2018) 118 – 126.
[21] Bönig, Stefan. *Experimentelle Untersuchung zur Festlegung von normgerechten Teibzahl-Grentzwerten fuer gleitsicheres Gehen [Experimental Investigation to Determine the Standardized Limit of the Coefficient of Friction for Slip Resistance During Walking]*. PhD diss., Wuppertal, Germany: Bergishe Universität-Wuppertal, 1996.

with the research of Sebald described below, provided critical data for the development of ANSI A326.3, the standard used to evaluate products tested in this report.

3.3.2 Sebald research on the relationship between human ambulation and tribometry

"System Oriented Concept for Testing and Assessment of the Slip Resistance of Safety, Protective, and Occupational Footwear" by Dr. Jens Sebald, also from Wuppertal University, was published in 2009.[22] Sebald studied five means of measuring COF on 20 floor coverings, with three slider materials, 54 shoes, and three lubricants. The BOT 3000 (predecessor to the BOT 3000E),[23] British Pendulum,[24] and German Ramp[25] were three of the devices used in the study. Polyvinyl chloride (PVC[26]) and ceramic tile were among the floor coverings assessed. The research shows a significant correlation between the BOT 3000 and the German Ramp, with a correlation coefficient of 0.879. Sebald's research provides data for the relationship between human ambulation and tribometry, particularly the BOT 3000, and underpins the DCOF standard in ANSI A326.3.

3.4 Static Coefficient of Friction (SCOF) and PBM manufacturer slip resistance criteria

According to the Resilient Floor Covering Institute (RFCI[27]), "RFCI members constantly evaluate slip resistance in the development of their flooring products, which are typically intended for use in dry conditions."[28] In review of the technical data sheets for all 22 of the PBM products tested in this report, none reported wet DCOF values, although 12 reported Static Coefficient of Friction

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[22] Sebald, Jens (2009). *System Oriented Concept for Testing and Assessment of the Slip Resistance of Safety, Protective, and Occupational Footwear.* Berlin: Pro Business Gmbh.

[23] The BOT 3000 is a drag-sled type tribometer and predecessor to the BOT 3000E. Drag-sled tribometers slide a standardized test foot over a test specimen to measure COF.

[24] The British Pendulum "is an impact-type tester used to measure energy loss when a rubber slider edge is propelled over a test surface." See ASTM E303 Section 1 *Scope*.

[25] The German Ramp is a device that measures slip resistance based on human ambulation. A user (attached to a safety harness) walks on test specimens wearing standard footwear at specific angles, which are incrementally increased until a slip occurs; the angle is then used to determine an "R-value" which classifies slip resistance. The device is specified in DIN 51130 *Testing of floor coverings; determination of the anti-slip properties; workrooms and fields of activities with slip danger; walking method; ramp test* German National Standard.

[26] PVC is a widely produced plastic material that can be found in some PBM flooring.

[27] RFCI "is an industry trade association of leading resilient flooring manufacturers and suppliers of raw materials, additives, and sundry flooring products for the North American market." https://web.archive.org/web/20190821132502/https://rfci.com/about-the-institute/.

[28] *Comments of the Resilient Floor Covering Institute to the Consumer Product Safety Commission on the National Floor Safety Institute's Petition for Labeling Requirements Regarding Slip Resistance of Floor Coverings*. https://web.archive.org/web/20190821132630/https://www.regulations.gov/contentStreamer?documentId=CPSC-2018-0014-0090&attachmentNumber=1&contentType=pdf.

(SCOF) values. SCOF is defined as the ratio of tangential force at the instant that movement of an object begins divided by the normal force of the object [29] (applicable to an object pushing off from a resting or standstill position).

3.4.1 ASTM D2047 *Standard Test Method for Static Coefficient of Friction of Polish-Coated Flooring Surfaces as Measured by the James Machine*

Technical documents of nine products tested in this report specified the ASTM D2047 test method, which is a laboratory-only, static coefficient of friction (SCOF) test method. ASTM D2047 was developed for use on dry surfaces and "is not intended for use on 'wet' surfaces or on surfaces wherein the texture, projections, profile, or clearance between the sculpted pattern of the surface does not permit adequate contact between the machine foot and the test surface."[30] Due to the equipment required by the method, ASTM D2047 cannot be used for in-situ measurements of flooring materials. Considering that the standard is for dry-only conditions and measures SCOF, ASTM D2047 was not chosen as a testing method for this research.

3.4.2 ASTM C1028 *Standard Test Method for Determining the Static Coefficient of Friction of Ceramic Tile and Other Like Surfaces by the Horizontal Dynamometer Pull-Meter Method*

Technical documents for three of the products studied for this report specified the ASTM C1028 test method, which is a dry or wet SCOF test method that was withdrawn by ASTM in 2014. Literature for one product tested specified a dry ASTM C1028 test value, and literature for the other two products did not specify whether the measurement was performed in wet or dry conditions, although the values provided appear to reflect dry conditions. Among other issues, the method often resulted in high SCOF values on smooth, wet surfaces due to "stiction."[31] Similar to how sheets of glass "stick" together in the presence of water, stiction causes the ASTM C1028 Neolite sensor to "stick" to smooth surfaces when moisture is present. ASTM C1028 test results can also be affected by the speed at which the sensor is pulled by the operator and whether the

[29] Tangential force is the force acting along the direction of motion, while normal force (or the weight of the object in a horizontal system) acts perpendicularly to the plane of motion. See Chapter 3, Section 3.2 of Sebald's *System Oriented Concept for Testing and Assessment of the Slip Resistance of Safety, Protective, and Occupational Footwear*.
[30] ASTM D2047, Section 1.1 of *Scope*.
[31] Bhushan, Bharat. *Adhesion and stiction: Mechanisms, measurement techniques, and methods for reduction*. Journal of Vacuum Science & Technology B: Microelectronics and Nanometer Structure (2003). 2262. See the definition of "stiction" in *Introduction*: "In some cases, the static friction force required to initiate sliding is larger than the kinetic friction force required to sustain sliding … in the presence of a thin liquid film, high static friction can occur due to meniscus/viscous effects; this is referred to as 'stiction'."

acceleration of a pull is consistent. For these reasons, ASTM C1028 was not chosen as a testing method for this research.

3.5 ANSI A326.3 *American National Standard Test Method for Measuring Dynamic Coefficient of Friction of Hard Surface Flooring Materials*

ANSI A326.3 is a dry or wet DCOF test method suitable for testing in the laboratory or in the field. The test methodology is described in Section 5.2 of this report. ANSI A326.3 was chosen as the test method for this research because it can be used to measure the DCOF of flooring materials in wet conditions and because of its precision, which is detailed in Section 3.5.1. ANSI A326.3 calls for equipment that operates in wet conditions without experiencing stiction, is recommended by the manufacturer for use on vinyl materials,[32] and has widespread support in the flooring industry as detailed in Section 3.5.2. Additionally, it was developed by an ANSI accredited standards committee with stakeholders represented across the flooring industry as detailed in Section 3.5.2.

3.5.1 Precision of the ANSI A326.3 test method

According to ASTM E691, *Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method*, test method precision data is useful "in technical work when comparing test results against standard values (such as specification limits) or between data sources (different laboratories, instruments, etc.)." Repeatability "r" refers to precision of the results obtained using a particular test method on identical test items in the same laboratory by the same operator using the same equipment, while reproducibility "R" refers to precision of results obtained using the same test method on identical test items in different laboratories with different operators using different equipment.[33] The standard deviation of repeatability and reproducibility are referred to as "sr" and "sR," respectively, and are useful indicators of test method precision. The ANSI A326.3 standard contains a precision statement that was determined through statistical examination of 126 test results, from six laboratories on seven different materials.[34] The precision statement details "r and R" values, in addition to sr and sR for each test surface. The sr and sR

[32] The BOT 3000E, which is specified in ANSI A326.3, "is a motorized drag-sled which moves at a constant velocity along the floor surface. While moving, the slip resistance is metered and recorded via a standardized rubber sensing module in contact with the floor."
https://web.archive.org/web/20191003201147/https://walkwaymg.com/pages/bot3000
[33] ASTM E691, Sections 3.1.6, 3.1.7, 3.1.10, and 3.1.11.
[34] ANSI A326.3, Section 11.0 *Discussion of Wet DCOF Method Precision*.

values ranged from 0.01 to 0.03, indicating the precision of the test method on the seven materials analyzed.

3.5.2 Support for the ANSI A326.3 DCOF standard

ANSI A326.3 was developed by the ANSI Accredited Standards Committee (ASC) A108, which has over 60 voting members representing a broad spectrum of stakeholders across the flooring industry. The ANSI A326.3 standard is recommended for use on flooring by the Tile Council of North America, the Natural Stone Institute (NSI)[35], the Concrete Polishing Council (CPC)[36], all tile manufacturers selling ceramic tile in the U.S., and numerous installation contractors, slip/fall experts, and forensic consultants, a few of which are footnoted below.[37,38,39] Additionally, ASTM C1731, *Standard Specification for Concrete Floor Tile*, specifically references ANSI A137.1-2012 Section 9.6, which was the basis for the development of the ANSI A326.3 test method.[40] All domestic and many international ceramic tile manufacturers provide DCOF test results in their product specification sheets from ANSI A326.3 testing on their products. As an example, two are footnoted below.[41,42]

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[35] NSI recommends the use of ANSI A326.3 on p. 6 of "Testing Frictional Properties of Natural Stone Walking Surfaces." https://web.archive.org/web/20190529201819/http://pubs.naturalstoneinstitute.org/pub/977637c3-e1ee-32ea-7fdb-a8c2ba0e8126.

[36] CPC, formerly Concrete Polishing Association of America (CPAA), and a specialty council of the American Society of Concrete Contractors (ASCC), recommends the use of ANSI A326.3 in the report "CPAA Adopts New Position on Measurement of Polishing Concrete Floors' Slip Resistance." https://web.archive.org/web/20190821132742/https://www.ascconline.org/Portals/0/PS-2_CPC%20Slip%20Resistance_WebSC.pdf?ver=2017-11-21-151038-480.

[37] https://web.archive.org/web/20190930124954/http://mooreeng.com/walkway-safety-auditing/

[38] https://web.archive.org/web/20190930125822/https://www.griponusa.com/commercial/

[39] https://web.archive.org/web/20190930125132/https://slipsafefloors.com/certified-testing

[40] Prior to 2019, ANSI A137.1 *American National Standard Specifications for Ceramic Tile* contained a DCOF test method which shared criteria with A326.3 and was developed by ASC A108 prior to the development of A326.3. ANSI A137.1 was updated in 2019 to reference ANSI A326.3 for DCOF testing.

[41] Daltile, a large ceramic tile manufacturer in the United States, provides details on slip resistance factors to consider prior to tile selection, in addition to providing wet DCOF values on their product specification sheets. See https://web.archive.org/web/20190530184919/https://www.daltile.com/stylizer/tips-and-resources/tips-and-resources/factors-to-consider for slip resistance factors to consider and https://web.archive.org/web/20190930125234/https://digitalassets.daltile.com/content/dam/Daltile/website/resources/products/sales-sheets/embold/DAL_Embold_SS.pdf for a specification sheet example.

[42] Crossville, Inc., a large ceramic tile manufacturer in the United States, provides a catalog of wet DCOF value ranges for each of their products in addition to providing wet DCOF values on their product specification sheets. See https://web.archive.org/web/20190520173433/https://www.crossvilleinc.com/Resources/Tile-101/DCOF?tab=1 for their catalog of wet DCOF values, and

3.6 Relevance of other parameters on traction

3.6.1 Footwear material properties

The physical parameters of a flooring surface and the type of contamination it may be subjected to are not the sole factors that affect traction; the materials that come into contact with the floor and various human factors are also important components.[43] W. Chang and Matz (2001) showed that different footwear materials will yield different coefficients of friction for the same flooring material under the same conditions.[44] The BOT 3000E tribometer, which was used for this report, utilizes a styrene butadiene rubber (SBR) sensor. The results obtained from testing are specific to the SBR sensor coming into contact with the test contaminant and test surface.

3.6.2 Seamless systems and grout joints

Grout joints can have a significant beneficial effect on the in-situ slip resistance of flooring materials due to their impact on surface texture and drainage.[45] In contrast, flooring surfaces without grout joints may lack a mechanism for drainage, resulting in a water film and potentially standing water being present after a wetting event—both can negatively affect the slip resistance of the flooring surface. All of the products tested for this report are installed without grout joints; they are "clicked" together or butted together when glued down to minimize seams. For floors with a low wet DCOF value, lack of drainage resulting from an absence of grout joints or seams increases the slip hazard of those floors when wet.

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https://web.archive.org/web/20190930125658/https://www.crossvilleinc.com/getmedia/78e2f90d-3cec-4ecb-a520-2f1e080e8672/Crossville-Inc-Basalt-Fact-Sheet.pdf for a specification sheet example.

[43] Gronqvist, Raoul, J. Abeysekera, Gunvor Gard, Simon M. Hsiang, Tom B. Leamon, Dava J. Newman, Krystyna Gieloperczak, Thurmon E. Lockhart, and Clive Y. C. Pai (2003). 'The role of human factors in slipping' in *Measuring Slipperiness: Human Locomotion and Surface Factors*. Taylor & Francis Inc: New York. 66-72.

[44] Chang, Wen-Ruey, and Simon Matz. *The slip resistance of common footwear materials measured with two slipmeters*. Applied Ergonomics 32 (2001) 549-558.

[45] According to a study conducted by CNA Insurance, "the frequency of grout joints may help with drainage, thus improving traction." *Slip and Fall Study Report: Enhancing Floor Safety Through Slip Resistance Testing, Maintenance Protocols and Risk Awareness*. CNA (2017), 8. https://web.archive.org/web/20190821144404/https://www.tcnatile.com/images/pdfs/CNA_Risk_Control_Slip_and_Fall_Report_Final.pdf.

3.6.3 Directionality properties

A product that shows "directionality" is defined herein as one where wet DCOF measurements along one edge differ from measurements at a right angle by at least 0.05.[46] Directionality can affect the traction experienced when turning a corner. If the change in traction is unexpected, the change could result in a slip or fall.[47] Texture, surface roughness, and patterning in the flooring can cause directionality if more prevalent in one orientation.[48] Overall, directionality when wet was exhibited by six of the PBM products tested for this report, as determined by comparing measurements in one direction versus measurements at 90 degrees.

[46] According to Bonig in *Experimental Investigation to Determine the Standardized Limit of the Coefficient of Friction for Slip Resistance During Walking*, "persons are capable of distinguishing coefficients of friction sensorily at the given resolution of Dm = 0.05 during walking" (where Dm represents a change in friction).
[47] Iraqi et al. *Coefficient of friction testing parameters influence the prediction of human slips*. Applied Ergonomics 70 (2018) 118 – 126. This study conducted baseline walking trials on a dry surface, prior to exposing participants to unexpected liquid-contaminated exposure trials.
[48] Kim, In-Ju. *Investigation of Floor Surface Finishes for Optimal Slip Resistance Performance*, Safety and Health at Work 9 (2018) 17-24.

4.0 Scope of Study

4.1 Overview

This section describes the sampling conducted for this report and lists each product tested, including the type of composite material and the specimen ID assigned.

4.2 Sampling

Thirty-seven PBM flooring products were purchased between October 2018 and June 2019 from retail locations in South Carolina. These products were purchased based on the following criteria: (1) the product was easily obtainable, (2) was popular among specialty flooring resellers, designers, and architects, or (3) reflected current or upcoming trends among floor coverings. For this report, 22 of the purchased products were selected for wet DCOF testing based on claims of being waterproof, water resistant, or depicted being used in areas where flooring gets wet. The test samples included: three wood-polymer composite (WPC) products, three stone-polymer composite (SPC) products, 12 rigid polymeric core board (RCB) products, two floating-interlocking vinyl (FIV) products, and two glue-down vinyl (GDV) products.[49]

4.3 Listing of products

A list of products tested, with the type of composite material and the specimen number assigned, is provided in Table 4.3.1. In addition, product literature for each tested product was reviewed for warnings that the product could be slippery when wet.

Table 4.3.1: Specimen numbers and associated product types

[49] Information regarding product types was gathered from product webpages and associated product documents, including, but not limited to, product brochures, warranties, technical data sheets, and product installation guides.

Specimen number	Product type
S3	SPC
S5	FIV
S6	RCB
S8	RCB
S10	RCB
S11	GDV
S13	RCB
S14	RCB
S15	RCB
S16	FIV
S17	SPC
S19	GDV
S20	RCB
S21	WPC
S23	SPC
S24	WPC
S26	RCB
S31	WPC
S41	RCB
S42	RCB
S43	RCB
S44	RCB

4.4 Limitation of study

Test results in this report only apply to the specimens tested. The results from these tests cannot necessarily be extrapolated to products currently in the marketplace. For further information, please refer to the disclaimer concerning this report located on page two.

5.0 Product Testing

5.1 Overview

The ANSI A326.3 test method was used to measure wet DCOF values of the 22 PBM product samples. The validity, precision, and support for the method is discussed in Section 3.5.

5.2 ANSI A326.3 methodology

The ANSI A326.3 test method specifies that a BOT 3000E (or equivalent) tribometer, a styrene-butadiene rubber (SBR) sensor, and 0.05% sodium lauryl sulfate (SLS) solution be used to measure wet DCOF values. Image 5.2.1 shows the equipment used for testing. For each product, three specimens were tested four times each using a calibrated BOT 3000E.[50] The four tests were performed in a different direction on each specimen's surface so that directionality was taken into account.[51]

Each specimen was secured to a flat, rigid substrate when tested. As wet DCOF measurements are a test of the flooring surface and not the installation method, glue-down products were not attached with adhesives for this report as the means of attachment were not deemed relevant to the measurement of the surface DCOF.

[50] No information was found regarding how each manufacturer recommends their products be tested for wet DCOF.
[51] For each given test specimen, after making the first measurement, the calibrated BOT 3000E was turned 180° and the second measurement was made. The BOT was then turned 90° and the third measurement was made. After the third measurement was made, the BOT was turned 180° and the final measurement was made (see ANSI A326.3 Section 8.1 *Laboratory Test*).

(A) (B) (C)

Image 5.2.1: Equipment used for wet DCOF testing**:** (A) calibrated BOT 3000E, sensor reconditioning wheel, and SBR sensor, (B) calibrated BOT 3000E prior to making a measurement and (C) calibrated BOT 3000E after making a measurement

6.0 Results

6.1 Survey of product claims

In each manufacturer's[52] online information (including advertisements) for the 22 products tested for this report, products were claimed to be waterproof, water resistant, or depicted being used in areas where flooring gets wet. While the claims and advertisements could lead consumers to believe the products are suitable for areas where flooring gets wet, no indication of wet DCOF was provided for all 22 products.[53]

Literature for nine of the products tested for this report included dry ASTM D2047 test values, while literature for three products tested for this report specified ASTM C1028 values. Neither online product webpages, associated technical documents, nor warranty statements for 10 products tested for this report specified any type of COF value in dry or wet conditions.[54] Table 6.1.1 lists the manufacturer-specified COF test method found for each of the products tested.

Table 6.1.1: Tested products with manufacturer specified COF test method**.**

Specimen number	Specified COF test
S3	ASTM D2047
S5	ASTM D2047
S6	ASTM D2047
S8	ASTM D2047
S10	ASTM D2047
S11	None indicated
S13	ASTM D2047
S14	ASTM D2047
S15	None indicated
S16	None indicated
S17	None indicated

[52] In this context, the "manufacturer" is deemed to be the apparent manufacturer listed in the product literature, not the overseas contract manufacturers, if used.
[53] This statement, while determined after a thorough review of manufacturer's literature, does not eliminate the possibility that wet DCOF values were discussed in documents not found by the authors.
[54] This statement, while determined after a thorough review of manufacturer's literature, does not eliminate the possibility that COF test methods were discussed in documents not found by the authors.

S19	None indicated
S20	None indicated
S21	None indicated
S23	None indicated
S24	ASTM C1028 (unspecified dry or wet)[55]
S26	ASTM C1028 (dry only)
S31	None indicated
S41	ASTM D2047
S42	None indicated
S43	ASTM C1028 (unspecified dry or wet)[56]
S44	ASTM D2047

6.2 ANSI A326.3 test results

Table 6.2.1 summarizes the average wet DCOF results from testing 22 product specimens.[57] The table is based on a wet DCOF value of 0.42 as the threshold minimum specified in ANSI A326.3 for level interior flooring expected to be walked upon wet. In total, 72.7% of the tested products measured below 0.42, while 18.2% of the tested products measured above 0.42.

Table 6.2.1: ANSI A326.3 test results for product specimens

Wet DCOF below 0.42	Wet DCOF below 0.42 along "long edge," above 0.42 along "short edge"	Wet DCOF above 0.42	Total number of products tested
16	2	4	22

[55] Although unspecified, value appears measured under dry conditions.
[56] Ibid
[57] In some instances, there were individual measurements above 0.42 for products that averaged "below 0.42" in Table 6.2.1. Similarly, products included in Table 6.2.1 as "above 0.42" may have had some instances of individual measurements below 0.42.

6.2.1 Directionality of tested products

In total, six products (27.3%) exhibited directionality. Two or 9.1% of the tested specimens (S14 and S31) exhibited directionality straddling the 0.42 threshold, meaning measurements along one axis were below 0.42, while measurements along the respective perpendicular axis were above 0.42 (and differed by at least 0.05, see Section 3.6.3). For both products, the DCOF value below 0.42 was on the long axis. There were two specimens that are listed as "Wet DCOF below 0.42" in Table 6.2.1 that also exhibited directionality (S26 and S44). For the tested specimens that are listed as "Wet DCOF above 0.42," S8 and S17 exhibited wet directionality.

7.0 Discussion

7.1 Test results

From the survey of product literature (including advertisements), each product tested for this report is claimed to be waterproof, water resistant, or depicted being used in areas where flooring gets wet. Such claims and advertisements suggest that the products can be used in wet applications. While 18.2% of the products measured above a wet DCOF value of 0.42, 81.8% of the products measured either below 0.42 in all test directions (72.7%) or below 0.42 when tested on their long axis (9.1%). According to the ANSI A326.3 standard, any product measuring below 0.42 would not be suitable to be walked on when wet.

7.2 Contradictory claims, dry use test method, withdrawn method

7.2.1 Contradictory claims

Two products, S15 and S42, advertise as "waterproof" and contain instructions in their literature for installations in "wet areas such as bathrooms." However, their warranties state that each product should only be used in dry areas that are climate-controlled. No information regarding COF testing of these products was found, and each measured below 0.42 when tested per the ANSI A326.3 test method. According to the criteria in ANSI A326.3, S15 and S42 would not be suitable for use in "level interior spaces expected to be walked upon when wet." Given the disparity between the product claims and the product warranties, advertising for these products is confusing and arguably misleading.

7.2.2 Dry use test method (ASTM D2047) and withdrawn test method (ASTM C1028)

As shown in Table 6.1.1, nine products tested in this report specified ASTM D2047, a test method that is only used for evaluating SCOF in dry conditions. Further, three products specified ASTM C1028, a method that was withdrawn by ASTM due to a number of technical reasons. None of the 22 products tested for this report provided wet DCOF test data, rather they provided data from dry testing, or a withdrawn test method, or no data at all. The lack of wet DCOF data, combined with advertisements that promote wet area use, could lead to inappropriate flooring selections and unsafe use.

7.3 Lack of slipperiness warning

Product literature for five of the 22 products tested for this report contained generic language regarding the potential slipperiness of the flooring in wet conditions.[58] These statements were not specific to product use but rather found in literature such as installation or maintenance guides. For example, one installation guide warns that signage should be used to indicate when cleaning is occurring, as wet floors are slippery. This generic warning does not provide a specific measure of how the product performs in wet conditions.

Literature for 17 out of 22 products tested for this report did not contain any statement regarding potential slipperiness in wet conditions.[59] Of those 17 products, 12 measured below 0.42, and one measured below 0.42 on the long edge but above 0.42 on the short edge. According to ANSI A326.3, products with a wet DCOF below 0.42 are not intended to be walked upon when wet. Advertising such products for wet applications, without any clear product use warning regarding their slipperiness, potentially presents a serious danger to consumers.

7.4 Seamless systems

All the products tested for this report are installed as flooring without grout joints. The products are either "clicked" together or butted together (where possible) when glued down. As discussed in Section 3.6.2, seamless systems may allow for a water film or standing water to be present after a spill. This can increase the risk of hydroplaning that occurs when a liquid supports the weight of the object above.[60] This is particularly relevant and dangerous when such floors are walked upon with footwear with smooth soles. The hazard of floors with low, wet DCOF values below 0.42, exhibited by 18 out of 22 PBM flooring products tested in this report, is further compounded by use of seamless installation systems, which do not have grout joints that could prevent hydroplaning. While the tested PBM products with a DCOF value above 0.42 may be less slippery,

[58] Product literature associated with S8, S11, S31, S41, and S43 made generic statements regarding wet slipperiness.
[59] This statement, while made after a thorough review of manufacturer's literature, does not eliminate the possibility that slipperiness warnings were discussed or included in documents not found by the authors.
[60] Véronique Cerezo, Michel Gothie, Michaël Menissier, Thierry Gibrat. *Hydroplaning speed and infrastructure characteristics.* Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology, SAGE Publications, 2010, 224 (9), p.3. Section 3.1 describes hydroplaning using the scenario of a tire moving over wet pavement.

they are also installed in a seamless installation and potentially could produce dangerous hydroplaning conditions.

7.5 Directionality

Six products tested for this report exhibited directionality. Directionality in flooring products can cause a change in traction when changing the direction of ambulation (see Section 3.6.3). Regardless of measured DCOF value, directionality can be dangerous when unexpected, as any reduction in DCOF can result in loss of traction. As noted in Section 6.2.1, six of the 22 products tested exhibited directionality where a warning to consumers should be considered if sold for wet applications.

8.0 Conclusions

Each product for this report was tested because of claims of being waterproof, water resistant, or because it was depicted being used in areas where flooring gets wet. However, specific product slipperiness data for wet applications were not provided. Eighteen products (81.8%) had a wet DCOF below 0.42 in one or more directions, meaning those products did not meet the ANSI A326.3 criteria for interior, level floors expected to be walked upon when wet. Six products exhibited directionality when wet (including two with an average DCOF greater than 0.42), indicating that a change in direction of ambulation could cause a change in traction to occur. If unexpected, such a change could result in a dangerous loss of traction. Further, the hazard of low, wet DCOF values for products tested in this report is compounded by the design of PBM flooring systems installed without grout joints.

Overwhelmingly, the products tested for this report—drawn from major brands with significant market penetration—do not meet the ANSI A326.3 criteria for use in wet applications, yet the products fail to warn consumers regarding their wet slip resistance when used as advertised. Further, no warning regarding directionality is provided. Without appropriate warnings, unsafe flooring selections and unsafe product usage could result. At a minimum, a dry use-only warning should be indicated for the products exhibiting wet directionality or measuring below 0.42 in any direction.