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Standardized Waterproof Testing of Plastic Based Material Flooring (PBM Flooring)

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Clemson University
Bishop Materials Laboratory

Research Report | December 2019

Standardized Waterproof Testing of Plastic Based Material Flooring (PBM Flooring)

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This report was prepared in collaboration with Dr. John Sanders of the Bishop Materials Laboratory at Clemson University and the Tile Council of North America Product Performance Testing Laboratory and is protected by copyright law. It reflects a summary of research in progress, which continues to evolve, and is intended to apply only as to product specimens actually reviewed and tested. Results may not necessarily apply or be extrapolated to items that were not tested. The report may refer to information from third parties, which is beyond the control of the authors. The report is not an endorsement, recommendation, approval, certification, or criticism of any particular product, method, or application, and it is offered "as is" without warranty of any kind.

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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, evaluated the extent that water can leak through plastic based material (PBM)[1] floor coverings advertised as 100% waterproof. To make this assessment, product literature was examined to determine which test methods were used to support the manufacturers'[2] claims of products being waterproof. Neither test methods or data to justify a 100% waterproof claim were found, despite a thorough review of product literature.[3]

ASTM, ANSI, ISO, and CEN standards were examined for relevant test methods for waterproofness. Two methods were identified: (1) EN 13553, *Resilient Floor Coverings - Polyvinyl Chloride Floor Coverings for Use in Special Wet Areas – Specification*, is used to assess water penetration for plastic flooring materials, and (2) ASTM D4068, *Standard Specification for Chlorinated Polyethylene Sheeting for Concealed Water-Containment Membrane*, is used to assess waterproof membranes commonly used in wet area applications to protect the substrate. To be considered watertight, both methods specify that test specimens show no evidence of water leaking during testing.

All the products tested for this report failed to meet the criteria outlined in EN 13553 and ASTM D4068. Testing results for each product are detailed in section 6.2 for EN 13553, and section 6.3 for ASTM D4068. When the results from EN 13553 are extrapolated to the area of an average bathroom (40 square feet)[4], flow rates ranged from 12.1 L/hr. (3.2 Gal/hr.) to 187.0 L/hr. (49.4 Gal/hr.). As detailed in section 3, these volumes of water can do significant damage to a home.

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[1] Plastic Based Material (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] This statement does not eliminate the possibility that test methods or data were discussed in documents not found by the authors.
[4] Average bathroom size as indicated by the following:
https://www.improvenet.com/a/7-awesome-layouts-that-will-make-your-small-bathroom-more-usable,
https://www.hunker.com/12579430/how-big-is-the-average-bathroom,
https://www.homestratosphere.com/bathroom-sizes/,
https://www.reference.com/business-finance/size-average-bathroom-56f5cc6a836759b6,
https://www.doorwaysmagazine.com/bathroom-dimensions/

This report shows that the PBM products tested leak under the conditions of the test methods. Believing the products are waterproof as advertised could lead to an inappropriate flooring selection and may result in damage to the subfloor and surrounding areas. The results from this report suggest a dry use-only caution, or warning regarding lack of waterproofness, should be considered for products that perform similarly to those tested in this report

2.0 Introduction

This report presents an assessment of PBM floor coverings advertised as 100% waterproof and whether water will leak through such flooring products when tested per standardized methods for waterproofness. This report also includes an assessment as to whether the tested products are suitable for wet use or 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.

Twenty-three PBM flooring products were purchased between October 2018 and February 2019 from retail locations in South Carolina. These products were purchased based on the following criteria: (1) product was easily obtainable,[5] (2) was popular among specialty flooring resellers, designers, and architects,[6] or (3) reflected current or upcoming trends among floor coverings.[7] For this report, of the 23 PBM flooring products purchased, all products advertised as "100% waterproof" and installed with interlocking joints were selected for research (10 in total).[8,9]

The background for this report and supplemental information is provided in section 3. The scope of the study is defined in section 4 and the methods for assessing waterproofness are detailed in section 5. Results are presented in section 6. Section 7 summarizes the conclusions.

[5] Products were available for local pickup in 14 days or less.
[6] Products were advertised as "best sellers" with online retailers or were recommended by local retailers specializing in flooring.
[7] Based on advertisements from online retailers, local retailers specializing in flooring, or observations from Surfaces Trade Show held in Las Vegas, Nevada, 2019.
[8] Products described as 100% waterproof but without interlocking joints were omitted due to the product having no barrier to prevent water passing through seams.
[9] Claims of being 100% waterproof were found by the authors in product literature or advertisements and have been archived using an internet archive "Wayback Machine." https://web.archive.org/.

3.0 Background

3.1 Overview

This section discusses lack of PBM industry standards for waterproofness, problems associated with water leakage, and consumer preferences for waterproof flooring as determined from market research.

3.2 Lack of industry standards

Traditionally, vinyl flooring has not been used in areas where flooring gets wet due to the risk of peeling, cupping, discoloring, and glue degrading.[10,11,12] Today, many PBM products are advertised as "100% waterproof." However, neither standardized test methods nor data to support these claims were found despite a thorough review of product literature.[13] Further, it was observed that products advertised as "100% waterproof" often contained statements in their literature excluding damage to the substrate or surrounding structure from water.[14] To evaluate the waterproofness of PBM products addressed in this report, methods for testing materials used in wet applications were applied, specifically EN 13553 and ASTM D4068 (See Section 4.2).

3.3 Risks from water leaking through floor coverings

When floor coverings are installed in wood-framed structures, water leaking through the floor covering to the subfloor and surrounding areas can lead to structural integrity degradation.[15,16,17,18] Additionally, PBM floor coverings create a non-ventilated area between the sub-floor and floor covering after installation.[19] Given sufficient time and the presence of moisture, mold growth can

[10] https://www.floordaily.net/floorfocus/luxury-vinyl-installation-comes-with-unique-challe
[11] https://www.lumberliquidators.com/blog/protecting-your-flooring-investment-in-the-spring-and-summer/
[12] https://floorcentral.com/resilient-flooring-vinyl-floor-linoleum/sheet-vinyl-flooring-stain/
[13] This statement does not eliminate the possibility that test methods were discussed in documents not found by the authors.
[14] For example, the warranty for one product tested as part of this report indicates that the product will not be negatively impacted when exposed to water such as swelling or buckling, but the warranty excludes damage from water leaking.
[15] https://www.waterdamageadvisor.com/water-damage/structural-damage/
[16] https://www.networx.com/article/water-damaged-subfloor
[17] https://www.sciencedirect.com/science/article/pii/S1876610217347914
[18] https://www.angieslist.com/articles/how-fast-can-water-damage-ruin-home.htm
[19] TenWolde, A. (2000, November). Mold and decay in TriState homes. In *Proceedings of the second annual conference on durability and disaster mitigation in wood-frame housing*. Madison, WI: Forest Products Society (pp. 53-57).

occur and deteriorate the subfloor.[20] Further, surrounding structural elements can be at risk through moisture wicking from the subfloor through the walls.[21] This is compounded in a non-ventilated area as such can remain wet for a longer period of time, increasing the likelihood of water damage and mold growth.[22] Sections of subflooring damaged by water must be repaired or replaced to avoid structural failure in the home.[23] Water damage can also lead to other hazards such as electrical risk,[24] rot,[25] and plaster swelling and breaking.[26]

3.4 Consumer preference for waterproof floors

Recent market research surveys of flooring purchasers identified that flooring described as "waterproof" ranked 8.9 out of 10 in importance, where 1 is not at all important and 10 is extremely important when deciding which floor covering to purchase.[27] Consumers preference for waterproof flooring appears to be reflected in the marketplace as PBM manufacturers now widely advertise their products as "100% waterproof."

Flooring comprised from plastic based materials is currently the fastest growing flooring category in the United States. From 2013 to 2017, the PBM category experienced rapid and significant growth, increasing the PBM share of the flooring market from 4.5% to 8.1%.[28] At a recent national trade show for floor coverings, of the 45 exhibiting PBM manufacturers reviewed, all of the products were advertised for use in areas where flooring gets wet and described as "100% waterproof. "[29]

[20] Tzeng J, Rangineni J, *Comparison Study of Mold Growth Resistance of Plastic Based Material Flooring (PBM Flooring) and Ceramic Tile Flooring*, Clemson University, December 2019.
[21] Viitanen H, Vinha J, Salminen K, Ojanen T, Peuhkuri R, Paajanen L, et al. 2010. Moisture and bio-deterioration risk of building materials and structures. J Build Phys. 33(3):201–224.
[22] TenWolde, 53-57.
[23] *Structural Condition Assessment of In-Service Wood*, by Robert J. Ross, Brian K. Brashaw, and Xiping Wang.
[24] Electrical risk due to water damage, https://www.esfi.org/resource/water-damaged-electrical-equipment-608
[25] Structural and health risks due to water damage, https://www.tapcohomedry.com/health-can-damp-impact/
[26] Damage to plaster when subjected to water, https://www.hunker.com/12602544/what-happens-when-plaster-walls-get-wet
[27] The Farnsworth Group (March 2019). [Floor coverings usage and attitudes among remodelers, architects, designers, and homeowners]. Unpublished data.
[28] *Floor Covering Weekly* magazine (2018), *2017 Annual Statistical Report*.
[29] TCNA market research performed at Surfaces, January 2019. The international Surfaces Event is marketed as the "largest North American floor covering, stone, and tile industry event."

4.0 Scope of Study

4.1 Overview

This section describes the test methods used to evaluate waterproofness and the criteria for selecting products for testing.

4.2 Evaluation methods

In North America, there are currently no consensus standards used to determine waterproofness of PBM flooring.[30] Additionally, PBM floor covering manufacturers of the products tested for this report do not provide data or test methods supporting advertisements of "100% waterproof."

When examining ASTM, ANSI, ISO, and CEN standards for test methods relating to waterproofness, two methods were identified: 1) The European standard, EN 13553, which provides a procedure for evaluating the waterproofness of polyvinyl chloride (PVC) flooring and 2) ASTM D4068, which defines test methods for evaluating the performance of water-containment membranes and is specified by the ceramic tile industry for wet area flooring applications, per ANSI A118.10.

In the absence of specific North American PBM standards for assessing waterproofness, EN 13553 and ASTM D4068 (already in use in the flooring industry) were selected to evaluate the waterproofness of the PBM specimens.

4.3 Sampling

Twenty-three PBM flooring products were purchased between October 2018 and February 2019 from retail locations in South Carolina. These products were purchased based on the following criteria: (1) product was easily obtainable, (2) was popular among specialty flooring resellers, designers, and architects, or (3) reflected current or upcoming trends among floor coverings.

[30] ANSI and ASTM Standards for the resilient flooring categories of the products included in this report were reviewed for waterproofness criteria and test methods; none were found.

For this report, all products advertised as "100% waterproof" and installed with interlocking joints were selected for research (10 in total).[31] The test specimens included the following: one wood-polymer composite (WPC) product, three stone-polymer composite (SPC) products, and six rigid polymeric core board (RCB) products. Specimen numbers and product types are provided in Table 4.3.1.

Table 4.3.1: Specimen numbers and associated product types

Specimen number	Product type
S3	SPC
S6	RCB
S8	RCB
S10	RCB
S14	RCB
S15	RCB
S17	SPC
S20	RCB
S21	WPC
S23	SPC

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.

[31] Products defined as 100% waterproof but without interlocking joints were omitted due to the product having no barrier to prevent water passing through seams.

5.0 Waterproof Seam Evaluation

5.1 Overview

To evaluate water leakage through the seams of PBM floor coverings meeting the selection criteria outlined in section 4.3, two test methods were used: EN 13553 (*European specification for resilient floor coverings – polyvinyl chloride floor coverings for use in special wet areas*) and ASTM D4068 (*Standard specification for chlorinated polyethylene sheeting for concealed water-containment membrane*).

5.2 EN 13553 methodology

Testing using EN 13553 requires that the floor covering be installed on a rigid, non-porous substrate. For this testing, the substrate used was a 19 mm (3/4 inch) thick, transparent acrylic sheet. The acrylic sheet was raised and supported using three nominally 2-inch by 4-inch lumber pieces spaced 16 inches on center such that any water movement beneath the floor covering could be observed from below.

Each floor covering specimen was installed directly atop the substrate, without the use of adhesives or fasteners, per manufacturer specifications for free-floating flooring. The floor covering specimens were comprised of individual units assembled together to cover an area at least 500 mm × 800 mm per the standard. The units were connected to one another as specified by each manufacturer and using recommended tools when necessary, such as a rubber mallet to ensure a complete connection between each plank.[32]

A 500 mm long × 300 mm wide × 300 mm high transparent, watertight, and bottomless acrylic box-frame was constructed per the EN 13553 method. The box-frame was secured atop the floor covering assembly using silicone sealant and cured for at least 12 hours to seal the interface between the box-frame and each tested assembly.[33] The test assembly within the box-frame (the test area) was installed such that at least two seams of the product were parallel and at least one

[32] Manufacturers require that specimens not be fastened down at the edges such that natural expansion and contraction may occur.
[33] The silicone seal was thoroughly inspected and sealant was pushed into grooves to ensure no leaking could occur between the interface of the floor covering and the box-frame.

seam was perpendicular to the long dimension of the box-frame (Figure 5.2.2). For a drawing showing how the products were aligned, see Figure 5.2.1.

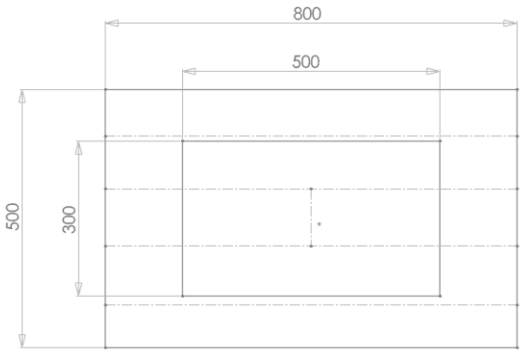


Figure 5.2.1: Orientation of box-frame in relation to floor covering seams. Seams are represented by dotted lines.

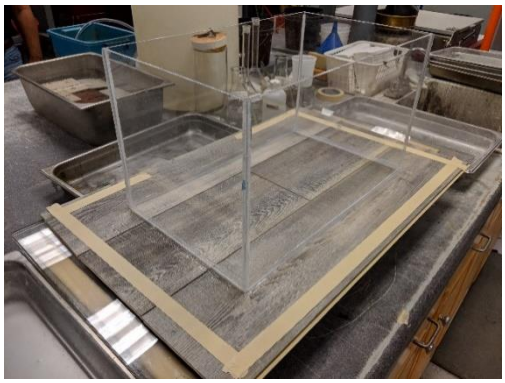


Figure 5.2.2: Box-frame installed atop floor covering test assembly.

After the sealant cured, the box-frame was filled with approximately 30 L of water to a level of 200 (± 10) mm above the surface of the test assembly. Test specimens were monitored for water leaking through the floor covering. Per EN 13553, any water leakage constitutes a failure of the subject material. For the purpose of this report, testing was allowed to continue for at least 1 hour after the first observation of water leakage so that the volume of water leaking per unit time could be determined for each specimen.

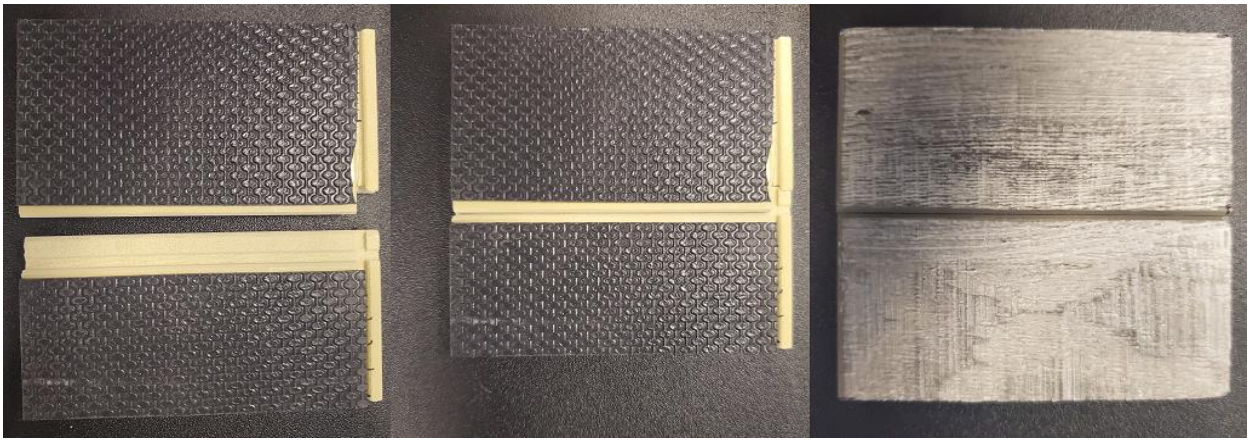
5.3 ASTM D4068 methodology

ASTM D4068 requires that hydrostatic pressure be applied to test specimens using a PVC pipe with an inner diameter of 51 mm and a water column of 610 mm. A ball valve was installed in the apparatus to isolate the test specimens from the hydrostatic pressure (Figure 5.3.1) prior to the test commencing. The ball valve created two distinct zones, a specimen side and a hydrostatic pressure side. With the ball valve closed, water was added to the apparatus on the specimen side such that the water level was equal to the height of the specimen holder. On the hydrostatic pressure side, water was added such that the water level was 610 mm above the water level of the specimen side.

Per the standard, the specimen size for this test was 76 mm × 76 mm. Each specimen consisted of two interlocking pieces of floor covering, assembled together per manufacturer specifications, with a seam in the center as shown in figure 5.3.2. Each floor covering specimen was secured to the apparatus using silicone sealant with the wear surface facing the water (i.e. downward-facing in this assembly). The silicone sealant was allowed to cure for at least 12 hours to seal the interface between the specimen and the apparatus.

Following preparation of each test assembly, the valve was opened to apply hydrostatic pressure to the floor covering specimen's wear surface. Per ASTM D4068, any water leakage constitutes a failure of the subject material. For the purposes of this report, testing was allowed to continue for 10 minutes after the first signs of water leaking so that the volume of water leaking per unit time could be determined for each specimen.

Figure 5.3.1: ASTM D4068 apparatus with specimen installed



Specimen separated (bottom view) Specimen assembled (bottom view) Specimen assembled (top view)

Figure 5.3.2: Specimen before being sealed to pressure tube

6.0 Results and Discussion

6.1 Overview

This section details the results for each test method and discusses the significance of the results. For both test methods, all PBM floor coverings tested leaked water through the seams. A wide range of leakage rates were recorded.

6.2 EN 13553 results

All 10 PBM floor covering products began leaking immediately upon initiating the test (well before reaching the required water level of 20 cm). As shown in Table 6.2.1, the measured rates of leakage ranged from 0.49 to 7.54 liters per hour (0.13 to 1.99 gallons per hour). For each assembly, water leakage was observed in three locations: (1) through the seams to underneath the floor covering (Figure 6.2.1); (2) into the seams and exiting at the edges of the assembly (Figure 6.2.2); and (3) into the seams and exiting atop the assembly, outside of the sealed containment box (Figure 6.2.3).

Table 6.2.1: Volume and rate of water leakage from PBM flooring specimens per EN 13553

EN 13553	
Specimen	**Water lost per hour in liters (gal)**
S3	6.13 (1.62)
S6	2.43 (0.64)
S8	2.25 (0.59)
S10	7.54 (1.99)
S14	2.54 (0.37)
S15	4.81 (1.27)
S17	1.91 (0.50)
S20	0.49 (0.13)
S21	4.22 (1.11)
S23	4.75 (1.25)

Figure 6.2.1: Water penetrating the flooring seam (seen from below the acrylic testing apparatus)

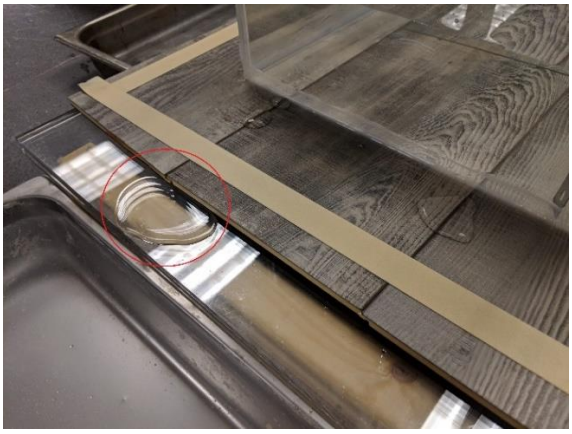


Figure 6.2.2: Water penetration into the seams and exiting at the edge of the assembly

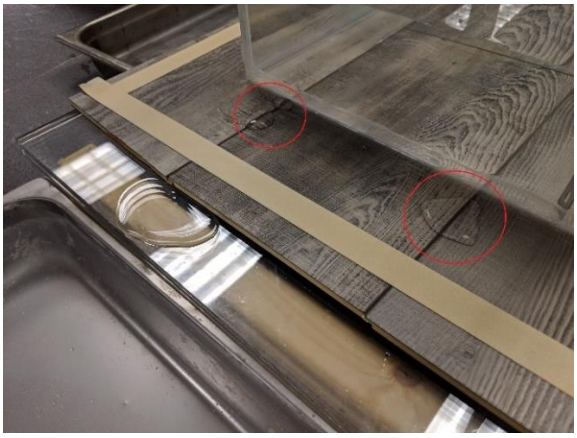


Figure 6.2.3: Water penetration into the seams and exiting atop the assembly, outside the sealed containment box

6.3 ASTM D4068 results

All 10 PBM floor coverings tested began leaking immediately after initiating the test. As shown in table 6.3.1, measured leakage ranged from 0.38 to 2.43 liters per hour (0.1 to 0.64 gallons per hour). All PBM floor covering products tested leaked through the seam with water exiting from the edges of the seam (figure 6.3.1). Additionally, some specimens leaked through the center seam to the back of the floor covering. (figure 6.3.2).

Table 6.3.1: Volume and rate of water leakage for PBM flooring specimens per ASTM D4068.

ASTM D4068		
Specimen	**Water lost (mL) per 10 minutes**	**Water lost liters per hour (gal)**
S3	166	0.99 (0.26)
S6	320	1.92 (0.51)
S8	320	1.92 (0.51)
S10	405	2.43 (0.64)
S14	190	1.14 (0.30)
S15	315	1.89 (0.50)
S17	190	1.13 (0.30)
S20	100	0.60 (0.15)
S21	64	0.38 (0.10)
S23	100	0.60 (0.16)

Figure 6.3.1: Water penetrating the seam and exiting from the edges

Figure 6.3.2: Water penetrating the seam and leaking to the back of the specimen

6.4 Water exposure and relevance to floor coverings tested

Averaging bathroom size from a variety of sources,[34,35,36,37,38] a typical bathroom in the United States is 3.7 m^2 (40 ft^2). The data collected for PBM products tested per EN 13553 can be used to estimate the amount of water that could leak through flooring installed in an average-sized bathroom under the test conditions. The assembly for EN 13553 is 0.3 x 0.5 m (11.8 x 19.7 in.), which covers a test area of 0.15 m^2 (1.61 ft^2). The PBM product that leaked the least amount of water (S20) leaked at a rate of 0.49 L/hr. (0.13 gal/hr.). The PBM product that leaked the most amount of water (S14) leaked at a rate of 2.54 L/hr. (0.37 gal/hr.). Extrapolating both rates of leakage from the test area of 0.15m^2 to a bathroom of 3.7m^2, PBM flooring, based on the specimens tested, has the potential to leak water in the range of 12.09 L/hr. (3.23 gal/hr.) to 185.99 L/hr. (49.44 gal/hr.) under the test conditions. Table 6.4.1 provides the leakage rates found per EN 13553 testing with a conversion to an average bathroom of 3.7 m^2 area. For comparison, the maximum flow rate from a kitchen sink faucet is 500 L/hr. (132 gal/hr.) and the average washing machine uses approximately 45 gallons of water per load.[39] As noted in Section 6.2, water leakage occurred

[34] https://www.improvenet.com/a/7-awesome-layouts-that-will-make-your-small-bathroom-more-usable
[35] https://www.hunker.com/12579430/how-big-is-the-average-bathroom
[36] https://www.homestratosphere.com/bathroom-sizes/
[37] https://www.reference.com/business-finance/size-average-bathroom-56f5cc6a836759b6
[38] https://www.doorwaysmagazine.com/bathroom-dimensions/
[39] Newer high efficiency washing machines may use as little as 15 gallons per load, https://www.home-water-works.org/indoor-use/clothes-washer.

well before reaching the required water level, however flow rates at low water levels were not specifically measured.

Table 6.4.1: EN 13553 data extrapolated to the area of an average bathroom in the United States.

EN 13553		**Water leakage potential for an average bathroom in U.S.**
Specimen	**Water lost per hour in liters (gal) over 0.15 m^2**	**Water lost per hour in liters (gal) over 3.7 m^2**
S3	6.13 (1.62)	151.21 (40.25)
S6	2.43 (0.64)	59.94 (15.90)
S8	2.25 (0.59)	55.50 (14.66)
S10	7.54 (1.99)	185.99 (49.44)
S14	2.54 (0.37)	62.65 (9.19)
S15	4.81 (1.27)	118.65 (31.55)
S17	1.91 (0.50)	47.11 (12.42)
S20	0.49 (0.13)	12.09 (3.23)
S21	4.22 (1.11)	104.09 (27.58)
S23	4.75 (1.25)	117.17 (31.06)

7.0 Conclusions

All the PBM floor coverings listed in this report were tested because they were advertised as being 100% waterproof. Although advertising for each product indicated waterproofness as a desirable quality, no test method or data was available from the product manufacturers to quantify this claim as described in Section 3.2. When tested using methods for testing materials used in wet applications per Section 4.2 and as elaborated in Section 5, all 10 products immediately showed signs of water leakage through the product seams. As described in section 6.2, products tested according to EN 13553 leaked with flow rates ranging from 0.49 L/h (0.13 gal/h) to 7.54 L/h (1.99 gal/h). As described in section 6.3, products tested according to ASTM D4068 leaked with flow rates that ranged from 0.38 L/h (0.10 gal/h) to 2.43 L/h (0.64 gal/h). Extrapolating the results from section 6.2 to an average bathroom in the United States per Section 6.4, leakage flow rates ranged from 12.09 L/h (3.23 gal/h) to 185.99 L/h (49.44 gal/h) under the test conditions.

As detailed in Section 3.3, products that do not prevent water from penetrating through the seams can lead to moisture-related problems. Further, as detailed in Section 3.2, it was observed that products advertised as "100% waterproof" often contain statements in their literature excluding damage to the substrate or surrounding structure from water. Given the consumer preference for waterproof floors, the promotion of many PBM products as waterproof, and the growing use of these products as detailed in Section 3.4, a dry use-only caution or warning regarding lack of waterproofness should be considered for products that perform similarly to those tested in this report. The absence of such warnings could lead to inappropriate flooring selections and potentially result in damage to the subfloor and surrounding areas.