This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: C373 – 18

Standard Test Methods for Determination of Water Absorption and Associated Properties by Vacuum Method for Pressed Ceramic Tiles and Glass Tiles and Boil Method for Extruded Ceramic Tiles and Non-tile Fired Ceramic Whiteware Products[1]

This standard is issued under the fixed designation C373; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 These test methods covers procedures for determining water absorption, bulk density, apparent porosity, and apparent specific gravity of non-tile fired unglazed ceramic whiteware[2] products, glazed or unglazed ceramic tiles, and glass tiles.

1.2 The values stated in metric units are normative. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not normative.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Significance and Use

3.1 Measurement of density, porosity, and specific gravity is a tool for determining the degree of maturation of a ceramic body, or for determining structural properties that may be required for a given application.

4. Apparatus and Materials

4.1 *Balance or scale,* of adequate capacity, suitable to weigh accurately to 0.01 g (0.00002 lb).

4.2 *Oven,* capable of maintaining a temperature of 150 ± 5°C (302 ± 9°F).

4.3 *Wire Loop, Halter, or Basket,* capable of supporting specimens under water for making suspended mass measurements.

4.4 *Suspended Mass Container (if Determination of Suspended Mass is Desired)*—A glass beaker or similar container of such size and shape that the sample, when suspended from the balance by the wire loop, specified in 4.3, is completely immersed in water with the sample and the wire loop completely free of contact with any part of the container.

4.5 *Stainless Steel Boiling Container,* suitable for boiling water and with sufficient capacity to hold the test specimens and quantity of water specified in 6.2. The container shall be equipped with a loose removable cover which does not allow pressure to build.

4.6 *Deionized (DI) or Distilled Water.*

4.7 *Microfiber Cloth.*

4.8 *Heat Source,* such as a hot plate, burner, or equivalent to heat the water to boiling.

4.9 *Desiccator*—a sealed chamber containing desiccants which is of sufficient size and capacity to allow specimens to cool while preventing the specimens from absorbing moisture from ambient air.

4.10 *Pressure Vessel,* capable of holding a vacuum of 91 ± 5 kPa (26.9 ± 1.5 inHg) below standard atmospheric pressure. The vessel shall be large enough to hold the required number of tile samples and the necessary volume of water to cover the tiles during testing. A modified 41.5 quart pressure cooker has been found to meet these requirements.

4.11 *Vacuum Pump,* capable of achieving and holding the required vacuum.

[1] These test methods is under the jurisdiction of ASTM Committee C21 on Ceramic Whitewares and Related Products and is the direct responsibility of Subcommittee C21.03 on Methods for Whitewares and Environmental Concerns.

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[2] Non-tile ceramic whitewares are ceramic whitewares as defined in ASTM Terminology Standard C242, excluding ceramic tiles.

*A Summary of Changes section appears at the end of this standard

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4.12 *Gauge,* capable of measuring the required vacuum. Gauge shall be installed on a manifold connected directly to the pressure vessel. Readings from any gauges present on the pump are not acceptable forms of measurement.

4.13 *Hoses, fittings, valves, solenoids, or combinations thereof,* assembled in such a way to allow manually or automatic operation.

4.14 *Timer,* accurate to 1 second.

5. Test Specimens:

5.1 *Non-tile Fired Ceramic Whitewares:*

5.1.1 At least five representative test specimens shall be selected that have not been previously tested. The specimens shall be unglazed and shall have as much of the surface freshly fractured as is practical. Sharp edges or corners shall be removed. The specimens shall contain no cracks. The individual test specimens shall weigh at least 50 g (0.11 lb).

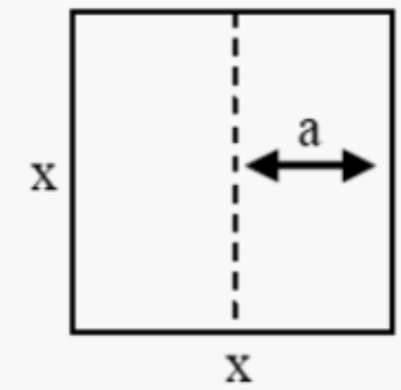
5.2 *Ceramic Tiles and Glass Tiles:*

5.2.1 Sampling shall be carried out in accordance with Table 1 and 5.2.2 through 5.2.8 based on the length (x), width (y), and the area of the tiles to be tested (for irregularly shaped tiles, see Note 1). Tiles and relevant specimens must contain no visible damage or cracks prior to testing and have not been previously tested. Any loose or contaminating material shall be removed. This includes any mesh, paper and adhesive that has been applied to mosaics. Cutting of specimens, as described in the following sections, shall consist of scoring and snapping, or sawing when impossible to score and snap with conventional tile scoring equipment (as can be the case with some glass tiles and textured and structured porcelain tiles).

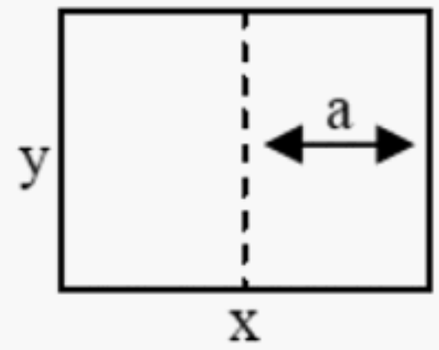
NOTE 1—For irregularly shaped tiles (hexagons, circles, and so forth), consider the area of the minimum rectangle in which the tile can be fit.

5.2.2 For tiles less than or equal to 420 cm^2 (65 in.^{2}), at least five representative test specimens shall be selected. Specimens shall be cut in half, within 10 mm (0.4 in.). Specimens shall be cut perpendicular to the longest side if the specimen has unequal sides. Select one half at random from each specimen for testing (see Fig. 1a and Fig. 1b).

5.2.3 For tiles greater than 420 cm^2 (65 in.^{2}) and less than or equal to 3600 cm^2 (558 in.^{2}), with x and y > 205 mm (8 in.), at least five representative test specimens shall be selected. A 205 × 205 mm (8 × 8 in.) portion, within 10 mm (0.4 in.), shall be cut from one corner of each specimen for testing (see Fig. 2).



(a.) Equal Sides: x ≤ 205 mm, , a = ½ x (within 10 mm)



(b.) Unequal Sides: area ≤ 420 cm^2, x > y, a = ½ x (within 10 mm)

FIG. 1 (a) & (b)

5.2.4 For tiles greater than 420 cm^2 (65 in.^{2}), with 205 mm (8 in.) < x < 1000 mm (39 in.) and y ≤ 205 mm (8 in.), at least five representative test specimens shall be selected. Each specimen shall be cut once perpendicular to the longest side, such that a 205 mm (8 in.) portion, within 10 mm (0.4 in.), is available for testing (see Fig. 3).

5.2.5 For tiles greater than 420 cm^2 (65 in.^{2}), with x ≥ 1000 mm (39 in.) and y ≤ 205 mm (8 in.), at least five representative test specimens shall be selected. Each specimen shall be cut twice, once on each end, perpendicular to the longest side, such that two 205 mm (8 in.) portions within 10 mm (0.4 in.), one from each end, are available for testing (see Fig. 4).

5.2.6 For tiles greater than 3600 cm^2 (558 in.^{2}), with x and y ≥ 410 mm (16 in.), at least three representative test specimens shall be selected. A 205 × 205 mm (8 × 8 in.) portion, within 10 mm (0.4 in.), shall be cut from each of the four corners of each specimen for testing (see Fig. 5).

5.2.7 For tiles greater than 3600 cm^2 (558 in.^{2}), with x ≥ 410 mm (16 in.) and 205 mm (8 in.) < y ≤ 410 mm (16 in.), at

TABLE 1 Sampling

Maximum Area	Reference Paragraph for Sample Cutting	# of Specimens per Tile to be Tested	Total # of Tiles	Total # of Specimens
Area ≤ 420 cm^2 (65 in.^{2})	5.2.2	1	5	5
420 cm^2 (65 in.^{2}) < Area ≤ 3600 cm^2 (558 in.^{2}) (with x and y > 205 mm [8 in])	5.2.3	1	5	5
Area > 420 cm^2 (65 in.^{2}) (with 205 mm [8 in.] < x < 1000 mm [39 in.] and y ≤ 205 mm [8 in.])	5.2.4	1	5	5
Area > 420 cm^2 (65 in.^{2}) (x ≥ 1000 mm [39 in.] and y ≤ 205 mm [8 in.])	5.2.5	2	5	10
Area > 3600 cm^2 (558 in.^{2}) (with x and y ≥ 410 mm [16 in.])	5.2.6	4	3	12
Area > 3600 cm^2 (558 in.^{2}) (with x ≥ 410 mm [16 in.] and 205 mm [8 in.] < y ≤ 410 mm [16 in.])	5.2.7	4	3	12

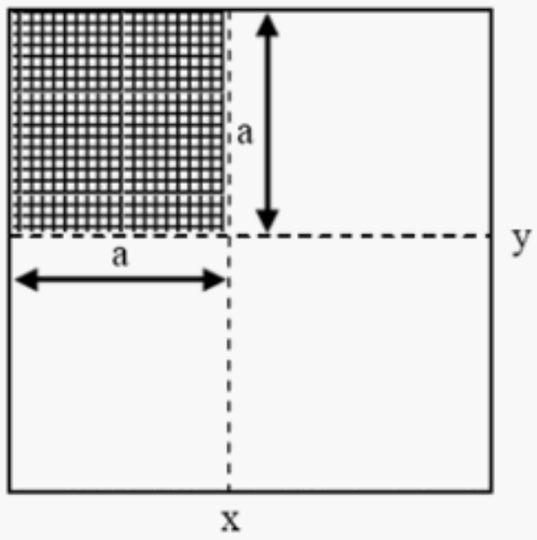


FIG. 2
x > 205 mm, y > 205 mm, 420 cm² < area ≤ 3600 cm²,
a = 205 mm (within 10 mm)

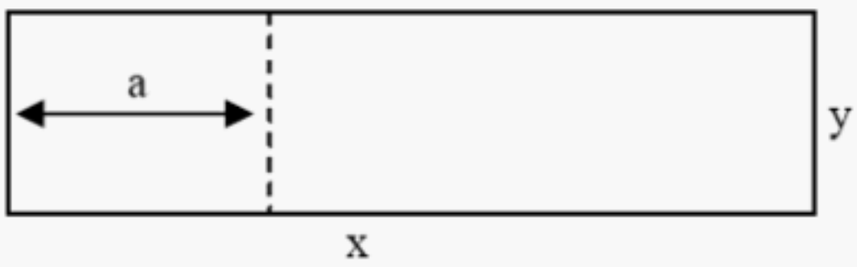


FIG. 3
205 mm < x < 1000 mm, y ≤ 205 mm, area > 420 cm²,
a = 205 mm (within 10 mm)

least three representative test specimens shall be selected. Each specimen shall be cut twice, at each end, perpendicular to the longest side, to produce two 205 mm (8 in.) portions, within 10 mm (0.4 in.). Each such 205 mm (8 in.) portion shall be cut a second time, in half, within 10 mm (0.4 in.) perpendicular to the first cut (see Fig. 6). All four pieces from each specimen shall be used for testing.

5.2.8 If a tile does not weigh at least 50 g (0.11 lb) prior to cutting, then multiple whole pieces may be used to equal one test specimen with a mass of at least 50 g (0.11 lb). At least five representative test specimens shall be assembled.

6. Procedure

6.1 Dry the test specimens to constant mass (Note 3) by heating in an oven at 150 ± 5°C (302 ± 9°F) for a minimum of 24 h (or such other time as has been established for the oven in use and the mass of the tiles being dried), followed by cooling in a desiccator. Determine the dry mass, *D*, to the nearest 0.01 g (0.00002 lb) (see Note 2).

NOTE 2—Specimens being tested directly following their manufacture may be considered fully dried so long as they have not been subjected to any process that wets the specimen post firing (such as can occur in cutting and polishing operations) and are placed in a desiccator sufficiently quickly (usually within no more than 30 min of exiting the kiln) that no moisture has been absorbed from ambient air.

NOTE 3—The drying of the specimens and the determination of their masses may be done either before or after the specimens have been impregnated with water. Usually the dry mass is determined before impregnation. However, if the specimens are friable or evidence indicates that particles have broken loose during the impregnation, the specimens shall be dried and weighed after the suspended mass and the saturated mass have been determined, in accordance with 6.4 and 6.5. In this case, the second dry mass shall be used in all appropriate calculations.

6.2 *Water Impregnation of Extruded Ceramic Tiles and Non-tile Fired Ceramic Whiteware Products Using Boil Method:*

6.2.1 *For Non-tile Fired Ceramic Whitewares*—Bring DI or distilled water to a boil in a stainless steel boiling container. (**Warning—**Handling water at boiling or near boiling temperature can present a safety hazard. Wear appropriate personal protective equipment.) Place the specimens in the boiling DI or distilled water, and use setter pins, a rustproof rack, or equivalent to separate the specimens from the bottom and sides of the stainless steel boiling container and from each other. The DI or distilled water shall be unused and of sufficient quantity that the test specimens are fully submerged and the mass ratio of water to test specimens is at least 3:1.

6.2.2 *For Extruded Ceramic Tiles*—Place the specimens in a stainless steel boiling container of DI or distilled water at room temperature, and use setter pins, a rustproof rack, or equivalent to separate the specimens from the bottom and sides of the stainless steel boiling container and from each other. The DI or distilled water shall be unused and of sufficient quantity such that the test specimens are fully submerged and the mass ratio of water to test specimens is at least 3:1. Bring the DI or distilled water with submerged specimens to a boil in one hour or less.

6.2.3 Boil the specimens for 5 h ± 5 min. Place a loose cover over the container to minimize water loss through evaporation. Test specimens shall be completely immersed in the boiling DI or distilled water throughout the duration of the 5 h boil. Add DI or distilled water as needed to ensure the specimens are completely immersed at all times. Ensure that the boil is maintained throughout the test and that the addition of water does not hinder the boil. After the 5-h boil, allow the specimens to continue to soak in the same DI or distilled water in which they were boiled for an additional 24 h ± 30 min., ensuring that the specimens remain completely immersed.

6.3 *Water Impregnation of Pressed Ceramic Tiles and Glass Tiles Using Vacuum Method:*

6.3.1 Place the specimens vertically with a cut side facing the bottom. Use spacers or a basket to separate the specimens from the bottom and sides of the pressure vessel and each other. Seal the pressure vessel. Evacuate to a pressure of 10 ± 5 kPa (3 ± 1.5 inHg) (91 ± 5 kPa (26.9 ± 1.5 inHg) below standard atmospheric pressure of 101 kPa (29.8 inHg)) and maintain it for 30 ± 2 min.

6.3.2 While maintaining the vacuum, slowly admit sufficient water, taking no longer than 10 min to fully submerge the specimens. Once the specimens are fully submerged, release the vacuum and allow the pressure vessel to return to atmospheric pressure. Once the pressure vessel reaches atmospheric pressure, allow the test specimens to soak for 15 ± 2 min.

6.4 *Determination of Suspended Mass*—After soaking of the test specimens for the amount of time specified in accordance with the appropriate water impregnation method, determine to the nearest 0.01 g (0.00002 lb) the mass, *S*, of each specimen while suspended in water. Perform the weighing by placing the specimen in a wire loop, halter, or basket that is suspended from the balance. Before actually weighing, tare the balance or scale with the loop, halter, or basket in place and immerse in water to the same depth as is used when the specimens are in place. If it is desired to determine only the percentage of water absorption, omit the suspended mass operation.

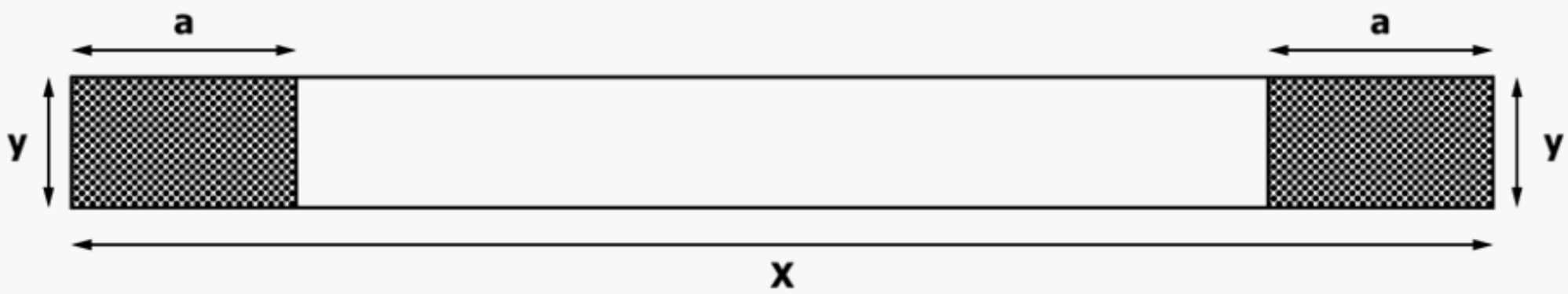


FIG. 4
x ≥ 1000 mm, y ≤ 205 mm, area > 420 cm², a = 205 mm (within 10 mm)

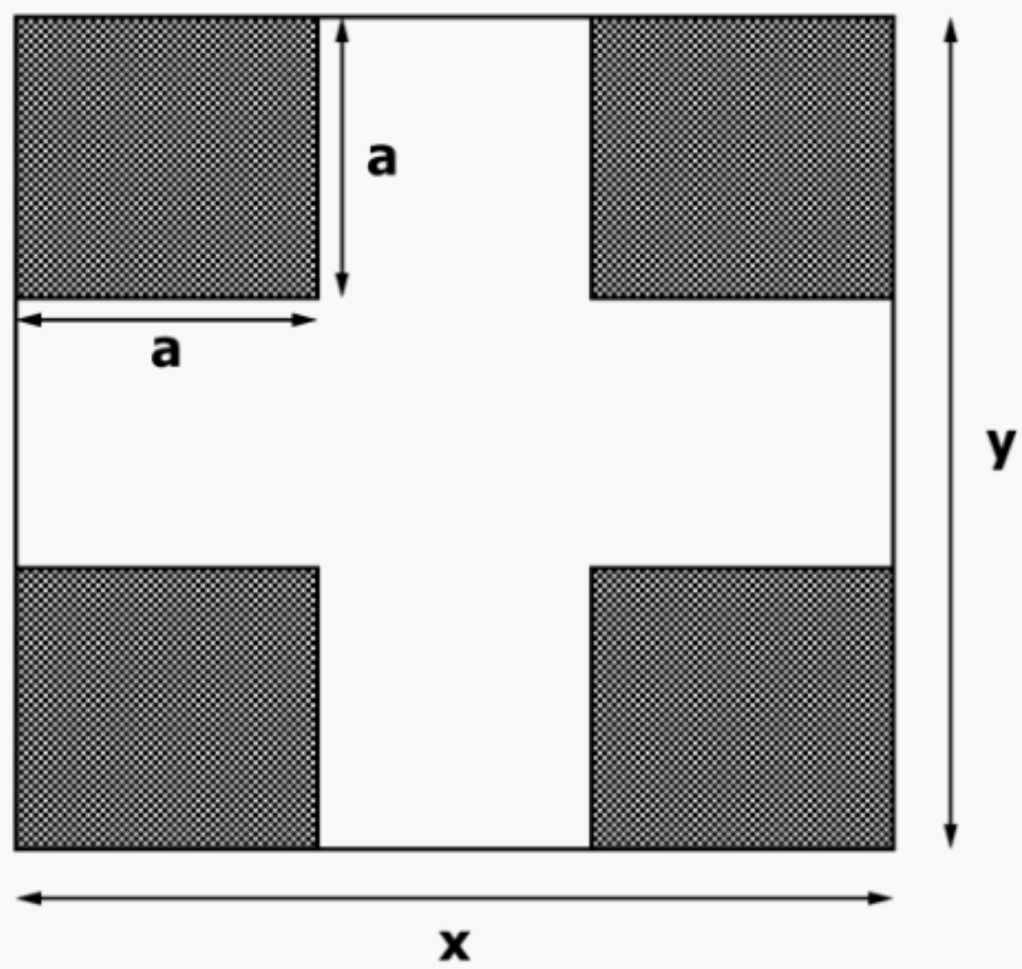


FIG. 5
x ≥ 410 mm, y ≥ 410 mm, area > 3600 cm²,
a = 205 mm (within 10 mm)

6.5 *Determination of Saturated Mass (Boil or Vacuum)*—After the determination of the suspended mass, or after soaking the test specimens for the amount of time specified in accordance with the appropriate water impregnation method, if the suspended mass is not determined, blot each specimen lightly with a damp microfiber cloth to remove all visible water droplets from the surface, and determine the saturated mass, M, to the nearest 0.01 g (0.00002 lb). A dry microfiber cloth shall be saturated with water equal to two times its dry weight (for example, a 50 g cloth is saturated with 100 g of water). This may be achieved by placing the cloth in a bowl, adding the required amount of water, and squeezing the cloth to ensure all of the water is absorbed and that the cloth is evenly saturated without any dry areas. The facial area of the microfiber cloth shall be at least 65 % of the total facial area of specimens tested (for example, five 100 x 100 mm specimens require a microfiber cloth surface area of 32 500 mm^2 or greater). Multiple microfiber cloths may be used to meet the required minimum cloth facial area. The blotting process shall involve patting the specimen lightly on all edges and surfaces with the damp microfiber cloth. Take care not to blot excessively as this could introduce error by withdrawing water from the pores of the specimen. Weight determination shall be performed immediately after the blotting process to avoid errors due to evaporation of water from the test specimen.

7. Calculation

7.1 In the following calculations, the assumption is made that 1 cm^3 of water weighs 1 g.

7.1.1 Calculate the exterior volume, V, in cubic centimeters, as follows:

$$V = M - S \tag{1}$$

7.1.2 Calculate the volumes of open pores, V_{OP}, and impervious portions, V_{IP}, in cubic centimeters as follows:

$$V_{OP} = M - D \tag{2}$$

$$V_{IP} = D - S \tag{3}$$

7.1.3 The apparent porosity, P, expresses, as a percent, the relationship of the volume of the open pores of the specimen to its exterior volume. Calculate the apparent porosity as follows:

$$P = [(M - D)/V] \times 100 \tag{4}$$

7.1.4 The water absorption, A, expresses as a percent, the relationship of the mass of water absorbed to the mass of the dry specimen. Calculate the water absorption as follows:

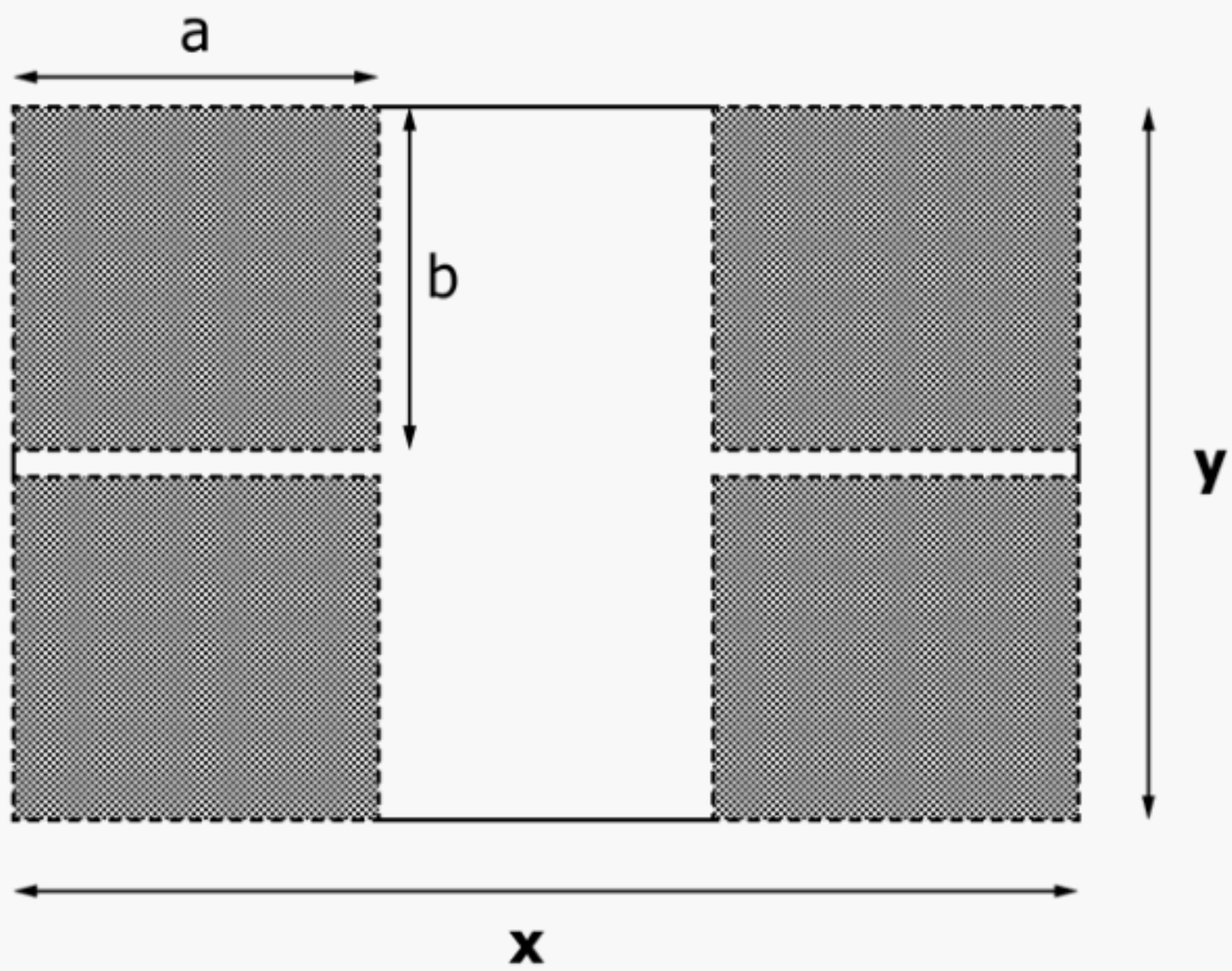


FIG. 6
x ≥ 410 mm, 205 mm < y ≤ 410 mm, area > 3600 cm^2,
a = 205 mm (within 10 mm), b = ½ y (within 10 mm)

$$A = [(M - D)/D] \times 100 \quad (5)$$

7.1.5 Calculate the apparent specific gravity, T, of that portion of the test specimen that is impervious to water, as follows:

$$T = D/(D - S) \quad (6)$$

7.1.6 The bulk density, B, in grams per cubic centimeter, of a specimen is the quotient of its dry mass divided by the exterior volume, including pores. Calculate the bulk density as follows:

$$B = D/V \quad (7)$$

8. Report

8.1 Report the average (Note 4) of all the specimens tested for each desired property (V, V_{OP}, V_{IP}, P, A, T, or B, or combinations thereof) and also the individual values to one decimal place by rounding to the nearest tenth. For example, 0.44 rounds to 0.4 and 0.46 rounds to 0.5. If the calculated property ends in exactly five hundredths, round to the nearest even tenth (for example, 0.45 rounds to 0.4, 0.55 rounds to 0.6, 0.65 rounds to 0.6, and 0.75 rounds to 0.8).

NOTE 4—The average shall be calculated using the individual values before they are rounded. The same rounding technique shall be applied to the average after it is calculated.

9. Precision and Bias

9.1 *Vacuum Method for Pressed Tiles*—The precision of this test method is based on an interlaboratory study of C373, Standard Test Methods for Determination of Water Absorption and Associated Properties by Vacuum Method for Pressed Ceramic Tiles and Glass Tiles and Boil Method for Extruded Ceramic Tiles and Non-tile Fired Ceramic Whiteware Products, conducted in 2017. Eight laboratories tested six different pressed tile sample sets using the vacuum method. Every "test result" represents an individual determination, and triplicate test results were reported by each participant. Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report No. RR:C21-1020.[3]

9.1.1 *Repeatability (r)*—The difference, within a 95 % confidence interval, between repetitive results obtained by the

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C21-1020. Contact ASTM Customer Service at service@astm.org.

TABLE 2 Pressed Tile Water Absorption (%)

Material	Average $\bar{x}$	Repeatability Standard Deviation s_r	Reproducibility Standard Deviation s_R	Repeatability Limit r	Reproducibility Limit R
Impervious Tile #1—Pressed	0.0675	0.0079	0.0144	0.0221	0.0402
Impervious Tile #2—Pressed	0.2333	0.0200	0.0597	0.0560	0.1670
Impervious Tile #3—Pressed	0.2783	0.0166	0.0435	0.0464	0.1219
Vitreous Tile—Pressed	2.8496	0.0469	0.0663	0.1312	0.1856
Semi-vitreous Tile—Pressed	3.9504	0.0418	0.0971	0.1171	0.2719
Non-vitreous Tile—Pressed	13.5946	0.1015	0.3286	0.2841	0.9202

same operator in a given laboratory applying this same test method with the same apparatus under constant operating conditions on identical test material in the normal and correct operation of this test method.

9.1.1.1 Repeatability limits are listed in Table 2.

9.1.2 *Reproducibility (R)*—The difference, within a 95 % confidence interval, between two single and independent results obtained by different operators applying this same test method in different laboratories using different apparatus on identical test material in the normal and correct operation of this test method.

9.1.2.1 Reproducibility limits are listed in Table 2.

9.2 *Boil Method for Extruded Tiles*—An intermediate precision study has been conducted using a single laboratory with three different operators. The referenced study involved test conditions of three different sets of tile. Three replicate tests were conducted for each condition (results are listed in Table 3).

9.3 *Bias*—No statement is made about the bias of this test method since no standard samples are available.

10. Keywords

10.1 apparent porosity; apparent specific gravity; bulk density; ceramic tile; fired whiteware products; glass tile; water absorption

TABLE 3 Extruded Tile Water Absorption (%)

Material	Average $\bar{x}$	Repeatability Standard Deviation s_r	Reproducibility Standard Deviation s_R	Repeatability Limit r	Reproducibility Limit R
Vitreous Tile #1—Extruded	2.1728	0.0444	0.0444	0.1245	0.1245
Vitreous Tile #2—Extruded	2.1523	0.0223	0.0246	0.0623	0.0689
Semi-vitreous Tile—Extruded	4.6048	0.1521	0.1521	0.4259	0.4259

SUMMARY OF CHANGES

Committee C21 has identified the location of selected changes to this standard since the last issue (C373 – 17) that may impact the use of this standard. (Approved Feb. 1, 2018.)

(1) Removed previous 5.2.3, Figs. 2 and 7 (affected sections and figures renumbered accordingly).
(2) Added new Table 1 and Fig. 6.
(3) Revised 5.2.1 – 5.2.8.

Committee C21 has identified the location of selected changes to this standard since the last issue (C373 – 16$^{\varepsilon 1}$) that may impact the use of this standard. (Approved Sept. 1, 2017.)

(1) Added Section 2 ("Referenced Documents").
(2) Revised Section 9.
(3) Added Tables 1 and 2.

Committee C21 has identified the location of selected changes to this standard since the last issue (C373 – 14a) that may impact the use of this standard. (Approved August 1, 2016.)

(1) Changed title from "Standard Test Method for Water Absorption, Bulk Density, Apparent Porosity, and Apparent Specific Gravity of Fired Whiteware Products, Ceramic Tiles, and Glass Tiles" to "Standard Test Methods for Determination of Water Absorption and Associated Properties by Vacuum Method for Pressed Ceramic Tiles and Glass Tiles and Boil Method for Extruded Ceramic Tiles and Non-tile Fired Ceramic Whiteware Products."
(2) Revised 1.1, 4.1, 4.2.1 – 4.2.9, 5.2 and 5.2.1, 5.4 and 5.5, 7.1, 8.1 and 8.1.1.
(3) Added 3.10 – 3.14, 5.3 – 5.3.2, new Notes 1 and 4, and new Figs. 4 and 6.

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