Designation: C 485 – 09

Standard Test Method for Measuring Warpage of Ceramic Tile[1]

This standard is issued under the fixed designation C 485; 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 This test method covers procedures for measuring diagonal and edge warpages of the following categories of ceramic tile:

1.1.1 *Square Tile*, 2 by 2 in. (51 by 51 mm) or larger, that are nominally flat, of uniform overall thickness, and have a smooth face of one of the types: unglazed, bright glazed, matte glazed, or finely crystalline glazed.

1.1.2 *Oblong Tile*, no facial dimension smaller than 2 in. (51 mm), that are flat, of uniform overall thickness, and have a smooth face of one of the types: unglazed, bright glazed, matte glazed, or finely crystalline glazed.

1.1.3 *Square and Oblong Tile*, no facial dimension smaller than 2 in. (51 mm), that are flat, but have an irregular face such as embossed, sloped, bumpy, wavy, coarsely crystalline, or wire-cut textured.

1.1.4 *Nonrectilinear Tile*, larger than 4 in.^{2} (26 cm^2), that are flat and of uniform body thickness with smooth or irregular face, such as hexagonal, diamond, Spanish type, and so forth.

1.1.5 *Trim Tile* meeting one of the descriptions in 1.1.1-1.1.4 except that only a part of the tile surface is flat. (Surface trim tile should be treated as flat tile whenever possible.)

1.1.6 *Square or Oblong Tile* with facial area less than 4 in.^{2} (26 cm^2) and at least two straight sides equal to or greater than 1.0 in. (25 mm) long. (Modular 1- by 1-in. tile are not in the scope of this test method.)

1.2 This test method is not applicable to tile having embossed surfaces that are not flat, or that have a combination of variable body thickness and an irregular face.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 242 Terminology of Ceramic Whitewares and Related Products

2.2 *ASTM Adjuncts:*

Warpage Gage for Ceramic Tile[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *tile*—see Definitions C 242.

3.1.2 *warpage*—curvature of a flat tile measured as deviation of the tile surface from a true plane along the edges or the diagonals. The deviation is measured at the mid-length of an edge or diagonal, expressed as a percentage of the length of the edge or diagonal, and called convex or concave with respect to the face of the tile.

4. Summary of Test Method

4.1 This test method consists of measuring the deviation from a straight line at the midpoint between reference points on the face or back of a tile. Measurements are made along the edges of a tile or along the diagonals, or both. The deviation is expressed as convex or concave warpage in relation to the tile face, and its magnitude is calculated as a percentage of the length of the edge or diagonal.

5. Significance and Use

5.1 This test method provides a means for determining whether or not a lot of ceramic tile meets the warpage requirements that may appear in specifications to assure satisfactory tile installations. In accordance with this test method, warpage is calculated as a percentage of the length of the edge or diagonal being tested. It is realized that the percentage values based on the overall edge length, or on the overall diagonal length of a tile will be slightly lower than those based on the distance between reference points. However, the ratio of the overall lengths to the distance between reference points will be practically constant for any particular

[1] This method is under the jurisdiction of ASTM Committee C21 on Ceramic Whitewares and Related Products and is the direct responsibility of Subcommittee C21.06 on Ceramic Tile.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Three drawings showing construction details are available from ASTM Headquarters. Order ADJC0485.

size of tile and, therefore, the percentage values will be comparable and equally indicative of warpage.

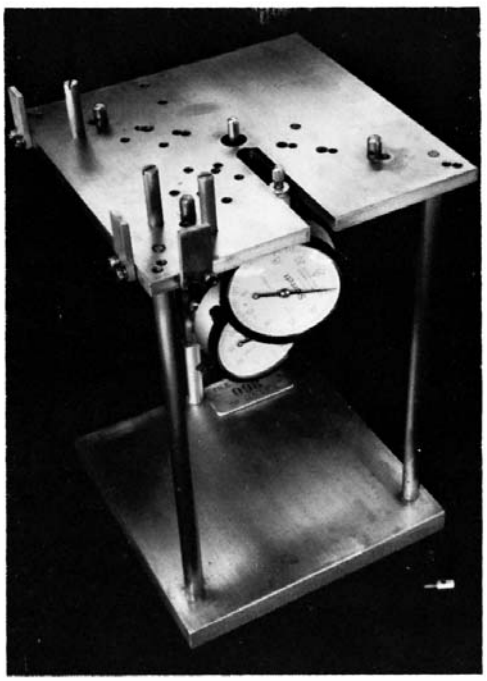

FIG. 1 Apparatus for Square Tile, Set Up for Measurement of 4¼-by 4¼-in. (108- by 108-mm) Tile

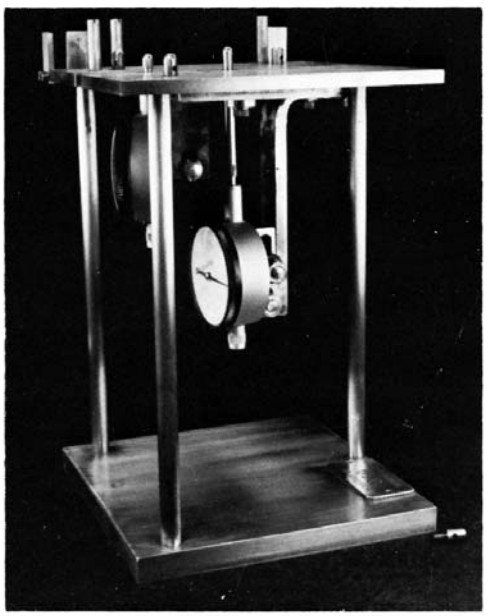

FIG. 2 Apparatus as Shown in Fig. 1, Showing Arrangement of Stem Extender

6. Apparatus

6.1 *General Apparatus*—The size and arrangement of the apparatus for measuring the warpages vary, depending on the size and shape of the tile to be measured. In general, the apparatus consists of two stationary pins (reference pins) spaced apart ¾ in. (19 mm) less than the length of the edge or diagonal being tested, and a dial indicator tip midway between the stationary pins and in line with them. The pins and the dial indicator are mounted firmly on the same rigid metal bar. The pins may have a hemispherical tip, as described in 6.2.2, or they may be conical to a point. A more versatile apparatus for standard sizes of tile consists of a metal plate having three movable reference pins, three movable registry stops, and the necessary number of dial indicators. See Fig. 1 and Fig. 2.

6.2 *Apparatus for Square Tile:*[3]

6.2.1 *Metal Plate*—A flat metal plate, 6 by 6 in. (152 by 152 mm) square and ¼ in. (6.4 mm) thick, with a 7⁄16-in. (11-mm) wide slot starting at the midpoint of one side and running at right angles to that side for a distance of 2⅝ in. (67 mm) toward the center of the plate. The plate also has a 7⁄16-in. diameter hole in the exact center of the plate. One side of the plate has two ⅛-in. (3.2-mm) thick, ½-in. (13-mm) wide, and 1-in. (25-mm) high projections, located not more than ½ in. from the corners, and a similar projection located on an adjacent side and not more than ½ in. from one of the corners of the first side. These projections serve as permanent registry stops for 6- by 6-in. tile during measurement.

6.2.1.1 In addition, the plate has a series of tapped holes for insertion of removable reference pins and removable registry stops. The centers of the holes for the reference pins are located for each nominal size of tile near three of its corners, ⅜ in. (9.5 mm) in from each side, when the tile is centered on the plate, except that for 2- by 2-in. (51- by 51-mm) tile the distance in from the edges is ¼ in. (6.4 mm). To receive the three registry stops, the centers of two holes are located for each nominal size of tile ½ in. (13 mm) from the corners of one side and ⅛ in. (3.2 mm) from the edge of the tile, while the center of a third hole is located on an adjacent side, ½ in. from one of the corners of the first side and ⅛ in. from the edge of the tile.

6.2.2 *Reference Pins*—Three movable reference pins ⅝ in. (16 mm) high and ¼ in. (6.4 mm) in diameter, with the free end ground to a hemispherical tip and the other end threaded for a distance of ¼ in. The reference pins are inserted in the metal plate to support the tile during measurement.

6.2.3 *Registry Stops*—Three ¼-in. (6.4-mm) diameter and 1¼-in. (32-mm) high, movable, flat top registry stops with a 1⁄16-in. (1.6-mm) wide and ⅛-in. (3.2-mm) deep slot on one end for the insertion of a screwdriver and threaded on the other end for a distance of ¼ in. The registry stops are inserted in the metal plate to fix the horizontal position of the tile during measurement.

6.2.4 *Dial Indicators*—Two adjustable dial indicators, reading in 0.001-in. (0.025-mm) increments and accurate to ±0.001 in. One is inserted from the bottom through the 7⁄16-in. (11-mm) hole in the center of the plate, permanently fastened to the underside of the metal plate, and used for measuring diagonal warpage. The other is inserted into the slot in the plate and fastened in any one of four positions which represent midpoints between reference pins on one side of each of the different nominal sizes of tile. This dial indicator is used for determining edge warpage.

6.2.5 *True Reference Plates*—Four ⅜-in. (9.5-mm) thick plates of true plane surface, made of steel or polished glass, one

each of the same dimensions as the four nominal sizes of tile which can be measured on this apparatus.

6.3 *Apparatus for Oblong Tile*:[3]

6.3.1 *Metal Plate*—A flat rectangular metal plate 8½ by 4¼ in. (216 by 108 mm) and ¼ in. (6.4 mm) thick, having two 7⁄16-in. (11-mm) wide slots. One slot should start at the midpoint of one 4¼-in. side and run at right angles to that side for a distance of 2¾ in. (70 mm) towards the center of the plate. The other slot should start at the midpoint of one 8½-in. side and run at right angles to that side for a distance of 1¾ in. (45 mm) towards the center of the plate. These slots are used for inserting the two dial indicators necessary to measure the edge warpage of one long and one short dimension of the tile simultaneously. There is also a 7⁄16-in. hole in the exact center of the plate for insertion of the third dial indicator, which is used for measuring diagonal warpage. One side of the plate has two ⅛-in. (3.2-mm) thick, ½-in. (13-mm) wide, and 1-in. (25-mm) high projections, located not more than ½ in. from the corners and a similar projection located on an adjacent side and not more than ½ in. from one of the corners of the first side. These projections serve as permanent registry stops for 8½ by 4¼-in. tile during measurement.

6.3.1.1 In addition, the plate has a series of tapped holes for insertion of movable reference pins and movable registry stops. The center of the holes for the reference pins is located for each nominal size of tile near its four corners, ⅜ in. (9.5 mm) in from each side, when the tile is centered on the plate. The centers of two of the holes to receive the three registry stops are located for each size of tile ½ in. (13 mm) from the corners of one side and ⅛ in. (3.2 mm) from the edge of the tile, while the center of the third hole is located on an adjacent side, ½ in. from one of the corners of the first side and ⅛ in. from the edges of the tile.

6.3.2 *Reference Pins*—See 6.2.2.

6.3.3 *Registry Stops*—See 6.2.3.

6.3.4 *Dial Indicators*—Three adjustable dial indicators, reading in 0.001-in. (0.025-mm) increments and accurate to ±0.001 in. One of them, used for the determination of diagonal warpage, is permanently fastened on the underside of the plate, with its stem projecting through the 7⁄16-in. (11-mm) hole in the center of the plate. The other two, used for measuring edge warpage, are inserted, one into each of the two slots in the plate, and fastened in any one of the various positions representing midpoints between reference pins on the same side of the various nominal sizes of tile. Because two of the dial indicators are in one line for viewing, one of them must be arranged at a different elevation than the other by using a stem extender, so that both dials may be read simultaneously (Fig. 2).

6.3.5 *True Reference Plates*—See 6.2.5.

7. Test Specimens

7.1 At least ten tile specimens shall be selected at random from the lot to be tested. Brush the specimens to remove all adhering particles of clay or sand.

8. Procedure

8.1 *General*—For nominally square tile use the apparatus described under 6.2. For oblong tile use the apparatus described under 6.3.

8.2 *Procedure for Square Tile*:

8.2.1 Depending upon the size of tile to be tested, insert the three registry stops and the three reference pins into the proper tapped holes in the metal plate and fasten them. Move and fasten the adjustable dial indicator in the slot so that its tip will fall at the midpoint between the two reference pins on the same side. Insert the proper reference plate and adjust the two dial indicators to zero reading when the reference plate rests on the reference pins and is in contact with the three registry stops.

8.2.2 Insert a piece of tile with its face resting upon the three reference pins and its edges in contact with the three registry stops. Read the two dial indicators, turn the tile 90° clockwise, and repeat the procedure until all four sides and the two diagonals have been measured.

8.3 *Procedure for Oblong Tile*:

8.3.1 Both diagonals of oblong tile cannot be measured for warpage without changing one of the reference pins. Depending upon the size of tile to be tested, insert the three registry stops and the three reference pins into the proper tapped holes in the metal plate and fasten them. Insert the two movable dial indicators, one in each slot of the plate and located so that the stem of one is at the midpoint between reference pins of one short dimension and the stem of the other at the midpoint between reference pins of one long dimension. Using the proper reference plate so that it rests on the three reference pins and its sides are in contact with the registry stops, adjust the three dial indicators to zero reading.

8.3.2 Place a tile face down on the reference pins so that its edges are in contact with the registry stops and read the three dial indicators. Turn the tile 180° and read the edge warpage of the second short and second long dimension of the tile. In order to determine the warpage of the second diagonal, change one of the reference pins and read the warpage of the second diagonal, after first resetting the dial indicators to zero with the reference plate. (In practice it will be found more expedient to read the edge warpage and the warpage of one diagonal of all the tile in a sample before changing the one reference pin to determine the warpage of the second diagonal.)

8.4 *Procedure for Square or Oblong Tile with an Irregular Face*, as defined in 1.1.3.

8.4.1 Tile with an irregular face on which accurate warpage measurements can not be made must be measured on the back, if possible. If the back is also unsuitable, no warpage measurements can be made in accordance with this test method.

8.4.2 A suitable back may be flat, embossed with a pattern, or ribbed if the following criteria are satisfied:

8.4.2.1 For diagonal warpage a flat area at least ¼ by ¼ in. (6.4 mm) in or near the center of the back must be in the same nominal plane and in line with similar flat areas near the corners of the back. The points within these flat areas at which the stationary points and the dial indicator tip of the apparatus contact the tile back may be chosen with reasonable latitude, but the same locations must be used on each tile in the sample.

8.4.2.2 For edge warpage a flat area at least ¼ by ¼ in. (6.4 mm) at the midpoint of an edge and no more than ½ in. (13 mm) away from the edge must be in the same nominal plane as and in line with similar flat areas near the corners of the tile. All three points of contact with the apparatus may be on a rib, for instance. At least two edges of the tile must be measurable for warpage.

8.4.3 Once the lines on which warpage will be measured are established, determine the gage length (distance between stationary pins on the three-point apparatus). Set the stationary pins of the apparatus at a distance apart equal to the gage length, with the tip of the dial indicator mid-way between them. Using a true reference plate (see 6.2.5), calibrate the apparatus to read a minimum of zero on the dial indicator when the apparatus is held in contact with the reference plate and rocked slowly from side to side on line of contact. (If no minimum can be established, it probably means the three points are not in line and the apparatus must be adjusted.)

8.4.4 With the tile back up on a flat work surface, measure the deviation from a plane on an established line by placing the stationary points of the apparatus on the established points on the tile back. Rock the apparatus slowly side to side to establish a minimum reading. Record the reading as plus (+) or minus (−) to indicate convex or concave curvature of the tile (with respect to the tile face). Repeat the procedure for all tile in the sample and all equal gage lengths before resetting the apparatus for other gage lengths on the tile.

8.5 *Procedure for Nonrectilinear Tile*, as defined in 1.1.4:

8.5.1 Depending on the shape, and to some extent the size, of the tile to be tested, determine the lines on which warpages will be measured. A maximum of six (four edge warpages and two diagonal warpages) and a minimum of two warpages per tile are acceptable. *Examples:* A round tile would require two warpages at right angles with the dial indicator tip contacting the center of the tile (diagonal warpages). A diamond-shaped tile would require four edge warpages and two diagonals. A nonrectilinear tile with no straight edges would require two diagonal warpages, one on the longest face dimension and another at right angles to it. A triangle-shaped tile would require three edge warpages.

8.5.2 If the tile have an irregular face, combine instructions from 8.4 for using the back of the tile with those for nonrectilinear tile.

8.5.3 Once the lines on which warpage will be measured are established, placing lines for edge warpage ⅜ in. (9.5 mm) away from the tile edge they parallel, determine the ideal gage length (distance between stationary pins on the three-point apparatus) by establishing two points on the lines ⅜ in. away from the nearest tile edge or edges. Set the stationary pins of the apparatus at a distance apart equal to the ideal gage length, or closer than the ideal gage length by no more than ½ in. (13 mm). The tip of the dial indicator shall be exactly mid-way between the stationary pins and in line with them. Using a true reference plate (see 6.2.5), calibrate the apparatus to read a minimum of zero on the dial indicator when the apparatus is held in contact with the reference plate and rocked slowly side to side on the line of contact. (If no minimum can be established, it probably means the three points are not in line and the apparatus must be adjusted.)

8.5.4 With the tile face up on a flat work surface, measure the deviation from a plane on an established line by placing the stationary points of the apparatus on the established points on the tile surface, or evenly between them if the stationary points are less than the ideal gage length apart. Rock the apparatus slowly side to side to establish a minimum reading. Record the reading as plus (+) or minus (−) to indicate convex or concave curvature of the tile. Repeat the procedure for all tile in the sample and all equal gate lengths on the tile before resetting the apparatus for other gage lengths on the tile.

8.6 *Procedure for Trim Tile*, as defined in 1.1.5:

8.6.1 This test method is applicable to the flat section or straight edges of trim tile when they exist.

8.6.2 Follow the procedures for the applicable paragraphs 1.1.1-1.1.4, but if extraordinary means are required, consider the shape not within the scope of this test method.

8.7 *Procedure for Square or Oblong Tile with Facial Area Less than 4 in.^{2} (26 cm^2)* as defined in 1.1.6:

8.7.1 Warpage measurement of small, flat tile must be performed with wire feeler gages. Only edge warpage measurements are possible. Determine whether the front or back of the tile will be used to measure warpage; front is preferred when it is suitable. Determine the lengths of the flat portion of the face along an edge. Consult the specification to find the maximum warpage allowed and choose wire feeler gages that will permit go-no-go measurement. *Example:* if a maximum of 0.4 % warpage is allowed and the flat portion of the edge is 1 in. (25 mm) long, 0.004-in. (0.10-mm) diameter wires are chosen as the feeler gage.

8.7.2 Place the tile face to be measured against the surface of a true reference plate (see 6.2.5). If the tile does not rock on the edge being checked, try to slip the wire under the tile at the midpoint of that edge. If the wire does not fit under the tile, the tile passes. If it does fit, the tile fails. If the tile rocks on the edge being checked, place one wire under the very end of the edge and, holding the tile tight to that wire and the plate, try to slip a second wire under the opposite end of the edge being checked. If the second wire does not fit under, the tile passes. If it does, the tile fails.

9. Calculation

9.1 Calculate the percentage of warpage as follows:

$$\text{Warpage, } \% = (A/B) \times 100 \quad (1)$$

where:

A = amount of warpage in inches measured to the nearest 0.001 in. (in millimetres to the nearest 0.025 mm) and

B = gage length, measured to nearest 1/16 in. (1.6 mm) plus ¾ in. (19 mm) and expressed in inches to the nearest 0.001 in. (expressed in millimetres to the nearest 0.025 mm).

10. Report

10.1 Report the following information:

10.1.1 Nominal size of the tile tested,

10.1.2 The category or categories (see 1.1.1-1.1.6) into which the tile were placed, and

10.1.3 Percent of warpage, either convex or concave, of each edge and diagonal tested, except in the case of tile less than 4 in.^{2} (26 cm^2), report number of "passes" and "fails."

11. Precision and Bias

11.1 The precision of any warpage measurement is approximately ±0.05 %. Bias depends primarily on the perfection of the true reference plate, but no interlaboratory data are available to estimate bias.

12. Keywords

12.1 ceramic tile; warpage