Designation: ~~C609 – 07 (Reapproved 2019)~~ C609 – 20

Standard Test Method for Measurement of Light Reflectance Value and Small Color Differences Between Pieces of Ceramic Tile[1]

This standard is issued under the fixed designation C609; 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 the measurement of Light Reflectance Value (LRV) and visually small color difference between pieces of glazed or unglazed ceramic tile, using any spectrophotometer that meets the requirements specified in the test method. LRV and the magnitude and direction of the color difference are expressed numerically, with sufficient accuracy for use in product specification.

1.2 LRV may be measured for either solid-colored tile or tile having a multicolored, speckled, or textured surface. For tile that are not solid-colored, an average reading should be obtained from multiple measurements taken in a pattern representative of the overall sample as described in 9.2 of this test method. Small color difference between tiles should only be measured for solid-color tiles. Small color difference between tile that have a multicolored, speckled, or textured ~~surface,~~surface are not valid.

1.3 For solid colored tile, a comparison of the test specimen and reference specimen should be made under incandescent, fluorescent and daylight illuminant conditions. The use of multiple illuminants allows the color difference measurement to be made without the risk of wrongly accepting a match when the tiles being compared are ~~metamers. (See~~metamers (see 3.1.4~~.)~~).

1.4 The values stated in inch-pound units are to be regarded as ~~the~~ standard. The values given in parentheses are provided for information ~~only.~~only and are not considered standard.

1.5 *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.*

1.6 *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:*[2]

C242 Terminology of Ceramic Whitewares and Related Products

D2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates

E259 Practice for Preparation of Pressed Powder White Reflectance Factor Transfer Standards for Hemispherical and Bi-Directional Geometries

E284 Terminology of Appearance

3. Terminology

3.1 *Definitions:*

3.1.1 *color difference,* ~~ΔE~~ΔE^* *and* ~~ΔE~~ΔE_H~~—~~*, n—*the vector sum of the three component differences ΔL^*, Δa^*, and Δb^* for ΔE^* and ~~ΔL~~ΔL_H~~,Δa~~, Δa_H~~,Δb~~, Δb_H for ~~ΔE~~ΔE_H. The superscript * indicates color difference based on the use of CIELAB color space equations, while the subscript H indicates color difference based on the use of the Hunter equations. ~~ΔE~~ΔE_H is expressed in units

[1] This test 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.

Current edition approved ~~Aug. 1, 2019~~April 1, 2020. Published ~~August 2019~~April 2020. Originally approved in 1967. Last previous edition approved in ~~2014~~2019 as C609 – 07 ~~(2014).~~(2019). DOI: ~~10.1520/C0609-07R19.~~10.1520/C0609-20.

[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.

of judds, while ~~ΔE~~ΔE^* is a unit-less value. Either form of the ~~ΔE~~ΔE can be solved for using the equation shown in 10.3. For both the CIELAB and Hunter equations, the values ΔL, Δa, and Δb are obtained by calculating the component differences as follows:

~~$\Delta L = L_t - L_r$~~
~~$\Delta a = a_t - a_r$~~
~~$\Delta b = b_t - b_r$~~

$$\Delta L = L_t - L_r$$
$$\Delta a = a_t - a_r$$
$$\Delta b = b_t - b_r$$

where:

t = test specimen, and
r = reference specimen.

The quantity ΔE has a positive value and it describes the magnitude but not the direction of color difference between the test specimen and the reference specimen. The direction of color difference depends upon the algebraic signs of the components ΔL, Δa, and Δb. A positive ΔL value means that the test specimen is lighter than the reference against which it is being compared, and a negative ΔL value means that the test specimen is darker. However, the algebraic signs of chromaticity components, Δa and Δb, do not convey an easily visualized difference in color attributes and can best be visualized by plotting the corresponding points in the chromaticity plane.[3]

3.1.2 *color ~~space—~~space, n—*the colors of opaque specimens such as ceramic tile are described in terms of three color scales *L, a*, and *b*. Scale *L* is a measure of lightness, *a* is a measure of redness or greenness, and *b* is a measure of yellowness or blueness. The units for each of the three scales are so chosen that they represent equally perceptible color differences. The interrelation of these color scales is more readily visualized if the scales are represented geometrically as the three mutually perpendicular axes of a three-dimensional color space, with the *L* axis in the vertical direction, the positive *a* axis (redness) to the right, and the positive *b* axis (yellowness) in a counterclockwise direction from the positive *a* axis (see Fig. 1).

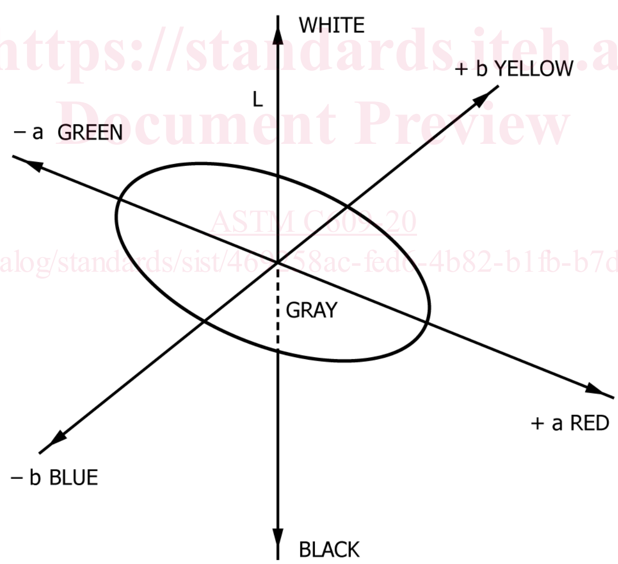

FIG. 1 ~~Three-Dimensional~~Three-dimensional Color Space

3.1.3 *light reflectance value, ~~(LRV)—~~(LRV), n—*the luminance factor *Y*, of a sample expressed as a percent. Thus, a *Y* value of 70 would equate to an LRV of ~~70%.~~70 %. The LRV indicates the portion of light cast on a sample that is not absorbed.

3.1.4 *~~metamers—~~metamers, n—*~~See~~see Terminology E284.

3.1.5 *reference ~~specimen—~~specimen, n—*any tile for which a match is desired.

3.1.6 *~~repeatability—~~repeatability, n—*the standard deviation of results obtained by the same operator using the same instrument in successive measurements.

3.1.7 *~~reproducibility—~~reproducibility, n—*the standard deviation of results obtained by different operators using the same or different types of instruments in different laboratories.

[3] Illing, A. M., Balinkin, I., "Precision in Measurement of Small Color Differences," *American Ceramic Society ~~Bulletin~~ Bulletin,* ~~,~~Vol 44, No. 12, 1965, pp. 956–962.

3.1.8 ~~standard—~~standard, n—the plaque or other media of established tristimulus value, against which standardization of the instrument is made.

3.1.9 *test ~~specimen—~~specimen, n—*any piece of tile whose LRV or color difference from a reference specimen is to be evaluated.

3.1.10 *~~tile—~~tile, n—*~~See~~see Terminology C242.

3.1.11 *~~spectrophotometric—~~spectrophotometric, n—*measurement of the spectral reflectance or transmittance curve of a material.[4]

4. Summary of Test Method

4.1 This test method explains the technique for measuring the LRV and color of tile specimens with a spectrophotometric instrument that meets the specified requirements. Such instruments should give results comparable to differences observed by the human eye, and yield for each color a unique, three-number characterization, having known relationship to the tristimulus values *X, Y*, and *Z*.

4.2 Spectrophotometic measurement systems commonly provide measurement data in a variety of color units and allow for automatic conversion of data from one color system to another. Select equations are included in this test method for manual determination of LRV from Y, L^*, or L_H. Equations are also provided for calculation of L^*, a^*, b^*, and L_H, a_H and b_H from tristimulus values *X, Y*, and *Z*. The algebraic differences in *L, a,* and *b* values, between any two specimens, are then used to calculate the color difference, ~~ΔE.~~ΔE. If manual calculations are required, consult the instrument supplier for conversions not provided within this test method.

4.3 The complete description of the amount and direction of a color difference between any two pieces of solid colored tile can be given simply as the three respective differences between the pairs of values for *L, a*, and *b*. For some purposes, ΔE alone provides enough information, since its magnitude gives a fairly good correlation with human opinions about the size of a color difference.

4.4 To protect against approval of a metameric color match, multiple illuminates must be used when evaluating color difference between solid colored tiles. A test specimen needs to prove suitable with respect to a reference specimen under incandescent, fluorescent and daylight illuminant conditions in order to be judged as acceptable.

5. Significance and Use

5.1 This test method describes the means of determining the LRV of a tile specimen. Certain building codes require the use of materials rated by LRV. Application of this test method provides the means for rating ceramic tile. LRVs reported for ceramic tile should include reference to the observer and illuminant for which the rating is valid.

5.2 LRV is a property dependent on the overall color of a tile specimen. Control of LRV is achieved through control of color and adherence to color specifications will govern the acceptability of a product with respect to LRV. Therefore, a product cannot be judged as having an unacceptable LRV unless the color of the product is found to be unacceptable.

5.3 Mixtures of several tile products are commonly installed on a surface, requiring a means to calculate LRV for a product mix. The rating obtained for an individual tile product can be used to calculate the LRV for a product mix using the following equation:

~~$$LRV_{product\ mix} = \sum p_1 LRV_1 + p_2 LRV_2 + \ldots + p_n LRV_n \quad (1)$$~~

$$LRV_{\text{product mix}} = \sum p_1 LRV_1 + p_2 LRV_2 + \ldots + p_n LRV_n \quad (1)$$

~~where:~~

where:

n = number of products included in the mix
~~$p_{1\ to\ n}$ = the proportion of the surface area taken up by each product, the sum of p_1 to p_n must equal one~~
~~LRV_{1} to n = the LRV for each product used~~

n = number of products included in the mix,
$p_{1\ \text{to}\ n}$ = the proportion of the surface area taken up by each product; the sum of p_1 to p_n must equal one), and
$LRV_{1\ \text{to}\ n}$ = the LRV for each product used.

For example, a mixture of two products is used on a surface. Two thirds of the surface area is covered by product A with a LRV of 75 %, and one third of the surface is covered by product B with an LRV of 60 % (see Fig. 2~~Fig. 2).~~). Using the equation, the product mix is found to have an LRV of 70 %.

5.4 The test method described herein provides instrumental means as the basis for judging color difference. Magnitude of color difference between pairs of ceramic tile can be determined and expressed in numerical terms.

[4] Billmeyer, F.W. Jr., Saltzman, M., *Principles of Color Technology, 2nd Edition*, John Wiley & Sons, Inc., New York, NY, 1981, p. 78, 85.