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Standard Test Method for Water Immersion and Drying for Evaluation of Flood Damage Resistance [1]

This standard is issued under the fixed designation E3075; 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.

INTRODUCTION

The performance of construction materials during flood events is an item of importance for property owners and communities, especially those located in flood-prone areas. Requirements for the use of flood-resistant building materials in flood hazard areas can be found in the US model codes, standards, and guidelines pertaining to flood resistant design and construction. To promote uniformity in evaluation of building material response to flooding, this test method prescribes standard conditions for water immersion, subsequent drying, and cleaning such as occur during flood events. Other deleterious effects of floods that are outside the scope of this test method include, but are not limited to, debris impact, flood velocity, wave action, water pressure differential, scour, erosion, biological and chemical contaminants in floodwater, and other factors including long-term occupant health impacts that would be adverse to continued use of the structure.

1. Scope

1.1 This test method is intended to apply to building materials used in construction below the base flood elevation (BFE) including, but not limited to: individual building materials and composite assemblies of building materials that constitute permanent integral parts of a finished building including walls, floors, ceilings, stairways, built-in partitions, finishes, cladding, and other similarly incorporated architectural and structural items.

1.2 Requirements for evaluation of other hazards associated with flood damage including, but not limited to: debris impact, flood velocity, wave action, water pressure differential, scour, erosion, biological and chemical contaminants in floodwater, and other factors that would be adverse to continued use of the structure for its intended purpose including long-term occupant health impacts are outside of the scope of the methods presented herein.

1.3 The water immersion, drying, and cleaning procedures specified in this test method establishes standard conditions for laboratory evaluation of test specimen response to water immersion, subsequent drying, and cleaning. The results of these tests are one factor in assessing the characteristics of building materials with regard to water immersion, drying, and ability to be cleaned. Application of these test results to predict these characteristics for actual building construction requires the evaluation of test conditions as compared to conditions of end-use.

1.4 The water immersion and drying procedures shall not be construed as representative of water makeup, duration of immersion, or conditions of drying during an actual flood event because actual flood conditions vary with such factors as makeup of water, depth and duration of immersion, and ambient temperature and humidity.

1.5 The cleaning procedures specified in this test method are intended to simulate surface cleaning that normally occurs after flooding.

1.6 The cleaning procedures specified in this test method shall not be construed as superseding standards or manufacturer's recommended methods for cleaning and restoration after flooding.

1.7 A commentary to this test method is provided in Appendix X1.

1.8 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.

1.9 *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.*

[1] This test method is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.25 on Whole Buildings and Facilities.

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2. Referenced Documents

2.1 *ASTM Standard:*[2]

D7789 Practice for Collection of Fungal Material from Surfaces by Swab

2.2 *Federal Standard:*[3]

44 CFR Part 60.3 Flood plain management criteria for flood-prone areas

2.3 *Other Standards:*

ANSI/IICRC S500 Standard and Reference Guide for Professional Water Damage Restoration[4]

International Plumbing Code [5]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *base flood elevation (BFE), n*—the height of the base (1-percent annual chance or 100-year) flood in relation to a specified datum, usually the National Geodetic Vertical Datum of 1929, or the North American Vertical Datum of 1988.

3.1.2 *potable tap water, n*—filtered tap water conforming to the bacteriological and chemical quality requirements of the Public Health Service Drinking Water Standards or the regulations of the public health authority having jurisdiction.

4. Summary of Test Method

4.1 The procedures described in this test method are used to evaluate the response of building materials noted in 1.1 when subjected to water immersion, subsequent drying, and cleaning.

4.1.1 This test method exposes test specimens to water immersion followed by a drying period and surface cleaning.

4.1.2 Test specimen orientation is consistent with orientation of the test specimen building material(s) in end use. For example, a test specimen simulating wall assembly construction is immersed in a vertical orientation, while a test specimen simulating floor/ceiling assembly construction is immersed in a horizontal orientation.

4.1.3 The cleaning specifications are intended to simulate surface cleaning that normally occurs after flooding.

5. Significance and Use

5.1 This test method establishes water immersion, drying, and cleaning procedures to be used when determining whether building materials noted in 1.1 are flood damage resistant for applications that comply with the National Flood Insurance Program (NFIP) [44 CFR § 60.3(a)(3)].

5.2 This test method exposes the test specimen to water immersion and drying conditions to simulate the effects of wetting and subsequent drying that occurs with a flood event. The wetting and drying exposure is followed by surface cleaning. This test method provides a measure of how test specimens may respond to water immersion, subsequent drying, and cleaning that occur with flood events.

5.3 This test method is useful for determining water absorption characteristics of different test specimens in terms of percent increase in test specimen weight, their drying characteristics in terms of elapsed time to dry to equilibrium weight, and changes in physical appearance following water immersion and surface cleaning.

5.4 This test method is useful in comparing the water absorption characteristics of different test specimens, their drying characteristics, and changes in physical appearance following water immersion and surface cleaning. This test method is also useful in comparing test specimen physical dimensions before water immersion, immediately following removal from water immersion, after drying, and after cleaning.

5.5 The ability to directly compare test results will vary by many factors including test specimen size and whether test specimens are individual building materials or composite assemblies of building materials.

6. Test Specimens

6.1 The test specimens shall be identified as fully as possible by including the building materials and details of construction, method of fabrication, and other pertinent details that potentially affect the response to water immersion, drying, and cleaning.

NOTE 1—Test specimens can vary in size and makeup depending on the purpose of the testing. Where the purpose of testing is to evaluate the response of a particular building material to exposures in this test method, test specimen can consist solely of the building material of interest. Such test specimens enable evaluation of the building material alone without influence by water absorption, drying, and dimensional change characteristics of other building materials that are used in test specimens consisting of a composite assembly of building materials. Where the purpose of testing is to evaluate the response of a composite assembly of building materials to exposures in this test method to more closely address conditions representative of end use, test specimens can consist of a composite assembly of building materials as used such as occur in wall or floor/ceiling assembly construction.

6.2 Where applicable based on the purpose of testing, test specimens shall include joints, fasteners, adhesives, and other materials as appropriate to the end-use.

6.3 Before water immersion, test specimens shall be conditioned in a controlled environment at 75 ± 5 °F (24 ± 3 °C) and 50 ± 5 % relative humidity (RH) until the equilibrium weight for the test specimen is achieved. Periodic weighing shall be used to make a determination regarding whether equilibrium weight is achieved.

6.3.1 The equilibrium weight, $W_{initial}$, shall be determined before water immersion.

NOTE 2—In practice, RH control is not exact and fluctuations occur during the conditioning period. Since change in weight because of RH fluctuation is usually small relative to the total change that a test specimen will experience, a steady increase or decrease in mass will generally occur during most of the conditioning period. As the test specimen approaches

[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] Available from U.S. Government Publishing Office, 732 N. Capitol St., NW, Washington, DC 20401-0001, http://www.access.gpo.gov.

[4] Available from Institute of Inspection Cleaning and Restoration Certification (IICRC), 4043 South Eastern Avenue, Las Vegas, NV 89119, http://www.iicrc.org.

[5] Available from, and a registered trademark of, International Code Council (ICC), 500 New Jersey Ave., NW, 6th Floor, Washington, DC 20001, http://www.iccsafe.org.

equilibrium weight, weight change associated with fluctuations in RH will cause a change in the direction of weight change, which is a sign that equilibrium weight has been reached. The reversal of direction of weight change can be used for equilibrium weight determination. A minimum of three results confirming the reversal is recommended.

7. Water Specifications

7.1 Water shall be filtered potable tap water at 75 ± 5 °F (24 ± 3 °C) having a pH within the range of 6.0 to 9.0 and greater than 95 % of chlorine and fluorides removed with sewage surrogate, mold surrogates, and nutrients added in the quantities specified as follows:

7.1.1 *Sewage Surrogate*—$10^6 \pm 0.05 \times 10^6$ MPN/L Escherichia coli;

7.1.2 *Mold Surrogates*—$10^6 \pm 0.05 \times 10^6$ cfu/L Penicillium brevicompactum, $10^6 \pm 0.05 \times 10^6$ cfu/L Aureobasidium pullulans, and $10^6 \pm 0.05 \times 10^6$ cfu/L Eurotium herbariorum; and

7.1.3 *Nutrients*—0.1 % (weight/volume) potato dextrose extract.

7.2 In this test method, references to water in which test specimens are immersed indicates use of water in accordance with specifications in 7.1.

8. Procedure

8.1 *Water Immersion*—Immerse test specimens in water in accordance with specifications in 7.1 to the level specified in 8.1.2 for a period of not less than 72 h nor more than 80 h.

8.1.1 *Apparatus*—A corrosion resistant tub or container, clean and free of debris, shall be used for soaking test specimens and shall be of adequate size to accommodate water immersion of test specimens as required in this test method.

8.1.2 *Test Specimen Orientation:*

8.1.2.1 Where end-use is in a vertical orientation (for example, a wall assembly specimen), immerse test specimens to 50 ± 10 % of the height of the specimen.

8.1.2.2 Where end-use is in a horizontal orientation (for example, a floor or ceiling assembly specimen), immerse such that no portion of the test specimen is less than 1 in. (25 mm) below the surface of the water.

8.1.3 The test specimens shall be placed on supports capable of supporting the test specimens off the bottom of the water bath while submerged to the specified depth. For test specimens that may otherwise float, weights or other methods of keeping test specimens submerged to the specified depth shall be used.

8.2 *Water Absorption*—Compute water absorption as a percent increase over the initial pre-immersion test specimen weight as:

$$WA = \frac{W_{wet} - W_{initial}}{W_{initial}} \times 100 \quad (1)$$

where:

WA = Percent increase in test specimen weight due to water immersion;

W_{wet} = Weight of wet test specimen measured within 1 h after removal from water immersion, g; and

$W_{initial}$ = Equilibrium weight of test specimen before water immersion, g.

NOTE 3—The weight increase after water immersion can be determined by subtracting $W_{initial}$ from W_{wet}. When other characterizations of water absorption are reported, such as ratio of weight increase to the dry volume of the test specimen, it is important to describe the basis for determination of volume of the test specimen. The description should include factors such as whether the test specimen volume is based only on solid portions of materials making up the test specimen, whether dry volume is based on actual measured dry dimensions at equilibrium weight or specified nominal dimensions for the test specimen under dry conditions.

8.3 *Drying*—Remove test specimens from the water mixture and dry in a controlled environment at 75 ± 5 °F (24 ± 3 °C) and 50 ± 5 % RH until the equilibrium weight of the test specimen is achieved.

8.3.1 Measure test specimen weight within 1 h of removal of the test specimen from the water mixture and periodically thereafter to determine when equilibrium weight, W_{final}, is achieved (see 6.3).

8.4 The elapsed time to reach equilibrium weight after removal from water immersion, W_{final}, shall be recorded.

8.5 *Cleaning*—Clean the test specimens with generally available, anti-bacterial soap and potable tap water and rinse with potable tap water.

NOTE 4—Use of a microfiber cloth or non-metal wire scrub brush as applicable for the test specimen has been shown to be sufficient to remove the presence of mold and bacteria contaminants introduced into the water from exposed surfaces of the test specimen.

8.6 *Swabbing Requirements*—Assess test specimens for surviving sewage and mold surrogates by swabbing the test specimen on three surface locations using the techniques established in Practice D7789.

9. Report

9.1 The following information shall be provided in a report:

9.1.1 Date(s) of test and report;

9.1.2 Names and addresses of the organization that requested the tests and the testing organization that conducted the tests;

9.1.3 A description of the test specimens as a whole, including all parts and components, manufacturer of products, applicable material standard, applicable material specification, construction details, drawings or photographs showing pertinent construction details, and the number tested;

9.1.4 A description of the test procedure, including a description of testing apparatus for water immersion tests and environmental conditions for drying;

9.1.5 Detailed test results including test specimen equilibrium weight before water immersion, $W_{initial}$; test specimen weight within 1 h after removal from water immersion, W_{wet}; percent increase in specimen weight after water immersion, WA; immersion duration; final equilibrium weight, W_{final}; time to reach equilibrium weight after removal from water immersion; and results from swabbing for surviving sewage and mold surrogates;

9.1.6 A description of the test specimen after completion of each portion of testing (pre-water immersion, immediately after removal from water immersion, after drying, and after

cleaning) including appearance, changes in physical dimensions, and any other pertinent observations including photographs;

9.1.7 The name(s) and titles of individual(s) conducting the test and the author of the report; and

9.1.8 Any additional data or information considered useful for a better understanding of the test results, conclusions, or recommendations (append to the report).

10. Precision and Bias

10.1 There has not been a study to determine repeatability and reproducibility of this test method, but precision data will be available within five years of approval and publication of this test method.

10.2 *Bias*—There are no accepted reference materials suitable for determining the bias for this test method. Therefore, no statement on bias is being made.

11. Keywords

11.1 Federal Emergency Management Agency; FEMA; flood damage resistance; flooding; National Flood Insurance Program; NFIP

APPENDIX

(Nonmandatory Information)

X1. COMMENTARY TO THE TEXT

INTRODUCTION

The National Flood Insurance Program (NFIP) requires the lowest floor of all new and substantially improved structures located in special flood hazard areas (SFHA) to be elevated at or above the base flood elevation (BFE). For all building materials below the BFE, flood-damage-resistant materials are required to be used. FEMA TB 2[6] identifies some building materials as flood-damage resistant based on their ability to withstand "direct and prolonged contact" with floodwater without sustaining damage that requires more than minor repair to restore these materials to pre-flood condition. This test method provides standard wetting and drying exposure conditions and requirements for surface cleaning for evaluation of flood damage resistance for building materials not listed in FEMA TB 2. This test method provides a standard approach for determining a building material's response to wetting, drying, and surface cleaning that occur with flood events and is not intended to supersede other applicable codes or standards related to flood-damage resistance.

[6] FEMA Technical Bulletin 2, *Flood-Damage Resistant Materials Requirements*, 2008, available from the FEMA Resource & Document Library at https://www.fema.gov/resource-document-library.

X1.1 Commentary to Section 1, Scope

X1.1.1 This test method requires test specimens to be exposed to standard conditions for wetting, drying, and surface cleaning. Other deleterious effects of floods that are outside the scope of evaluation under this test method include, but are not limited to, debris impact, flood velocity, wave action, scour, erosion, and other factors that would be adverse to continued use of the structure. Although the long-term occupant health impacts of floodwaters and long-term structural deterioration associated with floodwater impacts are outside the scope of this test method, care should be taken in accounting for these impacts in designing and constructing flood-prone structures.

X1.1.2 Standard wetting exposure, drying conditions, and surface cleaning methods are specified in this test method to enable evaluation by use of fixed reference conditions. These reference conditions are not intended to represent an actual flood exposure. Floods vary widely in duration and impacts. Environmental conditions such as temperature, humidity, and drying conditions can also vary widely. In some cases, cleanup and the initiation of remediation efforts occur within hours of floodwater receding. In other cases, it may take days or, in some cases, weeks or even months before these efforts can begin. Additionally, floodwaters vary widely in potential contaminants and the concentration of these contaminants left after a flood can vary not only from flood to flood but also among specific geographic locations within a given flood.

X1.2 Commentary to Section 5, Significance and Use

X1.2.1 This test method provides water immersion, drying, and cleaning procedures for use in evaluation of a building materials response to water immersion, drying, and ability to be cleaned including for those applications where materials are required to be flood damage resistant to comply with the National Flood Insurance Program (NFIP) [44 CFR § 60.3(a)(3)]. Other uses of the test method include comparative testing to evaluate effects of different specimen construction on building material response under fixed reference conditions for water immersion and drying exposure conditions. Such testing

has not been previously standardized even though response of building materials to water immersion and subsequent drying has been undertaken over many years both in the US and internationally. While fixed reference conditions are specified, this test method does not establish performance levels or acceptance criteria for flood damage resistant materials and is therefore not considered to be suitable alone for making a determination of whether a building material is flood damage resistant.

X1.3 Commentary to Section 6, Test Specimens

X1.3.1 The term "building material" is inclusive of products and building construction materials of interest. The test method can be applied to evaluate a particular building material's response to the specified water immersion, drying, and surface cleaning procedures; response of the particular material as part of an assembly; and the response of the overall assembly. Test specimens that incorporate the building material of interest as part of a wall or floor/ceiling assembly representative of end use including incorporation of joints, fasteners, or other materials (for example, grouts, mastics, and adhesives) and construction features enable evaluation of the building material's response in conditions more representative of end-use than test specimens consisting solely of the building material of interest. Test specimen size will vary based on the building material being evaluated based on factors such as typical full-size in end use, applicable standards common to the building material for evaluation in end-use applications, and purpose of the testing which may include evaluation of the response of the building material with other building materials as part of an assembly.

X1.4 Commentary to Section 7, Water Immersion Requirements

X1.4.1 The baseline water is "filtered" potable tap water in accordance with the International Plumbing Code[5] because it is readily obtainable for testing and is judged suitable for subjecting materials to the effect of wetting and drying. The water should be filtered through a carbon filter capable of removing more than 95 % of chlorine and fluorides added during water treatment.

X1.4.1.1 *Sewage Surrogate*—A benign strain of E. coli serves as a surrogate for sewage- and soil-related microbes. Serial dilution tests measure the concentration of a target microbe in a sample with an estimate called the most probable number (MPN). The MPN is particularly useful for low concentrations of organisms (<100/g), especially in milk and water and those foods whose particulate matter may interfere with accurate colony counts. The MPN is the number that makes the observed outcome most probable. It is the solution for λ, concentration, in the following equation, which can be solved by iteration:[7]

$$\sum_{j=1}^{k} \frac{g_j m_j}{1 - \exp(-\lambda\, m_j)} = \sum_{j=1}^{k} t_j m_j \qquad \text{(X1.1)}$$

where:

- $\exp(x)$ = e^x,
- k = Number of dilutions,
- g_j = Number of positive (or growth) tubes in the jth dilution,
- m_j = Amount of the original sample put in each tube in the jth dilution, and
- t_j = Number of tubes in the jth dilution.

X1.4.1.2 *Mold Surrogates*—Penicillium brevicompactum, Aureobasidium pullulans, and Eurotium herbariorum mold species grow on water-damaged building materials and are readily cultured and distinctive from one another. The measure for mold surrogate concentration is a colony forming unit (cfu), which reflects the number of cells with the ability to multiply within the controlled sample.

X1.4.1.3 *Nutrients*—Potato dextrose extract is added at 1 g/liter (0.1 % w:v) to the water mixture in order to accelerate potential for mold and fungal growth by providing a reproducible nutrient source as a surrogate for organic material in floodwater.

X1.5 Commentary to Section 8, Procedure

X1.5.1 The immersion duration of 72 h is based on FEMA TB 2.

X1.5.2 The testing approach intends to immerse the test specimen in water to simulate the condition in which water inundates elements of the building structure (for example, water is on both the interior and exterior of the building structure). Water immersion of the test specimen reflects different exposures for test specimens depending on whether they are part of a wall assembly or a floor/ceiling assembly. Walls and other vertical assemblies are partly immersed (up to mid-height of the assembly), while floors and ceilings and other horizontal elements are fully immersed. For vertical assemblies, a 50 % immersion is expected to produce greater adverse effects (particularly for finish materials) as a result of differential thickness swell and effects of wicking.

X1.5.3 Supports for test specimens may consist of glass rods or other suitable material to keep the test specimen from directly contacting the base of the water bath container during water immersion or the floor during drying. Support materials should not adversely affect test specimen performance through staining, localized deformation, or damage of the test specimen caused by supporting test specimen weight or other causes.

X1.5.4 The support system should not artificially interfere with the connections between building materials in the test specimen. Floor and wall assembly test specimens may be supported from below. Ceiling assembly test specimens should be suspended in such a way that the supports do not artificially assist connections.

X1.5.5 Drying temperature and RH are intended to facilitate drying in ambient laboratory conditions; however, drying in a controlled environmental chamber may be preferred to ensure the required drying exposure is maintained throughout the duration of the test. To achieve drying, test specimens may be removed from water tanks or tanks may be drained and test

[7] *Laboratory Methods Bacteriological Analytical Manual*, Appendix 2, Most Probable Number from Serial Dilutions, U.S. Food and Drug Administration, October 2010.

specimens allowed to dry in emptied tanks. When test specimens are removed from tanks for weighing, handling should not cause draining of the test specimen that would not otherwise occur if removal from water immersion was based on draining of tanks with the test specimen left in place.

X1.5.6 The expectation of cleaning following flood exposure is a primary consideration under FEMA TB 2. The ability to be cleaned includes consideration of ability to remove any mold growth and the sewage surrogate on visible surfaces of test specimens without adversely affecting appearance and function of the specimen. The method of cleaning specified relies on use of generally available cleaning materials. It is not the intent of this test method to supersede restoration practices identified in IICRC S500. For example, a building material that is otherwise considered to be a flood damage resistant material per FEMA TB 2 and the requirements of this test method may need to be removed and replaced due to contamination, or the drying process may need to be expedited. The removal of wall sheathing products may be recommended during restoration to facilitate drying, gain access to wall cavities to clean contaminated materials, or to inspect covered materials.

X1.6 Commentary to Section 9, Report

X1.6.1 In addition to test specimen description, the intended requirements for reporting include observations of the appearance of visible surfaces, initial equilibrium weight, change in weight because of water absorption, time to reach equilibrium weight following removal from water immersion, final equilibrium weight, and any other effects considered useful for a better understanding of the test results, conclusions, or recommendations. These include, but are not limited to, staining that cannot be cleaned, differential thickness swell, or other differences in appearance prior to water immersion and after drying and cleaning. Photographs of specimen before water immersion and after drying and cleaning should be provided in accordance with Section 9.