



Designation: E2099 – 23

Standard Practice for Specification and Evaluation of Pre-Construction Laboratory Mockups of Exterior Wall Systems¹

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1. Scope*

1.1 This standard practice covers procedures and documentation to assist in the specification and evaluation of pre-construction laboratory mockups of exterior wall systems.

1.2 This standard practice addresses design and construction of the mockup, observation during mockup construction and testing, evaluation of the mockup test results, and documentation of the mockup and testing process. Coordination is required between the parties involved in the design, construction, and testing of the mockup to facilitate this process. Documentation should convey the results of pre-construction mockups from one party to others at appropriate stages in the process.

1.3 This standard practice recommends the selection and order of individual tests performed on the mockup in the absence of a specific test order.

1.4 This standard practice recommends a protocol for exchange of information between participants in the pre-construction mockup process.

1.5 Responsibility for specific activities is recommended by this practice. This practice is intended to provide a default structure in the absence of the assignment of specific responsibilities by the specifying authority.

1.6 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.

1.7 *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.*

¹ This practice is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.55 on Performance of Building Enclosures.

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2. Referenced Documents

2.1 ASTM Standards:²

E283 Test Method for Determining Rate of Air Leakage Through Exterior Windows, Skylights, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen

E330/E330M Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference

E331 Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference

E547 Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference

E631 Terminology of Building Constructions

E1233/E1233M Test Method for Structural Performance of Exterior Windows, Doors, Skylights, and Curtain Walls by Cyclic Air Pressure Differential

2.2 AAMA, Fenestration and Glazing Industry Alliance (FGIA) Standards:³

AAMA 501 Methods of Test for Exterior Walls

AAMA 501.1 Standard Test Method for Water Penetration of Windows, Curtain Walls and Doors Using Dynamic Pressure

AAMA 501.4 Recommended Static Test Method for Evaluating Curtain Wall and Storefront Systems Subjected to Seismic and Wind-Induced Inter-Story Drifts

AAMA 501.5 Test Method for Thermal Cycling of Exterior Walls

AAMA 501.7 Recommended Static Test Method for Evaluating Windows, Window Wall, Curtain Wall and Storefront Systems Subjected to Vertical Inter-Story Movements

AAMA 501.9 Surface Temperature Assessment for Condensation Evaluation of Exterior Wall Systems

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 the Fenestration and Glazing Industry Alliance (FGIA), 1900 E Golf Rd, Suite 1250 Schaumburg, IL 60173, <http://www.fgiaonline.org>.

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

AAMA CWM-19 Curtain Wall Manual
2.3 ASCE/SEI Standard:
ASCE/SEI 7 Minimum Design Loads and Associated Criteria for Buildings and Other Structures⁴
3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology E631, unless otherwise indicated.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *builder*—the builder of the mockup and the exterior wall system.

3.2.2 *elastic design displacement*—the lateral displacements, as provided by the building engineer of record, determined by elastic analysis or other suitable method, after which serviceability of the envelope is to be maintained. If unspecified, elastic design displacement for testing shall be as specified in Section 7.0 of AAMA 501.4.

3.2.3 *inelastic seismic design displacement, D_p* —the lateral displacements, as provided by the building engineer of record, determined by elastic analysis and amplified by Cd/Ie (ASCE/SEI 7) but not exceeding the allowable story drift, Δ_a (ASCE/SEI 7).⁴

3.2.3.1 *Discussion*—If using a performance-based design, the maximum inelastic drift may be larger than the allowable story drift.

3.2.4 *pre-construction mockup*—a full-size representation of the proposed exterior wall system built before the exterior wall design is completed in order to study proposed construction details, test for performance and possibly judge appearance of the exterior wall system.

3.2.5 *specifier*—the architect or professional design party responsible for the design of the exterior wall system.

3.2.6 *test agency*—the selected agency to conduct the required tests.

4. Significance and Use

4.1 Exterior wall systems require time to design, fabricate, construct and test. Mockups are generally a full-size representative portion of the proposed exterior wall system built to study proposed construction details, test for performance, and in some cases judge appearance of the exterior wall system. The project schedule shall allow time to design, construct, and test the pre-construction mockup and to implement any design changes, fabrication changes, or modifications of planned construction procedures, before construction of the exterior wall system commences.

4.2 Performance testing of pre-construction mockups verifies compliance with specified standards and design criteria. Performance tests in separate ASTM or other industry standards, are intended to represent the effects of environmental conditions, such as wind, rain, and temperature extremes. The tests provide a measure of the performance of the proposed exterior wall system under specific and controlled conditions.

⁴ Available from American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, Virginia, 20191-4382, <http://www.asce.org>

The specified design and specification of the pre-construction mockup must be appropriate for the performance test requirements. Separate tests may be required for individual mockup materials or components.

4.3 Pre-construction mockup specimens require input from Specifier, Builder, and Test Agency. Coordination of their efforts facilitates this process. Documentation should convey the results of preconstruction mockups from one party to others at appropriate stages in the process.

4.4 The referenced standards provided in this practice identify the historical standards typically utilized in pre-construction performance testing. This practice allows for the development and use of other project specific test procedures for various components that encompass exterior wall systems.

5. Design

5.1 The Specifier is responsible for the requirements of this section, unless stated otherwise.

5.2 Provide sufficient information on the design documents to describe the materials, details and performance testing requirements of the mockup.

5.3 Mockup Materials:

5.3.1 All framing and cladding elements of the exterior wall system in accurate full size, orientation, and configuration.

5.3.2 Color and finish of materials, if the appearance of the mockup is to be judged.

5.3.3 Joints between components.

5.3.4 Thermal insulation, if thermal testing is specified.

5.3.5 Structural support and attachment of the exterior wall system to the building frame.

NOTE 1—Tolerances between elements of the exterior wall system and the building support should be considered and tested in a “worst-case” condition in the mockup.

5.4 *Mockup Systems*—Elements of the exterior wall system that are designed to control:

5.4.1 Air infiltration.

5.4.2 Water penetration.

5.4.3 Wind pressure.

5.4.4 Movements of wall system due to thermal effects, volumetric changes or building frame movements.

5.4.5 Seismic movements, if the building is in a seismically active region.

5.5 *Mockup Size*—The mockup shall be of sufficient size to represent the following typical elements of the exterior wall system including interior and exterior corners where appropriate. Refer to Section 8 of Test Methods E283, E330/E330M, and E331 for requirements of the test specimens.

NOTE 2—Confirm the maximum size mockup that the Test Agency can accommodate. In some projects, multiple mockups may be necessary to test all desired conditions of the project.

5.5.1 *Height*—Minimum one typical floor height plus an additional height so that typical horizontal conditions are represented. For exterior wall systems that have multi-floor structural elements or water control systems that occur on

alternate floors, the mockup shall include the height of the minimum number of floors to represent one repetition of the exterior wall design.

NOTE 3—Typical details that occur adjacent to floor level, such as horizontal gutters and anchorage to the building, should not be located immediately adjacent to the mockup edge, since this creates a “non-job” condition that can lead to misinterpretation of mockup test results.

5.5.2 Width—Minimum two repetitive widths of the exterior wall system plus an additional width so that typical vertical conditions are represented. Other conditions, such as corners, end conditions and projecting bays shall be included, if practical.

5.6 Mockup Details—Provide the following details in mockup design drawings:

5.6.1 Illustrate the elevation view of the mockup in one of the two following ways:

5.6.1.1 Designate an area of the elevation drawings which represents the materials, height and width of the mockup.

5.6.1.2 Provide a separate mockup elevation drawing that represents the materials, height and width of the mockup. The mockup need not be an actual representation of one area of the exterior wall system, but instead can combine the parts of the exterior wall system in a manner that represents typical conditions.

5.6.2 Illustrate the mockup in section and detail views sufficient to describe the details of the mockup construction.

5.7 Mockup Testing Requirements—Specify the following testing requirements:

5.7.1 Test Load—Designate test loads for the mockup based on design wind pressures that are consistent with the corresponding area of the actual building.

NOTE 4—Mockup design wind pressures are the typical highest wind pressures for the building although not necessarily the highest “hot spot” wind pressures. Since the longest spans or largest units may not occur in the highest wind pressure zone, the specifier should exercise judgment in coordinating test specimen size with test loads to arrive at a test plan representative of the project as a whole. Refer to the requirements of Test Method **E330/E330M** for specific direction on appropriate wind loads and load factors.

5.7.2 Tests—List the ASTM standard, other standard tests, or custom test that are to be performed on the mockup. For each test listed, identify the test procedure, test parameters, and pass/fail criteria, by reference to published standards or by providing detailed descriptions. Provide the following information for each of the following test standards:

5.7.2.1 Test Method E330/E330M:

(1) The positive and negative test loads, the duration of maximum load and the number and location of deflection measurements, as required in Section 10 of Test Method **E330/E330M**. If the number and location of deflection measurements is not specified, the Test Agency shall recommend the number and location of deflection measurements.

(2) Maximum deflection criteria for critical elements of the mockup expressed as a dimensional unit or as a ratio of length of span. Deflection criteria expressed as a ratio of length of span should be calculated by the Test Agency in accordance with accepted practice.

5.7.2.2 Test Method E283—The test pressure difference and direction of air flow, unless the default requirements are acceptable, and the allowable air leakage rate, as required in Section 10 of **E283**.

5.7.2.3 Test Method E331—The test pressure difference and failure criteria for Test Method **E331**, unless the default requirements of Section 10 of **E331** are acceptable.

NOTE 5—Selection of test-pressure differences is subject to the Specifier’s judgement. Values of 20 % of maximum positive wind pressures in a range between about 5.2 lbf/ft² (0.25 kPa) to 15.0 lbf/ft² (0.70 kPa) are commonly used. (See AAMA 501.)

5.7.2.4 AAMA 501.1—The peak test pressure developed by the wind generator shall be equivalent to the test pressure stipulated for Test Method **E331** (**5.7.2.3**), unless specified otherwise.

5.7.2.5 Test Methods E547 and E1233/E1233M in lieu of Test Methods **E331** and **E330/E330M**, respectively, can be selected if appropriate to the requirements of the exterior wall system.

5.7.2.6 AAMA 501.4—If required to perform optional AAMA 501.4 tests, the elastic and inelastic design displacement, unless the default requirements (Section 7.2.5 and 7.4 respectively of AAMA 501.4) are acceptable.

NOTE 6—Specifier should evaluate the potential that the elastic displacement may be significantly less than the in-elastic displacement and may choose to increase the displacement to a level higher than the elastic level to verify that the window performs appropriately in the elastic range.

NOTE 7—Specifier should evaluate whether the code authority having jurisdiction may require the use of inelastic story drift (Δ) or seismic relative displacement (D_{pl}) for evaluating compliance with design requirements. An additional 1.25 factor may also be required if glass fallout ($\Delta_{fallout}$) is determined by detail engineering analysis.

5.7.2.7 AAMA 501.5—The high temperature (exterior ambient air) low temperature (ambient air) and indoor side compartment temperature, unless the default requirements (Section 8.4 of AAMA 501.5) are acceptable.

NOTE 8—Thermal insulation is often installed in the mockup immediately prior to performing thermal testing and removed after this test. The thermal insulation inhibits observation of test results in other tests.

5.7.2.8 AAMA 501.9—Recording of interior surface temperatures in accordance with AAMA 501.9 shall be specified if dew point calculations are required.

5.7.3 Order of Tests—List the order that the tests are to be performed. If no order is specified, the following test order, exclusive of the optional tests, shall be used by the Test Agency:

NOTE 9—Repeat tests are frequently specified to verify performance after a particular test, such as a structural performance or thermal cycling test that imposes movements on the mockup.

5.7.3.1 Prior to testing, unlock, fully open, close and lock operable windows, doors or other operable portions of the mockup for a minimum of 5 cycles. If repairs or adjustments are necessary repeat cycling after repairs or adjustments. Report the repairs or adjustments made prior to testing.

5.7.3.2 Test 1—Test Method **E330/E330M** at 50 % of the specified positive test load.

5.7.3.3 Test 2—Test Method **E283**.

5.7.3.4 Test 3—Test Method **E331**.