Designation: E 2099 – 00

Standard Practice for the Specification and Evaluation of Pre-Construction Laboratory Mockups of Exterior Wall Systems[1]

This standard is issued under the fixed designation E 2099; 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 standard practice describes 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 standard. This practice is intended to provide a default structure in the absence of the assignment of specific responsibilities by the specifying authority.

2. Referenced Documents

2.1 *ASTM Standards:*

E 283 Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen[2]

E 330 Test Method for Structural Performance of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference[2]

E 331 Test Method for Water Penetration of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference[2]

E 547 Test Method for Water Penetration of Exterior Windows, Curtain Walls and Doors by Cyclic Static Air Pressure Difference[2]

E 631 Terminology of Building Constructions[2]

E 1233 Test Method for Structural Performance of Exterior Windows, Curtain Walls, and Doors by Cyclic Static Air Pressure Differential[2]

2.2 *AAMA Standards:*

AAMA 501, Methods of Test for Exterior Walls[3]

AAMA 501.1, Standard Test Method for Exterior Windows, Curtain Walls and Doors for Water Penetration using Dynamic Pressure[3]

AAMA 501.4, Recommended Static Test Method for Evaluating Curtain Wall and Storefront Systems Subjected to Seismic and Wind Induced Interstory Drifts[3]

AAMA 501.5, Test Method for Thermal Cycling of Exterior Walls[3]

AAMA CW-DG-1, Testing of Aluminum Curtain Walls, *Curtain Wall Design Guide Manual*[3]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology E 631, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *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.

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

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

3.2.4 *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 a fullsize representative portion of the proposed exterior wall system built to study proposed construction details, test for performance and may be

[1] This test method is under the jurisdiction of ASTM Committee E-06 on Building Constructions and is the direct responsibility of Subcommittee E06.55 on Exterior Building Wall Systems.

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[2] *Annual Book of ASTM Standards*, Vol 04.11.

[3] Available from American Architectural Manufacturers Association, Schaumburg, IL.

used to 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 verities 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. 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 wail 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 comers where appropriate. Refer to Section 8 of E 283, E 330 and E 331 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.

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 *ASTM E 330*:

5.7.2.1.1 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 ASTM E 330. If the number and location of deflection measurements is not specified, the Test Agency shall recommend the number and location of deflection measurements.

5.7.2.1.2 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 *ASTM E 283*—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 E 283.

5.7.2.3 *ASTM E 331*—The test pressure difference and failure criteria for ASTM E 331, unless the default requirements of Section 10 of E 331 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 0.25 kPa (5.2 lbf./ft^2) to 0.70 kPa (15.0 lbf./ft^2) 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 ASTM E 331 (5.7.2.3), unless specified otherwise.

5.7.2.5 ASTM tests E 547 and E 1233 in lieu of ASTM E 331 and E 330, respectively, can be selected if appropriate to the requirements of the exterior wall system.

5.7.2.6 AAMA 501.4: The design displacement, unless the default requirements (Section 7.2.5 of AAMA 501.4) are acceptable.

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. Recording of interior surface temperatures (Section 5.6 of AAMA 501.5) shall be specified if dew point calculations are required.

NOTE 6—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.

5.7.3 *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 7—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 - ASTM E 330 at 50% of the specified positive test load

5.7.3.3 Test 2 - ASTM E 283

5.7.3.4 Test 3 - ASTM E 331

5.7.3.5 Optional Test 4 - AAMA 501.1

5.7.3.6 Optional Test 5 - AAMA 501.4 at 100% of the specified lateral displacement

5.7.3.7 Optional Test 6 - AAMA 501.5

5.7.3.8 Should Optional Test 5 or 6 be selected, add Test 7 - ASTM E 283 and Test 8 - ASTM E 331

5.7.3.9 Test 9 - ASTM E 330 at 100% of the specified positive and negative test load

5.7.3.10 Test 10 - ASTM E 331

5.7.3.11 Test 11 - ASTM E 330 at 150% of the specified positive and negative test load

5.7.3.12 Optional Test 12 - AAMA 501.4 at 150% of the specified lateral displacement

6. Construction

6.1 The Builder is responsible for the requirements of this section, unless stated otherwise.

6.2 Prepare shop drawings to describe all details of the mockup. Mockup shop drawings shall be reviewed and approved by the Specifier and Testing Agency prior to fabricating and constructing the mockup. When the mockup consists of multiple elements, such as windows set into an opaque wall system, then each element shall have shop drawings prepared that fully describe the element and its interface with the adjoining element.

NOTE 8—It is often necessary to allow time to repeat the mockup shop drawing review, in case the initial submittal is not acceptable to the Specifier. The effort taken in resolving issues on the mockup shop drawings will usually simplify review of project shop drawings.

6.3 Construct the mockup in accordance with the approved mockup shop drawings and design documents. Use the same supervisory personnel that will be responsible for the erection of the exterior wall system for the project so that they understand its design and construction. Build the mockup specimen at the Test Agency's laboratory, unless another location has been specified.

6.4 Coordinate with the Specifier and Test Agency when the mockup will be constructed, to allow independent observations of the mockup construction.

6.5 At any time during the construction and testing of the mockup if modifications are made to the mockup, notify the Specifier and Test Agency of the nature of these changes. Maintain a record of all changes and when they were performed during the mockup process.

6.6 Attend the mockup testing. Make any necessary repairs or modifications to the mockup as agreed to by the parties during the testing process.

7. Testing

7.1 The Test Agency is responsible for the requirements of this section, unless stated otherwise.

7.2 The Test Agency shall be independent of the Specifier and the Builder, unless stipulated otherwise.

7.3 Review the specified mockup and test program and notify the Specifier if laboratory equipment or space is not adequate to perform the specified testing.

7.4 Provide the Builder with information during shop drawing preparation as described in 6.2 in regards to the laboratory test frame to accommodate the prescribed test criteria and how the mockup should be connected to the test frame.

7.5 Provide the Specifier for review with a written proposed test program and procedure that confirms the specified requirements. Where requirements are not specified, stipulate the default requirements.

NOTE 9—The Specifier should recognize that changing specified or default requirements can impact the cost and time-frame of the exterior wall system.

7.6 Coordinate with the Specifier and Builder when the mockup will be tested, to allow independent observations of the mockup testing. If Specifier provides notification of intent to observe, do not proceed with testing without Specifier or his approved representative in attendance.

7.7 Conduct the specified tests in accordance with the requirements of the specified test methods and the specified order of tests. If during the testing it is apparent that changes are necessary to the test program, notify the Specifier and Builder's observers on-site for their approval before proceeding. If either the Specifier or the Builder does not have an observer on-site, the Test Agency can proceed with necessary modifications. Any modification should be reported in final documentation.

7.8 In the event that water leakage is encountered during the water testing directly after either a structural or displacement test, the mockup shall be repaired and subjected to the same structural or displacement test prior to the retest for water leakage. No additional deflection readings need to be taken during the repeat of the structural or displacement testing, unless structural changes have been performed on the mockup.

8. Documentation

8.1 The Test Agency shall provide a written report that satisfies the reporting requirements of the specified tests except for detailed drawing requirements, unless stipulated otherwise. The report shall state whether the specimen passed or failed each test. The report shall provide all recorded data. Location of recorded measurement shall be shown on the record shop drawings.

8.2 All test results shall be submitted simultaneously to the Specifier and Builder, including preliminary reports.

8.3 The Builder shall provide shop drawings that record all modifications made during the mockup process for approval by the Specifier. These shop drawings shall fulfill the detail drawing requirements of Section 13.1.3 of ASTM E 283, Section 12.1.3 of ASTM E 330 and Section 12.1.3 of ASTM E 331. All changes shall be clearly noted by means of bubbling or other appropriate drawing technique. These drawings shall be provided to the Test Agency for incorporation or reference with their report.

8.4 The Specifier shall judge the appearance of the mockup, if color and finish were specified (see 5.3.2). The appearance should be judged either acceptable or not acceptable. If judged not acceptable, the Specifier shall state in writing what changes are necessary to create acceptable appearance.

8.5 The Builder shall review submitted reports and shall certify that modifications noted in the reports will be incorporated on the exterior wall system.

9. Keywords

9.1 buildings; exterior wall systems; laboratory; pre-construction