Designation: E1233/E1233M – 14

Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights, and Curtain Walls by Cyclic Air Pressure Differential[1]

This standard is issued under the fixed designation E1233/E1233M; 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 describes the determination of the structural performance of exterior windows, doors, skylights, and curtain walls under cyclic air pressure differential, using a test chamber. This test method is applicable to all curtain wall assemblies, including, but not limited to, metal, glass, masonry, and stone components.[2]

1.2 This test method is intended only for evaluating the structural performance associated with the specified test specimen, and not the structural performance of adjacent construction.

1.3 Procedure A shall be used for life cycle test loads.

1.4 Procedure B shall be used for wind event test loads.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.6 *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. Specific hazard statements are given in Section 7.*

1.7 *The text of this test method references notes and footnotes that provide explanatory materials. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

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

E631 Terminology of Building Constructions

E997 Test Method for Evaluating Glass Breakage Probability Under the Influence of Uniform Static Loads by Proof Load Testing

E998 Test Method for Structural Performance of Glass in Windows, Curtain Walls, and Doors Under the Influence of Uniform Static Loads by Nondestructive Method

E1300 Practice for Determining Load Resistance of Glass in Buildings

E1886 Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials

E1996 Specification for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Windborne Debris in Hurricanes

2.2 *ASCE/SEI Standard:*[4]

ASCE/SEI 7 Minimum Design Loads for Buildings and Other Structures

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 *design wind load, n*—the uniform static air pressure differences, inward and outward, for which the specimen would be designed under service load conditions using conventional wind engineering specifications and concepts, expressed in pascals [or pounds-force per square foot]. This

[1] This test method is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.51 on Performance of Windows, Doors, Skylights and Curtain Walls.

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[2] Additional information on curtain wall assemblies can be obtained from the American Architectural Manufacturers Association (AAMA), 1827 Walden Office Square, Suite 550, Schaumburg, IL 60173-4268, http://www.aamanet.org.

[3] 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.

[4] Available from American Society of Civil Engineers (ASCE), 1801 Alexander Bell Dr., Reston, VA 20191, http://www.asce.org.

pressure is determined by either analytical or wind-tunnel procedures (such as are specified in ASCE/SEI 7).

3.2.2 *one cycle, n*—beginning at a specified air pressure differential, the application of positive (negative) pressure to achieve another specified air pressure differential and returning to the initial specified air pressure differential.

3.2.3 *permanent deformation, n*—displacement or change in dimension of the specimen after the applied load has been removed and the specimen has relaxed for the specified period of time.

3.2.4 *positive (negative) cyclic test load, n*—the specified differential in static air pressure, creating an inward (outward) loading, for which the specimen is to be tested under repeated conditions, expressed in pascals [or pounds-force per square foot].

3.2.5 *positive (negative) maximum test load, n*—the specified differential in static air pressure, creating an inward (outward) load, for which the specimen is to be tested for required minimum ultimate strength, expressed in pascals [or pounds-force per square foot].

3.2.6 *stick system, n*—a curtain wall assembly composed of individually framed continuous members, vertical mullions, and horizontal rails that are installed in a sequential, piece-by-piece process. The completed system is assembled entirely in the field.

3.2.7 *structural distress, n*—a change in condition of the specimen indicative of deterioration under repeated load or incipient failure, such as cracking, fastener loosening, local yielding, or loss of adhesive bond.

3.2.8 *test specimen, n*—the entire assembled unit submitted for test (as described in Section 8).

3.2.9 *unit/panel system, n*—a curtain wall assembly composed of pre-assembled groups of individual framing members. The completed system is designed to be modular, transportable, and installed as a finished assembly.

4. Summary of Test Method

4.1 This test method consists of sealing the test specimen into or against one face of a test chamber, supplying air to or exhausting air from the chamber in accordance with a specific test loading program at the rate required to maintain the test pressure differential across the specimen, and observing, measuring, and recording the deflection, deformations, and nature of any structural distress or failures of the specimen.

4.2 The test loading program calls for the application of a specified spectrum of pressure cycles followed by the application of positive and then negative maximum test loads. The specifier must provide the information required in Section 10.

5. Significance and Use

5.1 This test method is a standard procedure for determining structural performance under cyclic air pressure differential. This typically is intended to represent the long-term effects of repeated applications of wind load on exterior building surface elements or those loads that may be experienced during a hurricane or other extreme wind event. This test method is intended to be used for installations of window, curtain wall, and door assemblies for which the effects of cyclic or repeated loads may be significant factors in the in-service structural performance of the system and for which such effects cannot be determined by testing under a single application of uniform static air pressure. This test method is not intended to account for the effect of windborne debris. This test method is considered appropriate for testing unique constructions or for testing systems that have insufficient in-service records to establish their performance under cyclic loading.

5.1.1 The actual loading on building surfaces is quite complex, varying with wind direction, time, height above ground, building shape, terrain, surrounding structures, and other factors. The resistance of many window, curtain wall, and door assemblies to wind loading is also complex and depends on the complete history of load magnitude, duration, and repetition. These factors are discussed in ASCE/SEI 7 and in the literature **(1-12)**[5].

5.2 This test method is not intended for use in evaluating the adequacy of glass for a particular application. When the structural performance of glass is to be evaluated, the procedure described in Standard Test Method E997 or E998 shall be used.

5.3 The proper use of this test method requires knowledge of the principles of pressure and deflection measurement.

5.4 Two types of cyclic air pressure differentials are defined: (Procedure A) Life cycle load (X1.1) and (Procedure B) Wind event load (X1.2). When testing under uniform static air pressure to establish structural performance, including performance under proof load, Standard Test Method E330/E330M applies. Consideration of windborne debris in combination with cyclic air pressure differential representing extreme wind events is addressed in Standard Test Method E1886 and Standard Specification E1996.

5.5 Typical practice in the United States for the design and testing of exterior windows, curtain walls, and doors has been to consider only a one-time application of design wind load, increased by an appropriate factor of safety. This design wind load is based on wind velocities with actual average probabilities of occurrence of once in the design life of the structure. The actual in-field performance of such assemblies, however, is dependent on many complex factors, and there exists significant classes of applications where the effects of repeated or cyclic wind loading will be the dominating factor in the actual structural performance, even though the magnitudes of such cyclic loads may be substantially lower than the peak load to which the assembly will be subjected during its design life. Examples of assemblies for which the effects of cyclic loading may be significant are included in Appendix X2.

5.5.1 When cyclic load effects are significant, the actual in-field performance of the assembly will depend on the complete load history to which the assembly is subjected. The history includes variable sustained loads as well as gusts, which occur at varying frequencies and durations. Such load

[5] The boldface numbers in parentheses refers to the list of references at the end of this test method.

histories are not deterministic, requiring the specifier to resort to a probabilistic approach for test parameters. The resistance of an assembly to cyclic loading is similarly complex. When available, endurance curves (stress/number *(S/N)* curves) can be used to estimate the fatigue resistance of a particular material. A major uncertainty in applying these data, however, is that the stress in an element induced by a unit pressure load is usually not known *a priori*. The problem is further complicated by the fact that the load to which the in situ assembly is subjected is not a repetitive load of given magnitude but one that varies in frequency, duration, and magnitude such as loads associated with a wind event.

5.5.2 To establish practical test parameters, the considerations in 5.1 – 5.5.1 must be modeled by a simple loading program that approximates the actual loading with respect to its damage potential. For the case of life cycle loads, the anticipated actual loading may include critical pressures that will occur with greater frequency during the design life of the structure than is practical to use for testing. In such cases, the actual load magnitude and number of repetitions must be represented in the test by an equivalent load of larger magnitude and fewer repetitions. For the case of specific wind event loads, the entire test loading program may be developed from wind tunnel testing or by using methods defined in the literature.

5.5.3 In this test method, the test assembly is first subjected to pressure cycles. The assembly is expected to survive this loading without apparent structural distress. Following this, the assembly is subjected to positive and negative maximum test loads. The maximum test loads may represent sustained loads or gust loads, or both.

5.6 Design wind velocities may be selected for particular geographic locations and probabilities of occurrence based on data from wind velocity maps such as provided in ASCE/SEI 7.

5.7 The person specifying the test must translate the anticipated wind velocities and durations into static air pressure differences and durations. Complexities of wind pressures as related to building design, wind intensity versus duration, frequency of occurrence, and other factors must be considered. Superimposed on sustained winds are gusting winds which, for short periods of time, from fractions of seconds to a few seconds, may move at considerably higher velocities than the sustained winds. Wind tunnel studies, computer simulations, and model analyses are helpful in determining the appropriate wind pressures for buildings by showing how a particular building acts under wind velocities established by others. **(1-6)**[5].

5.8 Specification of a test program based on a comprehensive treatment of all of the above considerations is a complex task. The procedures presented in Appendix X1 may be used to establish test parameters when a comprehensive analysis of the problem is not possible. The procedures account for the expected magnitude variation and occurrence frequency in wind velocities; they are not intended to account for turbulent wind load or structural resonance effects **(2)**.

5.9 Some materials have strength or deflection characteristics that are time dependent. Therefore, the duration of the applied test load may have a significant impact on the performance of materials used in the test specimen. The most common examples of materials with time-dependent response characteristics that are used in curtain walls are glass, plastics, and composites that employ plastics. For this reason, the strength of an assembly is tested for the actual time duration to which it would be exposed to a sustained or a gust load, or both, as discussed below. For practical purposes, cyclic load effects are to be considered to be duration-dependent, and the cyclic test loads need be applied only long enough for the chamber pressure to stabilize. In the past, practice in the United States generally has been to require a minimum test period for maximum test loads of 10 s for specified loads equal to 1.5 times the design pressure, unless otherwise specified. Thus a safety factor was incorporated in the testing. If the design wind load is determined through the analytical procedures of ASCE/SEI 7, the test load shall be based on the nominal loads derived from the load combinations used in allowable stress design. With higher test loads and longer time durations, the designer must also consider what safety factors are essential, particularly with regard to gust wind loads. Gust wind loads are of relatively short duration, so that care shall be exercised not to specify or allow unnecessarily long duration loads for purposes of testing the adequacy of the structure to withstand wind gusts.

NOTE 1—In applying the results of tests by this test method, note that the performance of a wall or its components, or both, may be a function of fabrication, installation, and adjustment. The specimen may or may not truly represent every aspect of the actual structure. In service, the performance will also depend on the rigidity of the supporting construction and on the resistance of components to deterioration by various other causes, including vibration, thermal expansion, contraction, etc.

6. Apparatus

6.1 The description of the apparatus is general in nature. Any equipment capable of performing the test procedure within the allowable tolerances is permitted.

6.2 *Major Components (see* Fig. 1*):*

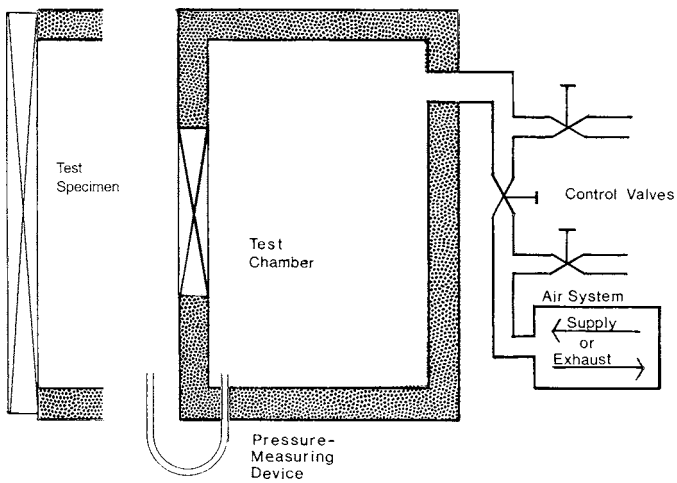

FIG. 1 General Arrangement of Testing Apparatus