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Standard Test Methods to Evaluate Seismic Performance of Suspended Ceiling Systems by Full-Scale Dynamic Testing [1]

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INTRODUCTION

The response of nonstructural components, such as suspended ceiling systems, can significantly affect the functionality of a building after an earthquake, even when the structural components are undamaged.

Traditional suspended ceiling systems, which consist of typical direct hung "T" shaped main runners and cross tees, are installed in accordance with the prescriptive requirements contained in Practice E580/E580M, the applicable sections of the International Building Code, and ASCE/SEI 7. Specification C635/C635M, Test ~~Method~~Methods E3090/E3090M, and Practice C636/C636M cover suspension systems and do not address seismic restraint of suspension systems or the performance of the ceiling panels. The performance of these traditional ceiling suspension systems is determined by mechanical testing of the connection's strengths and the load-carrying capability of the suspension members. Practice E580/E580M contains specific instructions concerning the placement of hanger wires, perimeter fastening, and seismic bracing.

There are nontraditional suspended ceiling systems that do not consist of the typical direct hung "T" members. Connection strengths of the structural suspension members are not directly related to the anticipated performance of the system under earthquake loads. In addition, the ceiling panels or tiles are not always supported on all four sides of the suspension members. The integrity of ceiling systems depends on the ability of the ceiling infill panels to remain in place during an earthquake and on the structural integrity of the suspension system. These test methods provide a means to evaluate the performance of traditional suspended ceilings, as well as many of these nontraditional type ceiling systems.

1. Scope

1.1 These test methods help evaluate the performance of a full-scale suspended ceiling system during a seismic event using a dynamic seismic simulator (shake table).

1.2 These full-scale procedures are not the only available procedures for evaluating the seismic performance of ceiling systems. These tests do not preclude the use of other small-scale or full-scale component or system testing.

1.3 These test methods contain two independent procedures.

[1] These test methods are under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.11 on Horizontal and Vertical Structures/Structural Performance of Completed Structures.

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1.3.1 Comparative method where the level of performance of an experimental system is compared to that of a control test system under the same set of conditions.

1.3.2 Non-comparative method where a single test is conducted to establish the level of performance of an experimental system.

1.4 These test procedures are valid and useful for all types of suspended ceiling systems.

1.5 The text of this standard uses notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.7 *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.*

1.8 *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]

C635/C635M Specification for Manufacture, Performance, and Testing of Metal Suspension Systems for Acoustical Tile and Lay-in Panel Ceilings

C636/C636M Practice for Installation of Metal Ceiling Suspension Systems for Acoustical Tile and Lay-In Panels

E580/E580M Practice for Installation of Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels in Areas Subject to Earthquake Ground Motions

E631 Terminology of Building Constructions

E3090/E3090M Test Methods for Strength Properties of Metal Ceiling Suspension Systems

2.2 *Other Standards:*

AC156 Seismic Certification by Shake-table Testing of Nonstructural Components[3]

ASCE/SEI 7 Minimum Design Loads and Associated Criteria for Buildings and Other Structures[4]

International Building Code[5] Chapter 16, Structural Requirements

3. Terminology

3.1 *Definitions*—For definitions related to building construction, see Terminology E631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *comparative testing, ~~n—~~v*—testing where the level of performance of an experimental system is compared to that of a control system under the same set of conditions.

3.2.2 *control ~~system—~~system, n*—an existing, code compliant, suspended ceiling system with an established level of performance.

3.2.2.1 *Discussion*—

A suspended ceiling system constructed using code compliant components and in accordance with code compliant installation requirements.

3.2.3 *experimental ~~system—~~system, n*—a suspended ceiling system with a level of performance that has not been established.

3.2.4 *grid component disengagement, n*—grid connection failure where main runner splice failure, tee-to-tee connection failure, and/or perimeter clip failure occurs.

3.2.5 *level of ~~performance—~~performance, n*—a boundary between acceptable and unacceptable performance of the system.

3.2.6 *non-comparative ~~testing—~~testing, v*—testing where a single test is conducted to establish the level of performance of an experimental system.

3.2.6.1 *Discussion*—

Non-comparative testing can be used as supporting data for a certificate of conformance.

3.2.7 *panel loss, n*—a panel disengaging from the ceiling plane and falling to the floor.

3.2.8 *required response spectrum ~~(RRS)—~~(RRS), n*—the required response spectrum generated using the formulas and normalized spectra detailed in AC156.

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[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 ICC Evaluation Service, LLC, 3060 Saturn Street, Suite 100, Brea, CA 92821, https://icc-es.org.

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

3.2.9 *test response spectrum ~~(TRS)~~ (TRS), n*—the acceleration response spectrum that is developed from the actual time history of the motion of the seismic simulator test as measured by reference control accelerometers mounted on the shake table at a location near the base of the test frame.

3.2.10 *uniformly distributed weight, ~~Wp~~ Wp, n*—the weight of the ceiling system, including the ceiling grid; ceiling panels; light fixtures; heating, ventilation, and air conditioning (HVAC) fixtures and ductwork; sprinklers; and piping; etc., or various combinations of these components that are supported by the test frame.

3.2.11 *white ~~noise~~ noise, n*—a broadband random motion used to establish the natural frequency and damping ratio of the ceiling test frame and the attached ceiling system.

3.2.11.1 *Discussion*—

White noise is one test of resonant frequency search. It is also permitted to use the sine sweep tests, or equivalent, to the resonance tests.

4. Summary of Test Methods

4.1 *Procedure A – Comparative Test Method*—This method shall be used to compare the performance of a proposed experimental system to that of a control system of similar, uniformly distributed weight. The experimental system shall include all components of the ceiling system being evaluated. The experimental system is attached to a test frame, which is then attached to the seismic simulator, which transmits the motion of the simulator to the ceiling system. To be acceptable, the experimental system shall demonstrate equal to or superior performance to the control system when subjected to the same test protocol.

4.2 *Procedure B – Non-comparative Test Method*—This method utilizes a single assembly to establish the level of performance of a ceiling system. The experimental system shall include all components of the ceiling system being evaluated. The ceiling suspension system is attached to a test frame, which is then attached to the seismic simulator, which transmits the motion of the simulator to the ceiling system.

5. Significance and Use

5.1 The test protocol evaluates those complex suspended ceiling systems that cannot be assessed by simple engineering calculations contained in ASCE/SEI 7 and Practice E580/E580M. It is not intended to replace the requirements in ASCE/SEI 7. Suspended ceiling systems are considered nonstructural components of buildings.

6. Seismic Simulator (Shake Table)

6.1 All seismic simulators used for these evaluations shall be tri-axial.

6.2 Each system shall be tested in accordance with the Seismic Certification Test Procedure as prescribed in AC156. For ceiling systems, $z/h_{Vertical} = 0$ and $z/h_{Horizontal} = 1$.

6.3 The test frame for the ceiling system shall have a minimum area of 256 ft^2 [24 m^2] with the aspect ratio of the length to the width no greater than 4:1. The frame shall also be of sufficient size to adequately subject all lateral force resisting mechanisms to the simulator movements.

PROCEDURE A

7. Comparative Test Method

7.1 Construct a control system on the shake table to act as a test for the comparison. The control system shall be installed in accordance with Section 13.5.6 of ASCE/SEI 7.

NOTE 1—It is permissible that this control system has been previously tested and documented.

7.2 Load the control system to the desired uniformly distributed weight.

7.3 Conduct a pre-test inspection to verify that all components are properly installed as near as possible to actual construction practices prior to any testing.

7.4 Conduct axis resonant frequency search tests using a ~~low level~~ low-level amplitude single-axis sinusoidal sweep along each orthogonal axis of the simulation platform. A low-level white noise excitation, or equivalent, along each orthogonal axis of the simulation platform is also permitted. The resonance tests shall be used to establish the natural frequency and damping ratio of the ceiling test frame and the attached ceiling system.

7.5 S_{DS} is a derived value from S_S.S_{DS}=⅔ $F_a S_S$ where F_a is the site coefficient for ASCE/SEI 7. Either S_S or S_{DS} are permitted to be used in these test methods. All acceleration increments shall be adjusted accordingly. The values of S_S or S_{DS} are to be regarded separately as standard. Each value is to be used independently of the other, and the chosen value shall be used uniformly throughout the entire standard.

7.6 Estimate the level of performance of the control system in accordance with Section 9 and start testing at a lower level of acceleration (S_s or S_{DS}). Subject the system to the determined horizontal and vertical motions matched to a specific ~~test response spectrum (TRS).~~ TRS. After establishing a passing level by test, increase acceleration at a minimum of 0.25 g increments or more until failure occurs or the maximum capacity of the seismic simulator has been reached. The system shall be inspected after each increment and its condition recorded. The failure criteria in 9.2 shall be used to assess the ceiling performance.

~~NOTE 2—S_{DS} is a derived value and is also permitted to be used. All acceleration increments shall be adjusted accordingly. S_{DS} = 2/3 $F_a S_S$ where F_a is the site coefficient for ASCE/SEI 7.~~

7.7 Conduct a post-test inspection of the ceiling systems after each acceleration increment. This is to verify that components have not been damaged during shaking and that the system is still functional. The failure criteria in 9.2 shall be used to assess the ceiling performance.

7.8 Conduct minor or simple repairs to the system and repeat the failed level before moving to a higher level. Any system modifications or repairs shall be detailed in the report section. Acceptable repairs include reseating of ceiling panels, reseating of grid members on perimeter molding, or replacement of an accessory clip. Perimeter clips are not considered accessory clips and are not to be repaired during a test. Replacement of grid components is not permitted.

7.9 Construct an experimental system to be tested as comparison to the control system.

7.10 Load the experimental system to the same uniformly distributed weight as the control system within ±5 %.

7.11 Repeat the steps in 7.4 through ~~7.8~~7.9. The experimental system shall be subjected to the same protocol and levels of accelerations as the control system.

7.12 The experimental system shall demonstrate the same or higher level of performance at the same acceleration levels as the control system to be considered as an equal.

PROCEDURE B

8. Non-comparative Test Method

8.1 Construct a suspended ceiling system to be tested. The ceiling shall be loaded to the desired uniformly distributed loading. The actual weight used shall be clearly stated and included in the report as defined in Section 10.

8.2 Conduct a pre-test inspection to verify that all components are properly installed as near as possible to actual construction practices prior to any testing.

8.3 Subject the ceiling system to axis resonant frequency search tests using a ~~low level~~ low-level amplitude single-axis sinusoidal sweep along each orthogonal axis of the simulation platform. A ~~low level~~ low-level white noise excitation, or equivalent, along