



ACCEPTANCE CRITERIA FOR DYNAMIC SEISMIC RETROFIT SYSTEMS FOR MASONRY STRUCTURES

AC205

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PREFACE

Evaluation reports issued by ICC Evaluation Service, Inc. (ICC-ES), are based upon performance features of the International family of codes and other widely adopted code families, including the Uniform Codes, the BOCA National Codes, and the SBCCI Standard Codes. Section 104.11 of the *International Building Code*® reads as follows:

The provisions of this code are not intended to prevent the installation of any materials or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

Similar provisions are contained in the Uniform Codes, the National Codes, and the Standard Codes.

This acceptance criteria has been issued to provide all interested parties with guidelines for demonstrating compliance with performance features of the applicable code(s) referenced in the acceptance criteria. The criteria was developed and adopted following public hearings conducted by the ICC-ES Evaluation Committee, and is effective on the date shown above. All reports issued or reissued on or after the effective date must comply with this criteria, while reports issued prior to this date may be in compliance with this criteria or with the previous edition. If the criteria is an updated version from the previous edition, a solid vertical line (|) in the margin within the criteria indicates a technical change, addition, or deletion from the previous edition. A deletion indicator (→) is provided in the margin where a paragraph has been deleted if the deletion involved a technical change. This criteria may be further revised as the need dictates.

ICC-ES may consider alternate criteria, provided the report applicant submits valid data demonstrating that the alternate criteria are at least equivalent to the criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. Notwithstanding that a product, material, or type or method of construction meets the requirements of the criteria set forth in this document, or that it can be demonstrated that valid alternate criteria are equivalent to the criteria in this document and otherwise demonstrate compliance with the performance features of the codes, ICC-ES retains the right to refuse to issue or renew an evaluation report, if the product, material, or type or method of construction is such that either unusual care with its installation or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause unreasonable property damage or personal injury or sickness relative to the benefits to be achieved by the use of the product, material, or type or method of construction.

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1.0 INTRODUCTION

1.1 Purpose: The purpose of this acceptance criteria is to establish requirements for recognition of seismic retrofit systems for masonry structures (SRS-MS) to be recognized in an ICC Evaluation Service, Inc. (ICC-ES), evaluation report under the 2003 *International Building Code*[®] (IBC) and the 1997 *Uniform Building Code*[™] (UBC). Bases of recognition are IBC Section 104.11 and UBC Section 104.2.8.

1.2 Scope: The objective of this acceptance criteria is to establish the strength, stiffness, damping, ductility, energy dissipation, and structural stabilization capacities of an SRS-MS for use in Seismic Zones 3 and 4 as defined in the UBC, and Seismic Design Categories D, E, and F as defined in the IBC.

This criteria applies to seismic retrofit systems within reinforced or unreinforced masonry structures. The design and construction of the seismic retrofit systems shall comply with Chapters 16 and 21 of the UBC or IBC.

1.3 Codes and Referenced Standards:

1.3.1 2003 *International Building Code*[®], International Code Council.

1.3.2 2003 *International Existing Building Code*[®] (IEBC), International Code Council.

1.3.3 1997 *Uniform Building Code*[™].

1.3.4 Specification for Masonry Structures (ACI 530.1-02/ASCE 6-02/TMS 602-02), American Concrete Institute.

1.4 Definitions:

1.4.1 Qualified: For purposes of this acceptance criteria, "qualified" shall mean qualified by the manufacturer and registered design professional and approved by the building official.

1.4.2 Registered Design Professional: An individual who is registered or licensed to practice their respective design profession as defined by the statutory requirements of the professional registration laws of the state or jurisdiction in which the project is to be constructed.

1.5 System Description: The seismic retrofit systems shall consist of corrosion-resistant metal, in-wall connectors and post-tensioning rods used at the interface between floor or roof diaphragms and masonry walls to dissipate, moderate, and redirect energy from seismic events in a predictable fashion within masonry structures.

The system uses double-cone connectors placed through vertical post-tension rods. The connectors allow the floor and roof diaphragms to displace in a controlled manner with respect to the walls during an earthquake event. The relative motion in the conical connectors transmits seismic energy into the vertical post-tension rods. The combination of the vertical motion of the wall mass and the elongation of the post-tension rods redirects a portion of the seismic energy and thereby reduces the lateral deformation of the building. System response can be controlled by varying the angle within the connector coupled with rod tensions specified by computer modeling.

2.0 BASIC INFORMATION

2.1 General: The following information shall be submitted to ICC-ES.

2.1.1 Description: Complete information concerning all components, including material specifications, thickness, size and the manufacturing process. This description shall also include connection methods and dimensions.

2.1.2 Installation Instructions: Installation details and drawings, noting installation requirements and/or limitations.

2.1.3 Packaging and Identification: Description of the method of packaging and identifying the system components. Product labeling shall include the ICC-ES evaluation report number.

2.2 Testing Laboratories, Reports of Tests and Product Sampling:

2.2.1 Testing Laboratories: Testing laboratories shall comply with Section 2.0 of the ICC-ES Acceptance Criteria for Test Reports (AC85) and Section 4.2 of the ICC-ES Rules of Procedure for Evaluation Reports.

2.2.2 Test Reports: Test reports shall comply with AC85. In addition to the information required by AC85, each test report shall contain the following: results of strength and stiffness tests conducted on companion masonry prisms; the input displacement history; and test results to include the force-deflection relationship, effective stiffness, and damping for each load cycle.

2.2.3 Sampling: Test specimens shall be sampled in accordance with Sections 3.1 and 3.4 of AC85.

3.0 RETROFITTING PROCESS

3.1 General: The items in Section 3.2 shall be included in the evaluation report.

3.2 Document: A document summarizing the process of retrofitting masonry structures with the SRS-MS shall be prepared for each jobsite and submitted to the building official for approval. The document shall address the following requirements:

3.2.1 Nondestructive Evaluation: A registered design professional shall determine the suitable nondestructive evaluation techniques to determine the following about the masonry structure: materials' quality, construction quality, voids, ties between wythes, anchorage, floor and roof diaphragms, and foundations. In-place masonry shear tests shall be included, based on requirements in IEBC Section A106.3.3.1 or UBC Standard 21-6. The mean value shall comply with the registered design professional's specification, but in no case be less than 50 psi (345 kPa). Based on this information, the registered design professional will determine a retrofit program consistent with this criteria.

3.2.2 Wall Stabilization: Compatible cementitious injected fills shall be custom-blended by qualified masonry injection firms under the direction of the registered design professional. Following protocol determined by the registered design professional, the injection firm shall stabilize the wall by reducing voids and augmenting anchorage.

3.2.3 A qualified masonry-drilling firm shall drill holes within the masonry structure to accommodate steel post-tension rods as specified by the registered design professional.

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Post-tension rods shall be corrosion-resistant to meet the requirements of Article 2.4 G of the Specification for Masonry Structures.

3.2.4 A qualified installer shall install the dynamic seismic retrofit system, including the connectors, per the registered design professional's design and supervision.

Continuous special inspection shall be provided during placement and stressing of post-tension rods in accordance with inspection requirements of Section 1701.5.4 of the UBC or Section 1704.4 of the IBC.

The registered design professional, using nondestructive techniques, shall, without exception, verify this work by structural observation in accordance with Section 1702 of the UBC or Section 1709 of the IBC.

3.2.5 The manufacturer and registered design professional shall perform inspections of the installation one and three years after application of post-tension forces, to measure force losses. The report of the inspection shall be submitted to the building official.

4.0 TEST REQUIREMENTS

4.1 Test Method: Tests shall be conducted on full-scale wall assemblies comprised of the SRS-MS and a representative wall, to determine response to dynamic cyclic loading. Loads are applied using either hydraulic or mechanical actuators to subject the component sub-assembly to dynamic cyclic loading. Analytical modeling shall demonstrate the effect of the SRS-MS in typical structural systems. The model shall account for spatial distribution of connectors, translation of the structure above the connector, and effects of vertical and bilateral loads.

4.1.1 Test Specimens: The SRS-MS shall be installed in a full-scale wall assembly extending 3 feet (914 mm) above and below a floor or roof diaphragm. Three such identical specimens shall be constructed and tested to represent typical construction in which usage is proposed.

4.1.2 Load Application: Test specimens shall be installed in a load frame that permits free movement and displacement at the connector and restrains rotation at either end. The specimen shall be free to move in a direction parallel with the post-tension rods. The specimen shall be loaded by applying dynamically varying displacements using at least 20 fully reversed cycles of sinusoidal excitation at a frequency of 2 Hz and a peak displacement equal to between 80 and 90 percent of the maximum displacement capacity of the dynamic retrofit system connector. Loads shall be applied directly to the dynamic retrofit system connector using a servo-controlled hydraulic actuator with digital control system.

4.1.3 Measurements: During the test, applied loads, actuator displacement, vertical connector displacement, and strain of the post-tension rod shall be measured continuously, using electronic gages in such a fashion that strength, stiffness degradation and energy dissipation characteristics of the system can be determined for each load cycle.

4.2 Conditions of Acceptance:

4.2.1 General: To show compliance with Section 4.2.2 and establish design parameters, the average values from the three tests may be used, provided the coefficient of variation is 15 percent, maximum. If the coefficient of

variation exceeds 15 percent, the critical values from an individual test shall be used.

4.2.2 Strength: The maximum strength of the system shall be no less than the calculated nominal axial load, moment and shear strengths (P_n , M_n , and V_n , respectively) determined in accordance with Chapter 21 of the UBC or IBC. The maximum strength of the system shall be no greater than the overstrength factor (λ_o) times the calculated nominal strength. The overstrength factor is dependent on the system and considers overstrength characteristics of the yielding material, with a minimum value of 1.25.

4.2.3 Stiffness: The effective stiffness of each loading cycle shall be calculated using the following relationship:

$$k_{eff} = \frac{|F^-|}{|\Delta^-|} + \frac{|F^+|}{|\Delta^+|} \quad (4-1)$$

where F^+ , F^- are the positive and negative forces, respectively, corresponding to the maximum displacements Δ^+ and Δ^- for each load cycle.

The effective stiffness for each load cycle shall not vary by greater than ± 15 percent from the average effective stiffness calculated from all cycles in the test. The k_{eff} value is used in Equation 4-2.

4.2.4 Damping: The equivalent viscous damping for each cycle shall be calculated as

$$\beta_{eff} = \frac{1}{2\pi} \frac{W_D}{k_{eff} \Delta_{ave}^2} \quad (4-2)$$

where:

W_D = the area enclosed by one complete cycle of the force-displacement curve

$$\Delta_{ave} = \frac{|\Delta^+| + |\Delta^-|}{2} \quad (4-3)$$

Equivalent viscous damping for each cycle shall be a minimum of 4 percent. For each test, the area under the hysteresis loop (W_D) for any one cycle shall not vary by greater than ± 15 percent of the average calculated from all cycles of that test.

5.0 QUALITY CONTROL

5.1 Components for Seismic Retrofit Systems for Masonry Structures shall be manufactured under an approved quality control program with inspections by an inspection agency accredited by the International Accreditation Service or otherwise acceptable to ICC-ES.

5.2 A quality control manual complying with the ICC-ES Interim Criteria for Quality Control Manuals (AC10) shall be submitted.

6.0 EVALUATION REPORT RECOGNITION

The evaluation report shall include the following:

1. The basic information described in Section 2.1.
2. The retrofitting process information described in Section 2.3.
3. Reference to the Design and Construction Requirements in Chapters 16 and 21 of the IBC and UBC. ■