



# ACCEPTANCE CRITERIA FOR SEISMIC DESIGN FACTORS AND COEFFICIENTS FOR SEISMIC-FORCE-RESISTING SYSTEMS OF AUTOCLAVED AERATED CONCRETE (AAC)

AC215

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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*<sup>®</sup> 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.

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# ACCEPTANCE CRITERIA FOR ESTABLISHING SEISMIC DESIGN FACTORS AND COEFFICIENTS FOR SEISMIC-FORCE-RESISTING SYSTEMS OF AUTOCLAVED AERATED CONCRETE (AAC)

## 1.0 INTRODUCTION

**1.1 Purpose:** The purpose of this acceptance criteria is to provide requirements for establishing seismic design factors and coefficients for autoclaved aerated concrete (AAC) seismic-force-resisting systems in ICC Evaluation Service, Inc. (ICC-ES), evaluation reports under the 2000 *International Building Code*® (IBC) and the 1997 *Uniform Building Code*™ (UBC).

**1.2 Scope:** For AAC seismic-force-resisting systems not listed in IBC Table 1617.6, analytical and test data shall be submitted that establish the dynamic characteristics and demonstrate the lateral force resistance and energy dissipation capacity to be equivalent to those for the structural systems listed in Table 1617.6, for equivalent response modification coefficient,  $R$ , system overstrength coefficient,  $S_o$ , and deflection amplification factor,  $C_d$ , values. In Section 1629.9.2 of the UBC, for AAC seismic-force-resisting systems not listed in Table 16-N, the coefficient  $R$  shall be substantiated by approved cyclic test data and analyses. For AAC seismic-force-resisting systems that are undefined within the IBC and UBC, the following factors and coefficients shall be determined in accordance with this criteria:  $R$ ,  $S_o$ , and  $C_d$ . This criteria is limited to use in undefined AAC systems only and shall not be applied to modify factors and coefficients for seismic-force-resisting systems already defined in the UBC and IBC.

### 1.3 Referenced Documents:

**1.3.1** 2000 *International Building Code*®, International Code Council.

**1.3.2** 1997 *Uniform Building Code*™.

**1.3.3** ASTM C 1386-98, Standard Specification for Precast Autoclaved Aerated Concrete (PAAC) Wall Construction Units, ASTM International.

**1.3.4** ASTM C 1452-00, Standard Specification for Reinforced Autoclaved Aerated Concrete Elements, ASTM International.

### 1.4 Definitions:

**1.4.1 Autoclaved Aerated Concrete (AAC):** A cementitious product based on calcium silicate hydrates in which low density is attained by inclusion of an agent that results in macroscopic voids. AAC is subjected to high-pressure steam curing.

## 2.0 BASIC INFORMATION

**2.1 General:** The following information shall be submitted:

**2.1.1 Report:** A summary report describing structure, AAC seismic-force-resisting system, procedures, and conclusions. The report shall be sealed by a registered design professional.

**2.1.2 Support Documentation:** Complete information concerning all components of the procedure, including test reports, calculations, computer modeling program, and ground motion time–history response spectra.

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

**2.3 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 companion physical requirements tests, including compressive strength, done in accordance with ASTM C 1386 or C 1452; the input displacement history; and the load-deflection relationship, hysteresis curves, effective stiffness, and damping for each load cycle.

**2.4 Product Sampling:** Unreinforced AAC test specimens shall be sampled in accordance with Section 3.1 or 3.2 of AC85. AAC containing reinforcement shall be sampled in accordance with Section 3.1 of AC85.

## 3.0 TEST AND PERFORMANCE REQUIREMENTS

### 3.1 Procedure for $R_d$ :

**3.1.1** The type of structure, as appropriate to the system (for example, cantilever or coupled-wall structures), is selected.

**3.1.2** The preliminary plan geometry of the structure, based on architectural layout and other restrictions, is selected.

**3.1.3** The structure's height or number of stories, based on the architectural design, and other characteristics of the structure and seismic force-resisting system, is selected.

**3.1.4** The tributary width, based on architectural plan distribution and other characteristics of the structure and seismic force-resisting system, is selected.

**3.1.5** The weights of each level or story of the structure, using the selected tributary width, weight of components, and the density of the AAC materials, are calculated.

**3.1.6** The design spectrum according to the IBC or UBC, using the intended geographic location of the structure, is obtained.

**3.1.7** The structure is analyzed using the modal analysis procedure in Section 1618 of the IBC or Section 1631 of the UBC.

**3.1.8** The structure's elastic global drift ratio is calculated and compared with the maximum global drift ratio capacity for the structural system. Data for the structure's characteristics may be determined based on structural cyclic load tests that develop hysteresis curves or analysis, or in combination. In this step, the ductility-related force-reduction factor,  $R_d$ , is set to unity ( $R_d = 1$ ). If the global drift ratio of the structure exceeds the maximum global drift ratio capacity, then the number of seismic-force-resisting elements needs to be increased.

**3.1.9** The bending moments and shear forces acting on the structural system are obtained. In this step, the value of the factor  $R_d$  is again set to unity ( $R_d = 1$ ).

**3.1.10** The design overturning moment capacity of the structural system is set equal to the overturning moments calculated in Section 3.1.9.

**3.1.11** A suite of ground motions representative of the design response spectrum is selected. At least four suites applicable to different locations, in different seismic design categories or seismic zones, are required. Each suite shall consist of at least 10 earthquake ground motions. The response spectra for a given suite may be scaled to correspond to the selected design spectrum.

**3.1.12** One ground motion from the suite is selected.

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**3.1.13** A value of  $R_d$  greater than unity is selected. The structure is redesigned for a corresponding reduced overturning moment. For example, if  $R_d$  is selected as 2, then the required flexural capacity is reduced by a factor of 2.

**3.1.14** The global drift ratio and the displacement ductility demands in the structure are calculated using a dynamic nonlinear analysis. The computer program used for the analysis must duplicate the hysteretic behavior exhibited by the structural system under reversed cyclic loading. In this step, the ground motion selected in Section 3.1.12 is used with the design flexural capacity from Section 3.1.13.

**3.1.15** If the global drift ratio is less than the maximum available global drift capacity, then a larger value of  $R_d$  than that used previously is selected, and the procedures in Section 3.1.14 are repeated. If the global drift ratio is greater than the maximum available global drift capacity, then a smaller value of  $R_d$  than that used previously is selected ( $R_d = 1$ , minimum) and the procedures in Section 3.1.14 are repeated. This process is iterated until the global drift ratio demand is approximately equal to the maximum available global drift capacity.

**3.1.16** If the displacement ductility demand is less than the maximum displacement ductility capacity, then a larger value of  $R_d$  than that used previously is selected, and the procedures in Section 3.1.14 are repeated. If the displacement ductility is greater than the maximum available ductility, then a smaller value of  $R_d$  than that used previously is selected ( $R_d = 1$  minimum) and the procedures in Section 3.1.14 are repeated. This process is iterated until the displacement ductility demand is equal to the available ductility capacity.

**3.1.17** These procedures are repeated for other ground motions, other suites of ground motions and other structures to obtain a set of  $R_d$  factors for the structural system.

**3.1.18** The resulting  $R_d$  factor for the set is the 10 percent lower fractile value at a 90 percent confidence level.

**3.2 Procedure for Establishing  $S_{\text{overstrength}}$ :** The structural over-strength factor,  $S_{\text{overstrength}}$ , is the product of

independent over-strength factors as follows:  $S_{\text{overstrength}} = F_1 F_2 F_3 F_4 F_5 F_6$

where:

$F_1$  = Development of sequential plastic hinges in redundant structures.

$F_2$  = Material strengths higher than those specified in design.

$F_3$  = Strength reduction factors, N.

$F_4$  = Specified sections and reinforcement patterns greater than those required in design.

$F_5$  = Participation of nonstructural elements.

$F_6$  = Variation of lateral forces by comparing code forces to results of a modal analysis.

**3.3 Procedure for Establishing  $R$ :** The factor  $R$  is the product of the ductility-based force-reduction factor  $R_d$  and the over-strength factor  $S_{\text{overstrength}}$ :

$$R = S_{\text{overstrength}} R_d$$

**3.4 Procedure for  $C_d$ :**

**3.4.1** The value of the displacement amplification factor  $C_d$  is defined as the maximum nonlinear displacement during an earthquake ( $D_{\text{max}}$ ) divided by the elastic displacement ( $D_s$ ) calculated using reduced seismic design forces:  $C_d = D_{\text{max}}/D_s$ .

**3.4.2** The maximum inelastic displacements ( $D_{\text{max}}$ ) are calculated using the selected  $R$  and  $S_{\text{overstrength}}$ . The elastic displacements,  $D_s$ , are determined by dividing the idealized elastic displacement  $D_e$  by  $R$ .

**3.4.3** These procedures are repeated for other ground motions, other suites of ground motions and other structures to obtain a set of  $C_d$  factors for the structural system.

**3.4.4** The resulting  $C_d$  factor for the set is the 10 percent upper fractile value at a 90 percent confidence level. In addition,  $C_d$  need not exceed  $R$ . ■