IN-LB Inch-Pound Units

An ACI Standard

Seismic Evaluation and Retrofit of Existing Concrete Buildings—Code and Commentary

Reported by ACI Committee 369

ACI CODE-369.1-22

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Seismic Evaluation and Retrofit of Existing Concrete Buildings—Code and Commentary

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This code provides retrofit and rehabilitation criteria for reinforced concrete buildings based on results from the most recent research on the seismic performance of existing concrete buildings. The intent of this code is to provide provisions related to concrete material and concrete members, including material testing criteria, modeling parameters, and acceptance criteria for use within the ASCE 41 framework, similar to how the National Earthquake Hazards Reduction Program (NEHRP) Recommended Seismic Provisions produced by the Federal Emergency Management Agency (FEMA) (FEMA 450) have served as source documents for the International Building Code (IBC) and its predecessor building codes. Starting in the 2023 edition, ASCE 41 references ACI 369.1 directly for concrete-related provisions. Chapter and section numbers of ASCE 41 cited in ACI 369.1 correspond to ASCE 41-17 unless otherwise noted.

This code should be used in conjunction with Chapters 1 through 8 of ASCE 41-17 and applicable sections of the ACI 318-19 Building Code. Chapter 1 of ASCE 41 provides general requirements for evaluation and retrofit, including the selection of performance objectives and retrofit strategies. Chapter 2 of ASCE 41 defines performance objectives and seismic hazards. Chapter 3 of ASCE 41 provides requirements for evaluation and retrofit, including treating as-built information and selecting appropriate screening procedures. Chapter 4 of ASCE 41 summarizes Tier 1 screening procedures, while Chapters 5 and 6 summarize Tier 2 deficiency-based procedures and Tier 3 systematic procedures for evaluation and retrofit, respectively. Chapter 7 of ASCE 41 details analysis procedures referenced in ACI 369.1, including linear and nonlinear analysis procedures, acceptance criteria, and alternative methods for determining modeling parameters and acceptance criteria. Chapter 8 of ASCE 41 provides geotechnical engineering provisions for building foundations and assessment of seismic-geologic site hazards. References to these chapters can be found throughout the standard. The design professional is referred to FEMA 547 for detailed information on seismic rehabilitation measures for concrete buildings. Repair techniques for earthquake-damaged concrete components are not included in ACI 369.1. The licensed design professional is referred to ACI 562, FEMA 306,

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FEMA 307, and FEMA 308 for information on evaluation and repair of damaged concrete wall components.

This code does not provide modeling procedures, acceptance criteria, or rehabilitation measures for concrete-encased steel composite components.

Keywords: acceptance criteria; building; deformation-controlled; dynamic analysis; earthquake; force-controlled; modeling parameters; nonlinear analysis; retrofit; seismic evaluation, seismic assessment; structural evaluation.

INTRODUCTION

Earthquake reconnaissance has clearly demonstrated that concrete buildings designed before the introduction of seismic design codes in the 1980s are more vulnerable to severe damage or collapse when subjected to strong ground motion than concrete buildings built after that period. Seismic rehabilitation of existing buildings where new components are added or existing components are modified or retrofitted with new materials, or both, can be used to mitigate the risk to damage in future earthquakes. Seismic rehabilitation is encouraged not only to reduce the risk of damage and injury in future earthquakes but also to extend the life of existing buildings and reduce the need for new construction in the promotion of sustainability objectives.

This code is intended to cover all buildings of the usual types, both large and small. Requirements more stringent than the code provisions may be desirable for unusual construction. It is not possible to codify all problems encountered in the process of performing the seismic evaluation and retrofit of reinforced concrete buildings, nor is the intent of this code to do so. This code provides a basic framework for modeling and evaluation of structures that reflects the latest information available from researchers and practicing engineers enabling seismic evaluation and retrofit to be performed with a consistent set of criteria. Many provisions in this code rely on the use of sound engineering judgment for their implementation. The code and commentary cannot replace sound engineering knowledge, experience, and judgment. The commentary of this code provides references that describe in detail the implementation of methodologies adopted in the standard.

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CONTENTS

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CODE

CHAPTER 1—GENERAL

1.1—Scope

This code sets forth requirements for the seismic evaluation and retrofit of concrete components of the seismic-force-resisting system of an existing building. These requirements apply to existing concrete components, retrofitted concrete components, and new concrete components. Provisions of this code do not apply to concrete-encased steel composite components.

Chapter 2 specifies data collection procedures for obtaining material properties and performing condition assessments. Chapter 3 provides general analysis and design requirements for concrete components. Chapters 4 through 9 provide modeling procedures, component strengths, acceptance criteria, and retrofit measures for cast-in-place and precast concrete moment frames, concrete frames with masonry infills, cast-in-place and precast concrete structural walls, and concrete-braced frames. Chapters 10 through 12 provide modeling procedures, strengths, acceptance criteria, and retrofit measures for concrete diaphragms and concrete foundation systems.

COMMENTARY

CHAPTER R1—GENERAL

R1.1—Scope

These requirements were developed based on the best knowledge of the seismic performance of existing concrete buildings at the time of publication. These requirements are not intended to restrict the licensed design professional from using new information that becomes available before the issuance of the next edition of this code. Such new information can include tests conducted to address specific building conditions.

This code provides short descriptions of potential seismic retrofit measures for each concrete building system. The licensed design professional is referred to FEMA 547 for detailed information on seismic retrofit measures for concrete buildings. Repair techniques for earthquake-damaged concrete components are not included in this code. The licensed design professional is referred to FEMA 306, FEMA 307, and FEMA 308 for information on evaluation and repair of damaged concrete wall components.

Concrete-encased steel-composite components behave differently from concrete sections reinforced with steel reinforcement. Concrete-encased steel-composite components frequently behave as over-reinforced sections. This type of component behavior was not represented in the data sets used to develop the force-deformation modeling relationships and acceptance criteria in this code, and is not covered herein.

To preserve historic buildings, care should be exercised in selecting the appropriate retrofit approaches and techniques for application.

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CODE

CHAPTER 2—MATERIAL PROPERTIES AND CONDITION ASSESSMENT

2.1—General

Mechanical properties of in-place materials shall be obtained from available drawings, specifications, and other documents for the existing building in accordance with the requirements in 3.2 of ASCE 41. When these documents fail to provide adequate information to quantify material properties, such information shall be supplemented by materials testing based on requirements of Chapter 2. Material properties of existing concrete components shall be determined in accordance with 2.2. The use of default material properties based on historical information is permitted in accordance with 2.2.5. A condition assessment of the existing building and site shall be conducted in accordance with 2.3. The extent of materials testing and condition assessment performed shall be used to determine the knowledge factor as specified in 2.4. Mechanical properties of new materials used for retrofit of existing structures shall be obtained in accordance with 2.5.

COMMENTARY

CHAPTER R2—MATERIAL PROPERTIES AND CONDITION ASSESSMENT

R2.1—General

Chapter 2 identifies properties requiring consideration and provides requirements for determining building properties. Also described is the need for a thorough condition assessment and use of knowledge gained in analyzing component and system behavior. Personnel involved in material property quantification and condition assessment should be experienced in the proper implementation of testing practices and the interpretation of results.

When modeling a concrete building, it is important to investigate local practices relative to seismic design. Specific benchmark years can be determined for the implementation of earthquake-resistant design in most locations, but caution should be exercised in assuming optimistic characteristics for any specific building. Particularly with concrete materials, the date of original building construction significantly influences seismic performance. Without deleterious conditions or materials, concrete gains compressive strength from the time it is originally cast. Strengths typically exceed specified design values (28-day or similar). In older construction, concrete strength was often very low (less than 3000 lb/in.^{2}) and it was rarely specified in the drawings. Early adoptions of concrete in buildings often used steel reinforcement with relatively low strength and ductility, limited continuity, and reduced bond development. Continuity between specific existing components and elements, such as beams, columns, diaphragms, and shear walls, can be particularly difficult to assess because of concrete cover and other barriers to inspection.

Properties of welded wire reinforcement for various periods of construction can be obtained from the Wire Reinforcement Institute (2009).

Documentation of the material properties and grades used in component and connection construction is invaluable and can be effectively used to reduce the amount of in-place testing required. The licensed design professional is encouraged to research and acquire all available records from original construction, including photographs, to confirm reinforcement details shown on the plans.

Further guidance on the condition assessment of existing concrete buildings can be found in the following:

a) ACI 201.1R, which provides guidance on conducting a condition survey of existing concrete structures

b) ACI 364.1R, which describes the general procedures used for the evaluation of concrete structures before retrofit

c) ACI 437R, which describes methods for strength evaluation of existing concrete buildings, including analytical and load test methods

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