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Guide for Seismic Rehabilitation of Existing Concrete Frame Buildings and Commentary

Reported by ACI Committee 369

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This guide, which was developed based on the format and content of ASCE/SEI 41-06, Chapter 6.0, "Concrete," describes methods for estimating the seismic performance of both existing and new concrete components in an existing building. The guide is intended to be used with the analysis procedures and Rehabilitation Objectives established in ASCE/SEI 41-06 for the Systematic Rehabilitation Method. The guide provides recommendations for modeling parameters and acceptance criteria for linear and nonlinear analysis of beams, columns, joints, and slab-column connections of concrete buildings and the procedures for obtaining material properties necessary for seismic rehabilitation design.

Keywords: acceptance criteria; ASCE/SEI 41; beams; columns; frames; joints; modeling parameters; retrofit; seismic rehabilitation; slab-column connections.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Earthquake reconnaissance has clearly demonstrated that existing concrete frame buildings designed before the introduction of modern seismic codes are more vulnerable to severe damage or collapse when subjected to strong ground motion. 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 using new materials in the promotion of sustainability objectives.

1.2—Scope

This guide describes methods for estimating the seismic performance of concrete components in an existing building. The guide is intended to be used with the analysis procedures and Rehabilitation Objectives (ROs) established in ASCE/SEI 41-06 for the Systematic Rehabilitation Method. The methods described apply to existing concrete components of a building system, rehabilitated concrete components of a building system, and new concrete components added to an existing building system. Provisions of this guide do not apply to concrete-encased steel composite components.

Chapter 2 recommends data collection procedures for obtaining material properties and performing condition assessments. Chapter 3 provides general analysis and design requirements for concrete components. Chapter 4 provides modeling procedures, component strengths, acceptance criteria, and rehabilitation measures for cast-in-place concrete moment frames.

C1.2—Scope

This guide has been developed to provide a document that can be easily updated to reflect results from ongoing research on the seismic performance of existing concrete buildings. ACI 369R closely follows the format of Chapter 6, "Concrete" of ASCE/SEI 41-06, to make it readily accessible to engineers and to facilitate updates. Although the content in this version is similar to Chapter 6 of ASCE/SEI 41-06, this will change with timely updates specific to ongoing research. The intent is to provide a continuously updated resource document for future modifications to Chapter 6 of ASCE/SEI 41-06, similar to how the National Earthquake Hazards Reduction Program (NEHRP) Recommended 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.

The goal of developing a guide rather than a standard is to focus the updating effort on improving technical content over development of codified language. New research results reviewed by the committee can now be implemented more quickly, accelerating communication between researchers and engineers while providing design professionals with the latest recommendations for the seismic assessment and rehabilitation of concrete buildings. For this version of the guide, most sections are similar to Chapter 6 of ASCE/SEI 41 Supplement 1 (ASCE/SEI Ad Hoc Committee 2007). The most recent version, however, does not provide modeling procedures, acceptance criteria, and rehabilitation measures for precast concrete frames, infill frames, braced frames, shear walls, diaphragms, and foundations. Future versions will provide provision updates for concrete moment frames and will add provisions for concrete components and systems omitted in the present version of the guide.

This guide should be used in conjunction with Chapters 1 through 4 of ASCE/SEI 41-06. Chapter 1 of ASCE/SEI 41-06 provides rehabilitation requirements, including description of ROs, Building Performance Levels, and seismic hazard. Chapter 2 of ASCE/SEI 41-06 provides general design requirements, including determination of as-built information, limitations for linear and nonlinear analysis procedures, definition of force- and deformation-controlled actions, procedures for construction quality assurance, and methods for determining alternative modeling parameters and acceptance criteria. Chapter 3 of ASCE/SEI 41-06 provides a detailed description of all linear and nonlinear analysis procedures referenced in ACI 369R. Chapter 4 of ASCE/SEI 41-06 provides geotechnical engineering provisions for building foundations and assessment of seismic-geologic site hazards. References to these chapters can be found throughout the guide. This guide provides short descriptions of potential seismic rehabilitation measures for each concrete building system. The design professional, however, is referred to the FEMA report, FEMA 547, for detailed information on seismic rehabilitation measures for concrete buildings. Repair techniques for earthquake-damaged concrete components are not included in ACI 369R. The 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 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 guide. Concrete encasement is often provided for fire protection rather than for strength or stiffness, and typically lacks transverse reinforcement. In some cases, the transverse reinforcement does not meet detailing requirements in the American National Standards Institute (ANSI)/American Institute of Steel Construction (AISC) Code (ANSI/AISC 360). Lack of adequate confinement may result in expansion of the core concrete, which exacerbate bond slip and, consequently, undermines the fundamental principle that plane sections remain plane.

Testing and analysis used to determine acceptance criteria for concrete-encased steel composite components should include the effect of bond slip between steel and concrete, confinement ratio, confinement reinforcement detailing, kinematics, and appropriate strain limits.