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Seismic Rehabilitation of Existing Buildings

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STANDARDS

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The following standards have been issued:

ANSI/ASCE 1-82 N-725 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures
ASCE/EWRI 2-06 Measurement of Oxygen Transfer in Clean Water
ANSI/ASCE 3-91 Standard for the Structural Design of Composite Slabs and ANSI/ASCE 9-91 Standard Practice for the Construction and Inspection of Composite Slabs
ASCE 4-98 Seismic Analysis of Safety-Related Nuclear Structures
Building Code Requirements for Masonry Structures (ACI 530-02/ASCE 5-02/TMS 402-02) and Specifications for Masonry Structures (ACI 530.1-02/ASCE 6-02/TMS 602-02)
ASCE/SEI 7-05 Minimum Design Loads for Buildings and Other Structures
SEI/ASCE 8-02 Standard Specification for the Design of Cold-Formed Stainless Steel Structural Members
ANSI/ASCE 9-91 listed with ASCE 3-91
ASCE 10-97 Design of Latticed Steel Transmission Structures
SEI/ASCE 11-99 Guideline for Structural Condition Assessment of Existing Buildings
ASCE/EWRI 12-05 Guideline for the Design of Urban Subsurface Drainage
ASCE/EWRI 13-05 Standard Guidelines for Installation of Urban Subsurface Drainage
ASCE/EWRI 14-05 Standard Guidelines for Operation and Maintenance of Urban Subsurface Drainage
ASCE 15-98 Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD)
ASCE 16-95 Standard for Load Resistance Factor Design (LRFD) of Engineered Wood Construction
ASCE 17-96 Air-Supported Structures
ASCE 18-96 Standard Guidelines for In-Process Oxygen Transfer Testing
ASCE 19-96 Structural Applications of Steel Cables for Buildings
ASCE 20-96 Standard Guidelines for the Design and Installation of Pile Foundations
ANSI/ASCE/T&DI 21-05 Automated People Mover Standards—Part 1
ASCE 21-98 Automated People Mover Standards—Part 2
ASCE 21-00 Automated People Mover Standards—Part 3
SEI/ASCE 23-97 Specification for Structural Steel Beams with Web Openings
ASCE/SEI 24-05 Flood Resistant Design and Construction
ASCE/SEI 25-06 Earthquake-Actuated Automatic Gas Shutoff Devices
ASCE 26-97 Standard Practice for Design of Buried Precast Concrete Box Sections
ASCE 27-00 Standard Practice for Direct Design of Precast Concrete Pipe for Jacking in Trenchless Construction
ASCE 28-00 Standard Practice for Direct Design of Precast Concrete Box Sections for Jacking in Trenchless Construction
ASCE/SEI/SFPE 29-05 Standard Calculation Methods for Structural Fire Protection
SEI/ASCE 30-00 Guideline for Condition Assessment of the Building Envelope
SEI/ASCE 31-03 Seismic Evaluation of Existing Buildings
SEI/ASCE 32-01 Design and Construction of Frost-Protected Shallow Foundations
EWRI/ASCE 33-01 Comprehensive Transboundary International Water Quality Management Agreement
EWRI/ASCE 34-01 Standard Guidelines for Artificial Recharge of Ground Water
EWRI/ASCE 35-01 Guidelines for Quality Assurance of Installed Fine-Pore Aeration Equipment
CI/ASCE 36-01 Standard Construction Guidelines for Microtunneling
SEI/ASCE 37-02 Design Loads on Structures During Construction
CI/ASCE 38-02 Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data
EWRI/ASCE 39-03 Standard Practice for the Design and Operation of Hail Suppression Projects
ASCE/EWRI 40-03 Regulated Riparian Model Water Code
ASCE/SEI 41-06 Seismic Rehabilitation of Existing Buildings
ASCE/EWRI 42-04 Standard Practice for the Design and Operation of Precipitation Enhancement Projects
ASCE/SEI 43-05 Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities
ASCE/EWRI 44-05 Standard Practice for the Design and Operation of Supercooled Fog Dispersal Projects
ASCE/EWRI 45-05 Standard Guidelines for the Design of Urban Stormwater Systems
ASCE/EWRI 46-05 Standard Guidelines for the Installation of Urban Stormwater Systems
ASCE/EWRI 47-05 Standard Guidelines for the Operation and Maintenance of Urban Stormwater Systems
ASCE/SEI 48-05 Design of Steel Transmission Pole Structures

FOREWORD

In 2003, the Board of Direction approved the revision to the ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by the Society. All such standards are developed by a consensus standards process managed by the Society's Codes and Standards Committee (CSC). The consensus process includes balloting by a balanced standards committee made up of Society members and nonmembers, balloting by the membership of the Society as a whole, and balloting by the public. All standards are updated or reaffirmed by the same process at intervals not exceeding five years.

The material presented in this Standard has been prepared in accordance with recognized engineering principles. This Standard should not be used without first securing competent advice with respect to its suitability for any given application. The publication of the material contained herein is not intended as a representation or warranty on the part of the American Society of Civil Engineers, or of any other person named herein, that this information is suitable for any general or particular use or promises freedom from infringement of any patent or patents. Anyone making use of this information assumes all liability from such use.

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Balloting for this standard began with FEMA 356, *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, prepared by ASCE for the Federal Emergency Management Agency (FEMA). FEMA 356 was developed from FEMA 273, *NEHRP Guidelines for the Seismic Rehabilitation of Buildings*, developed for FEMA by the Applied Technology Council (ATC). ASCE acknowledges and is grateful for the over ten years of support provided by FEMA to the development of a new generation rehabilitation standard, and particularly for their support during this final step, the development of this consensus standard.

This standard was prepared through the consensus standards process in compliance with the procedures established by the ASCE Codes and Standards Committee and accredited by the American National Standards Institute (ANSI). Those individuals who served on the standards committee are:

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Appendix

The Structural Engineering Institute (SEI) of the American Society of Civil Engineers is committed to providing accurate, up-to-date information to its readers. To that end, SEI maintains a listing of errata at http://www.seinstitute.org/publications/errata.cfm.

Seismic Rehabilitation of Existing Buildings

1.0 REHABILITATION REQUIREMENTS

1.1 SCOPE

This standard for the *Seismic Rehabilitation of Existing Buildings*, referred to herein as "this standard," specifies nationally applicable provisions for the seismic rehabilitation of buildings. Seismic rehabilitation is defined as improving the seismic performance of structural and/or nonstructural components of a building by correcting deficiencies identified in a seismic evaluation. Seismic evaluation is defined as an approved process or methodology of evaluating deficiencies in a building, which prevent the building from achieving a selected Rehabilitation Objective. Seismic evaluation using ASCE 31 (ASCE 2002), the procedures and criteria of this standard, or other procedures and criteria approved by the authority having jurisdiction is permitted.

Seismic rehabilitation of existing buildings shall comply with requirements of this standard for selecting a Rehabilitation Objective and conducting the seismic rehabilitation process to achieve the selected Rehabilitation Objective. This standard does not preclude a building from being rehabilitated by other procedures approved by the authority having jurisdiction.

Symbols, acronyms, definitions, and references used throughout this standard are cited separately in sections located at the end of this standard.

C1.1 SCOPE

This standard is intended to serve as a nationally applicable tool for design professionals, code officials, and building owners undertaking the seismic rehabilitation of existing buildings. In jurisdictionally mandated seismic rehabilitation programs, the code official serves as the authority having jurisdiction. In voluntary seismic rehabilitation programs, the building owner, or the owner's designated agent, serves as the authority having jurisdiction.

This standard consists of two parts: Provisions, which contain the technical requirements, and Commentary, intended to explain the provisions. Commentary for a given section is located immediately following the section and is identified by the same section number preceded by the letter C.

It is expected that most buildings rehabilitated in accordance with this standard would perform within the desired levels when subjected to the design earthquakes. However, compliance with this standard does not guarantee such performance; rather, it represents the current standard of practice in designing to attain this performance. The practice of earthquake engineering is rapidly evolving, and both our understanding of the behavior of buildings subjected to strong earthquakes and our ability to predict this behavior are advancing. In the future, new knowledge and technology will improve the reliability of accomplishing these goals.

The procedures contained in this standard are specifically applicable to the rehabilitation of existing buildings and, in general, are more appropriate for that purpose than are new building codes. New building codes are primarily intended to regulate the design and construction of new buildings; as such, they include many provisions that encourage or require the development of designs with features important for good seismic performance, including regular configuration, structural continuity, ductile detailing, and materials of appropriate quality. Many existing buildings were designed and constructed without these features and contain characteristics such as unfavorable configuration and poor detailing that preclude application of building code provisions for their seismic rehabilitation.

Although it is intended to be used as a follow-up to a previous seismic evaluation, this standard can also be used as an evaluation tool to ascertain compliance with a selected rehabilitation objective. An ASCE 31, Tier 3 evaluation is an example of this use. It should be noted, however, that an evaluation using this standard may be more stringent than other evaluation methodologies because the provisions have been calibrated for use in design. Historically, criteria for evaluation have been set lower than those for design to minimize the need to strengthen buildings that would otherwise have only modest deficiencies.

The expertise of the design professional in earthquake engineering is an important prerequisite for the appropriate use of this standard in assisting a building owner to select voluntary seismic criteria or to design and analyze seismic rehabilitation projects, whether voluntary or required. The analytical work required by this standard must be performed under the responsible charge of a licensed professional engineer; however, that does not preclude a design professional without a professional engineering license, but with responsible charge, from leading a seismic rehabilitation project. For example, an architect with responsible charge can lead a seismic rehabilitation project conducted in accordance with the simplified rehabilitation described in Chapter 10.

This standard is intended to be generally applicable to seismic rehabilitation of all buildings—regardless of importance, occupancy, historic status, or other classifications of use. However, application of these provisions should be coordinated with other requirements that may be in effect, such as ordinances governing historic structures or hospital construction. In addition to the direct effects of ground shaking, this standard also addresses the effects of local geologic site hazards such as liquefaction.

This standard is arranged such that there are four analysis procedures that can be used, including the Linear Static Procedure, Linear Dynamic Procedure, Nonlinear Static Procedure, and Nonlinear Dynamic Procedure. The linear analysis procedures are intended to provide a conservative estimate of building response and performance in an earthquake, though they are not always accurate. Since the actual response of buildings to earthquakes is not typically linear, the nonlinear analysis procedures should provide a more accurate representation of building response and performance. In recognition of the improved representation of building behavior when nonlinear analysis is conducted, the nonlinear procedures have less-conservative limits on permissible building response than do linear procedures. Buildings that are found to be seismically deficient based on linear analysis may comply with this standard if a nonlinear analysis is performed. Therefore, performing a nonlinear analysis can minimize or eliminate unnecessary seismic rehabilitation and potentially lower construction costs.

This standard applies to the seismic rehabilitation of both the overall structural system of a building and its nonstructural components, including ceilings, partitions, mechanical, electrical, and plumbing systems.

With careful extrapolation, the procedures of this standard may also be applied to many nonbuilding structures such as pipe racks, steel storage racks, structural towers for tanks and vessels, piers, wharves, and electrical power generating facilities. However, the applicability of these procedures has not been fully examined for every type of structure—particularly those that have generally been covered by specialized codes or standards, such as bridges and nuclear power plants.

Jurisdictions will adopt this standard as an ordinance that only applies to the seismic rehabilitation of existing buildings or adopt this standard by reference as part of a comprehensive code addressing all aspects of rehabilitating existing buildings. In adopting this standard, the jurisdiction will select one or more rehabilitation objectives which must be met by buildings that have either been targeted by the jurisdiction for mandated seismic rehabilitation or—by reason of owner-initiated activities, such as major structural modifications—have come under the jurisdiction's rehabilitation ordinance. Since codes for new buildings have chapters that briefly address existing buildings, care must be taken in coordinating and referencing the adoption of this standard to avoid ambiguity and confusion with other ordinances and codes.

Since almost all structural seismic rehabilitation work requires a building permit, the code official will become an important part of the process. For voluntary rehabilitation efforts, the building owner and the code official need to come to agreement about the intended rehabilitation objective. The code official will verify that the owner's stated objective is met in the design and construction phases of the work. For jurisdictionally required rehabilitation efforts, whether caused by passive or active programs (see Appendix A), the code official will verify that the required objective is met. Because the approaches and technology of this standard are not yet in the mainstream of design and construction practices of the United States, it is imperative that the code official either develop the expertise in this methodology or utilize a peer review type of process to verify the appropriate application of this standard. A jurisdiction must also remain flexible and open to other analyses and evaluations, which provide a reasonable assurance of meeting the appropriate rehabilitation objective.

In addition to techniques for increasing the strength and ductility of systems, this standard provides techniques for reducing seismic demand, such as the introduction of isolation or damping devices. Design of new buildings and evaluation of components for gravity and wind forces in the absence of earthquake demands are beyond the scope of this standard.

This standard does not explicitly address the determination of whether or not a rehabilitation project should be undertaken for a particular building. Guidance on the use of this standard in voluntary or directed risk-mitigation programs is provided in Appendix A. Determining where these provisions should be required is beyond the scope of this standard. Once the decision to rehabilitate a building has been made, this standard can be referenced for detailed engineering guidance on how to conduct a seismic rehabilitation analysis and design.

Featured in this standard are descriptions of damage states in relation to specific performance levels. These descriptions are intended to aid the authority having jurisdiction, design professionals, and owners in selecting appropriate performance levels for rehabilitation design. They are not intended to be used for condition assessment of earthquake-damaged buildings. Although there may be similarities between these damage descriptions and those used for postearthquake damage assessment, many factors enter into the processes of assessing seismic performance. No single parameter in this standard should be cited as defining either a performance level or the safety or usefulness of an earthquake-damaged building.

Techniques for repair of earthquake-damaged buildings are not included in this standard, but are referenced in the commentary pertaining to Chapters 5 through 8 where such guidelines exist. Any combination of repaired components, undamaged existing components, and new components can be modeled using this standard, and each checked against performance level acceptance criteria. If the mechanical properties of repaired components are known, acceptance criteria for use with this standard can be either deduced by comparison with other similar components or derived.

1.2 DESIGN BASIS

The selection of a seismic Rehabilitation Objective and the performance-based design of rehabilitation measures to achieve the selected Rehabilitation Objective shall be in accordance with the rehabilitation process specified in Section 1.3. The use of alternative performance-based criteria and procedures approved by the authority having jurisdiction shall be permitted.

C1.2 DESIGN BASIS

Provisions of this standard for seismic rehabilitation are based on a performance-based design methodology that differs from seismic design procedures for the design of new buildings currently specified in national building codes and standards.

The framework in which these requirements are specified is purposefully broad so that Rehabilitation Objectives can accommodate buildings of different types, address a variety of performance levels, and reflect the variation of seismic hazards across the United States and U.S. territories.

The provisions and commentary of this standard are based primarily on the FEMA 356 *Prestandard* (FEMA 2000) with limited material taken from the FEMA 274 (FEMA 1997) Commentary. This standard is intended to supersede FEMA 356, but FEMA 274 remains a valid explanation for the provisions in this standard unless indicated otherwise in the relevant commentary of this standard. For this reason, section numbers in this standard remain essentially the same as in FEMA 356.

FEMA 356 was based on FEMA 273 (FEMA 1997), which was developed by a large team of specialists in earthquake engineering and seismic rehabilitation. The most advanced analytical techniques considered practical for production use have been incorporated. The acceptance criteria have been specified using actual laboratory test results, where available, supplemented by the engineering judgment of various development teams. Certain buildings damaged in the 1994 Northridge earthquake and a limited number of designs using codes for new buildings have been checked using the procedures of FEMA 273. A comprehensive program of case studies was undertaken by FEMA in 1998 to test more thoroughly the various analysis techniques and acceptability criteria. The results of this study are reported in FEMA 343, *Case Studies: An Assessment of the NEHRP Guidelines for the Seismic Rehabilitation of Buildings*. The results of the FEMA 343 case studies have been incorporated in the provisions of this standard, where possible. Similarly, information from FEMA 350 (FEMA 2000), FEMA 351 (FEMA 2000), and other reports published by the SAC Joint Venture project, formed as a result of the Northridge steel moment frame damage, has been incorporated where applicable. Engineering judgment should be exercised in determining the applicability of various analysis techniques and material acceptance criteria in each situation.

The commentary to this standard contains specific references to many other documents. In addition, this standard is related generically to the following publications.

1. FEMA 450, *2003 NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures,* also referred to herein as the *2003 NEHRP Recommended Provisions* (FEMA 2004).
2. FEMA 237, *Development of Guidelines for Seismic Rehabilitation of Buildings, Phase I: Issues Identification and Resolution* (FEMA 1992), which underwent an American Society of Civil Engineers (ASCE) consensus approval process and provided policy direction for this standard.
3. Applied Technology Council (ATC), ATC-28-2, *Proceedings of the Workshop to Resolve Seismic Rehabilitation Sub-Issues* (ATC 1993) provided recommendations to the writers of this standard on more detailed sub-issues.
4. FEMA 172, *NEHRP Handbook of Techniques for the Seismic Rehabilitation of Existing Buildings*