ASCE 4-98

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American Society of Civil Engineers

Seismic Analysis of Safety-Related Nuclear Structures and Commentary

This document uses both Système International (SI) units and customary units.

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ABSTRACT

This standard provides requirements for performing analyses for the purpose of new structure design or existing structure evaluation that will lead to the reliability of structures under earthquake motions. The goal of this standard is to provide rules and analysis parameters that are expected to produce seismic responses that have about the same probability of non-exceedance as the input. Specifications of input motions are provided. Analysis standards are given for modeling of structures, analysis of structures, soil-structure interaction modeling and analysis, input for subsystem seismic analysis, and special structures such as buried pipes and conduits, earth-retaining walls, above-ground vertical tanks, raceways, and seismic-isolated structures. Non-mandatory Appendix A provides a discussion on Seismic Probabilistic Risk Assessments and Seismic Margin Assessments.

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STANDARDS

In April 1980, the Board of Direction approved 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 Management Group F (MGF), Codes and Standards. The consensus process includes balloting by the balanced standards committee made up of Society members and nonmembers, balloting by the membership of ASCE as a whole, and balloting by the public. All standards are updated or reaffirmed by the same process at intervals not exceeding 5 years.

The following Standards have been issued.

ANSI/ASCE 1-82 N-725 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures

ANSI/ASCE 2-91 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 530-99/ASCE 5-99/TMS 402-99) and Specifications for Masonry Structures (ACI 530.1-99/ASCE 6-99/TMS 602-99)

ASCE 7-98 Minimum Design Loads for Buildings and Other Structures

ANSI/ASCE 8-90 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

ANSI/ASCE 12-91 Guideline for the Design of Urban Subsurface Drainage

ASCE 13-93 Standard Guidelines for Installation of Urban Subsurface Drainage

ASCE 14-93 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 and 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

ASCE 21-96 Automated People Mover Standards—Part 1

ASCE 21-98 Automated People Mover Standards—Part 2

SEI/ASCE 23-97 Specification for Structural Steel Beams with Web Openings

ASCE 24-98 Flood Resistant Design and Construction

ASCE 25-97 Earthquake-Actuated Automatic Gas Shut-Off Devices

FOREWORD

The material presented in this publication has been prepared in accordance with recognized engineering principles. This Standard and Commentary should not be used without first securing competent advice with respect to their 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.

PREFACE

There are four steps in the design and construction process that lead to the reliability of nuclear safety-related structures under earthquake motions:

1. Definition of the seismic environment;
2. Analysis to obtain response information;
3. Design or evaluation of the various structural elements;
4. Construction.

In the practice of structural engineering design and construction, sufficient conservatism is intentionally added in order to achieve the desired performance. The purpose of this standard is to provide requirements for performing Step 2 for design of new facilities. This standard may also be used for evaluation of existing facilities. The intent of the analysis methodology is that the output parameters maintain about the same probability of non-exceedance as the input. This is accomplished by specifying methods for analysis with essentially no conservative bias except for small levels of conservatism added only to account for modeling uncertainties such as selection of material properties, mass, geometry, and damping. For example, use of this standard will produce seismic responses that have about a 90% chance of not being exceeded for an input response spectrum specified at the 84th percentile non-exceedance level. No attempt has been made to compensate for excess conservatism or lack of conservatism in the other steps.

In response to changing perceptions of seismic hazard for operating facilities or for quantification of risk or margin for new facilities, evaluation of facilities for seismic events beyond the design basis may be performed. This is discussed in Appendix A, which is nonmandatory.

Techniques other than those specified in this standard, including experience gained from past earthquakes, special analyses and testing may also be used. However, such alternative methodologies shall be properly substantiated and shall conform to the intent of this standard.

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CONTENTS

Seismic Analysis of Safety-Related Nuclear Structures

1.0 GENERAL

1.1 INTRODUCTION

1.1.1 Purpose

This standard provides minimum requirements and acceptable methods for the seismic analyses of safety-related structures of a nuclear facility. This standard provides a methodology for calculating seismic responses in structures and to derive input motions for use in the seismic qualification of electrical and mechanical systems and components.

The purpose of the analytical methods is to provide only small levels of conservatism to account for uncertainties. The intentional conservatism is contained in the following three areas:

1. For soil-structure interaction, three cases are analyzed using different soil modulus values and the results use the envelope of the three cases.
2. For in-structure response spectra, the peaks are broadened.
3. For structural damping, conservative values are specified.

As a result, the output from the analyses using these methods will be at a slightly greater probability of non-exceedance than that of the input. For example, the seismic responses will have about a 90% chance of not being exceeded for an input response spectrum specified at the 84th percentile non-exceedance level.

1.1.2 Scope

1.1.2.1 Types of Structures Covered by This Standard

This standard is intended for use in the seismic analysis of all safety-related structures of nuclear facilities including, but not limited to, above and below ground structures, buried piping, above ground vertical tanks and structures with seismic isolation systems. Analysis of caisson and pile-supported foundations, unlined tunnels, and floating structures are not covered by this standard. However, nothing in this standard should be considered to preclude the use of these structures and structural elements.

1.1.2.2 Foundation Material Stability

The analysis procedures provided herein assume that the structures analyzed are adequately supported by their foundation materials and that no soil or rock failure occurs that would modify or void the seismic analysis.

1.1.3 General Requirements

1.1.3.1 Use of Analysis Results

The seismic responses determined from the analyses prescribed herein are to be combined with responses due to dead load and other prescribed loads.

1.1.3.2 Alternative Methodologies

Techniques other than those specified in this standard, including experience gained from past earthquakes, special analyses, and testing, may be used in lieu of the requirements specified herein. However, such alternative methodologies shall be properly substantiated and shall conform to the intent of this standard as expressed in the preface.

1.2 DEFINITIONS

The following terms are defined for general use in this standard. Specialized definitions also appear in some individual sections.

Apparent wave propagation velocity: The apparent propagation velocity of seismic waves through the ground relative to a fixed local coordinate system on the object analyzed.

Competent soil: Any natural or improved soil that has a shear wave velocity, $V_s \geq$ 1,000 fps (300 m/s).

Coupled: A descriptive term for mathematical models of structures and components that are interconnected and which influence the dynamic response of each other.

"Cut-off" frequency: The highest frequency which is adequately represented in the model for the soil structure interaction analysis procedure. It may be taken as twice the highest dominant frequency of the coupled soil-structure system for the direction under consideration, but not less than 10 Hz.

Design (or evaluation) ground acceleration: The value of the acceleration which corresponds to acceleration at zero period in the design ground-response spectrum.

Design (or evaluation) response spectrum: A smooth response spectrum of the free-field input mo-