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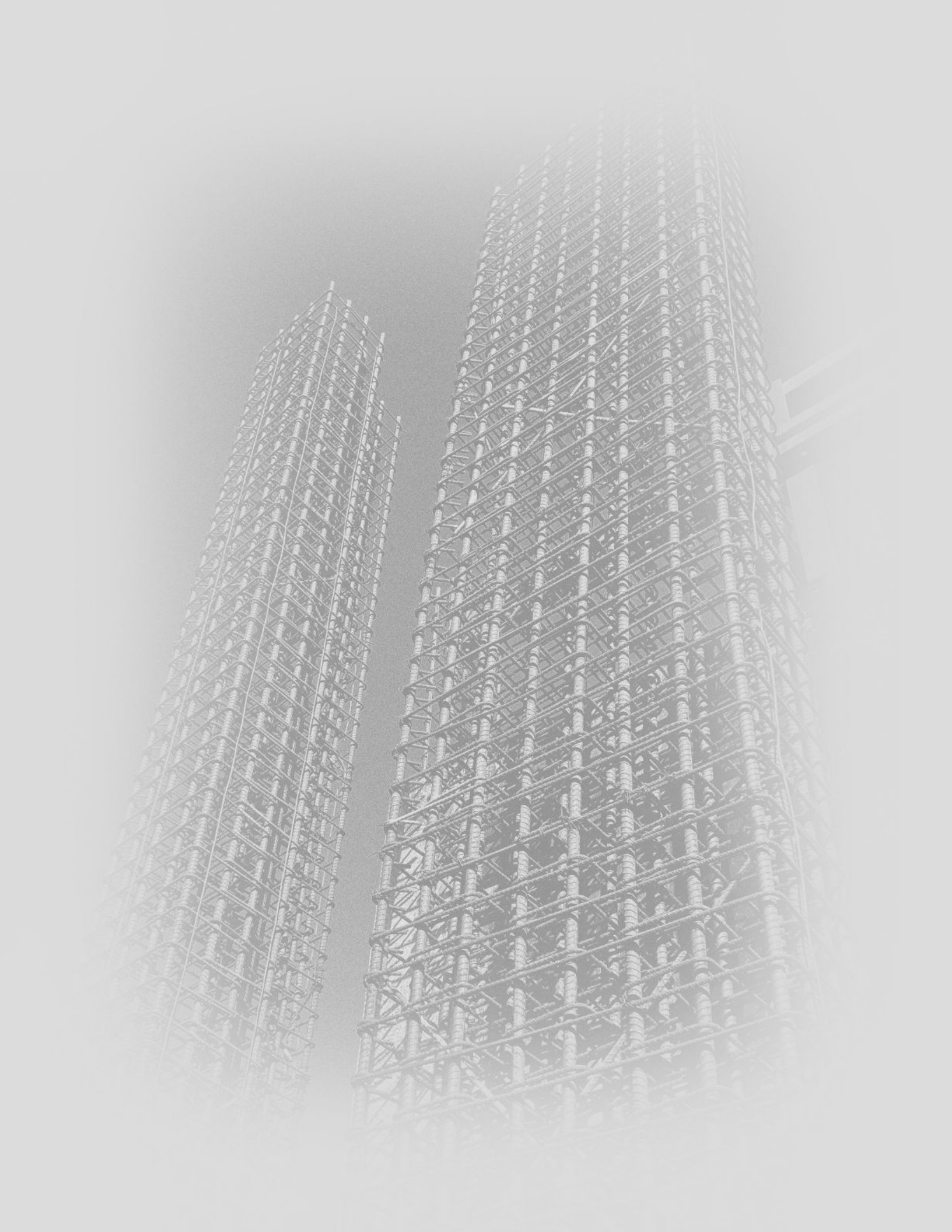
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Chapter 1

INTRODUCTION

1.1 Overview

The purpose of this design guide is to assist in the proper application of the earthquake provisions in the 2019 edition of *Building Code Requirements for Structural Concrete (ACI 318-19) and Commentary (ACI 318R-19)* for cast-in-place concrete buildings with nonprestressed steel reinforcing bars (Reference 1; see Appendix A for a list of references in this design guide). The main goals are to provide a simplified roadmap that can be used to navigate through the ACI 318 requirements and step-by-step design procedures and design aids that make designing and detailing reinforced concrete buildings subject to combinations of earthquake, gravity, and other load effects simpler and faster. The information in this publication can be used for reinforced concrete buildings of any size assigned to Seismic Design Categories B through F.

Throughout this publication, emphasis is placed on how to correctly apply the ACI 318 requirements, and explanatory material is provided to supplement the requirements. Readers who are interested in the origins of the provisions can find a wealth of information in the ACI 318 Commentary and accompanying references.

The design and detailing chapters are organized mainly by seismic force-resisting system. Design aids are provided that can be used to quickly determine preliminary member sizes and required reinforcement, to name a few. Step-by-step design procedures are given for the various types of structural members and practical design examples are provided that follow the steps in the design procedures and illustrate the proper application of the ACI 318 requirements. A number of examples address certain requirements in ACI 318 not covered in any other reinforced concrete resources. Also given in the chapters are guidelines and recommended typical details for the structural members with emphasis on constructability.

References are made throughout this publication to the CRSI *Design Checklists* and *Calculators*, which are supplemental resources that complement this Design Guide. The *Checklists* are easy-to-use lists of essential items that must be completed when designing and detailing steel reinforced concrete structural members in accordance with the 2019 edition of ACI 318. Their main purpose is to assure all requirements for a specific structural member, which are scattered throughout ACI 318, are addressed and not inadvertently skipped or forgotten. The *Calculators*, in the form of spreadsheets, can be used, among other things, to check designs, perform a parametric study, or quickly attain a feasible design in the preliminary design stage.

Throughout this publication, section numbers from ACI 318-19 are referenced as illustrated by the following: Section 18.10 of ACI 318-19 is denoted as ACI 18.10. Section numbers from the 2024 International Building Code (IBC) [Reference 2] and ASCE/SEI 7-22 (Reference 3) are referenced as follows: Section 1613 from the 2024 IBC and Section 12.2 of ASCE/SEI 7-22 are denoted as IBC 1613 and ASCE/SEI 12.2, respectively.

The notation used throughout this Design Guide conforms to the notation in Section 2.2 of ACI 318. Where additional notation is needed, it is clearly defined where initially introduced.

In addition to practicing engineers, this design guide is a valuable resource for educators, students, individuals studying for licensing exams, and building officials.

1.2 Organization of This Design Guide

The general seismic design criteria in IBC 1613 and ASCE/SEI Chapter 11 are given in Chapter 2. Included are methods to determine site class, design spectral response acceleration parameters, and design response spectra, as well as information on site-specific ground motion procedures. Also provided are methods to determine the Seismic Design Category (SDC) of a building.

The seismic design requirements for building structures in ASCE/SEI Chapter 12 are summarized in Chapter 3. Included is information on the following for steel reinforced concrete seismic force-resisting systems:

- Structural system selection and limitations
- Diaphragm flexibility
- Irregularities
- Redundancy
- Seismic load effects and combinations
- Direction of loading
- Analysis procedures and modeling criteria, including effective stiffness values for structural walls, coupling beams, columns, beams, and slabs in a moment frame, and diaphragms.
- Design seismic force determination for seismic force-resisting systems and diaphragms
- Structural wall anchorage
- Drift and deformation
- Foundation design

Properties of concrete and nonprestressed steel reinforcing bars permitted to be used in the design of reinforced concrete members are covered in Chapter 4. ACI 318 strength reduction factors are also included in this chapter.

Design and detailing requirements for bearing wall and building frame systems are given in Chapter 5 for ordinary and special structural walls. Included are methods on how to determine preliminary wall thickness and area of longitudinal reinforcement for systems with and without coupling beams. Design procedures and recommended details for ordinary and special structural walls are also provided. The examples in this chapter cover the following:

- Bearing wall systems in SDC B and D (including orthogonal load effects and structural piers)
- Building frame system with ductile coupled walls
- Building frame system analyzed using the requirements in ASCE/SEI 12.9.1 (i.e., a modal response spectrum analysis).

Chapter 6 contains design and detailing requirements for intermediate and special moment-resisting frame systems. General considerations for economy and constructability are presented, and an approximate method to determine preliminary beam and column sizes based on joint shear strength requirements is given for special moment frames. The examples in this chapter cover the design and detailing of ordinary, intermediate (including an example where a flat plate is utilized as the seismic force-resisting system), and special moment frames.

The design and detailing requirements for dual systems are given in Chapter 7 and are applicable to buildings assigned to SDC C and above. Examples include the design and detailing of the following:

- Dual system with ordinary reinforced concrete shear walls and intermediate moment frames in a building assigned to SDC C
- Dual system with reinforced concrete ductile coupled walls and special moment frames in a building assigned to SDC D.

Shear wall-frame interactive systems are covered in Chapter 8. Design and detailing requirements are illustrated for a system with ordinary reinforced concrete moment frames and ordinary reinforced concrete shear walls in a building assigned to SDC B.

Design and detailing requirements for diaphragms are given in Chapter 9 for buildings assigned to SDC B and above. Diaphragm modeling and analysis, in-plane stiffness modeling, and analysis methods for diaphragms with and without openings are the primary topics covered. Methods are presented on how to determine the center of rigidity, how to distribute the in-plane forces to the vertical elements of the lateral force-resisting system, and how to determine the required diaphragm and collector reinforcement. Examples include diaphragm analysis and design for the following:

- Ordinary moment frame system in a building assigned to SDC B
- Building frame system with ductile coupled walls in a building assigned to SDC D
- Building frame system with a horizontal irregularity in a building assigned to SDC D.

Comparisons of design diaphragm forces determined in accordance with the requirements in ASCE/SEI 12.10.1 and 12.10.3 (i.e., alternative design provisions) are provided in the examples.

Design and detailing requirements for members not designated as part of the seismic force-resisting system are given in Chapter 10. The requirements are illustrated in examples for beams and columns in a building assigned to SDC D and for a slab-column connection in a building assigned to SDC D.

Requirements for footings, foundation mats, pile caps, grade beams, slabs-on-grade, foundation seismic ties, piles, and drilled piers supporting buildings assigned to SDC C and above are given in Chapter 11. Pertinent requirements in IBC Chapter 18 and ASCE/SEI 12.13 are also included. Examples are given for the following foundation types supporting a special moment frame in a building assigned to SDC E:

- Isolated spread footing
- Drilled piers and grade beam
- Drilled piers and pile caps with grade beam seismic ties

Recommended design and detailing procedures are provided in this chapter that are meant to fill some of the gaps in the current design requirements.

References in this Design Guide are given in Appendix A. Appendix B contains properties of currently available steel reinforcing bars.