CHAPTER A5

EARTHQUAKE HAZARD REDUCTION IN EXISTING CONCRETE BUILDINGS

SECTION A501
PURPOSE

The purpose of this chapter is to promote public safety and welfare by reducing the risk of death or injury that may result from the effects of earthquakes on concrete buildings and concrete frame buildings.

The provisions of this chapter are intended as minimum standards for structural seismic resistance, and are established primarily to reduce the risk of life loss or injury. Compliance with the provisions in this chapter will not necessarily prevent loss of life or injury or prevent earthquake damage to the rehabilitated buildings.

SECTION A502
SCOPE

The provisions of this chapter shall apply to all buildings having concrete floors or roofs supported by reinforced concrete walls or by concrete frames and columns. This chapter shall not apply to buildings with roof diaphragms that are defined as flexible diaphragms by the building code, and shall not apply to concrete frame buildings with masonry infilled walls.

Buildings that were designed and constructed in accordance with the seismic provisions of the 1993 *BOCA National Building Code*, the 1994 *Standard Building Code*, the 1976 *Uniform Building Code*, the 2000 *International Building Code* or later editions of these codes shall be deemed to comply with these provisions, unless the seismicity of the region has increased since the design of the building.

Exception: This chapter shall not apply to concrete buildings where Seismic Design Category A is permitted.

SECTION A503
GENERAL REQUIREMENTS

A503.1 General. This chapter provides a three-tiered procedure to evaluate the need for seismic rehabilitation of existing concrete buildings. The evaluation shall show that the *existing building* is in compliance with the appropriate part of the evaluation procedure as described in Sections A507, A508 and A509, or shall be modified to conform to the respective acceptance criteria. This chapter does not preclude a building from being evaluated or modified to conform to the acceptance criteria using other well-established procedures, based on rational methods of analysis in accordance with principles of mechanics and approved by the authority having jurisdiction.

A503.2 Properties of cast-in-place materials. Except where specifically permitted herein, the stress-strain relationship of concrete and reinforcement shall be determined from published data or by testing. All available information, including building plans, original calculations and design criteria, site observations, testing and records of typical materials and construction practices prevalent at the time of construction, shall be considered when determining material properties.

For Tier 3 analyses, expected material properties shall be used in lieu of nominal properties in the calculation of strength, stiffness and deformabiltity of building components.

The procedure for testing and determination of material properties shall be from Section 6.2 of ASCE 41-06.

A503.3 Structural observation, testing and inspection. Structural observation, in accordance with Section 1709 of the *International Building Code* shall be required for all structures in which seismic retrofit is being performed in accordance with this chapter. Structural observation shall include visual observation of work for conformance with the approved construction documents and confirmation of existing conditions assumed during design.

Structural testing and inspection for new construction materials shall be in accordance with the building code, except as modified by this chapter.

SECTION A504
SITE GROUND MOTION

A504.1 Site ground motion for Tier 1 analysis. The earthquake loading used for the determination of demand on elements of the structure shall correspond to that required by ASCE 31 Tier 1.

A504.2 Site ground motion for Tier 2 analysis. The earthquake loading used for the determination of demand on elements and the structure shall conform to 75 percent of that required by the building code.

A504.3 Site ground motion for Tier 3 analysis. The site ground motion shall be an elastic design response spectrum prepared in conformance with the building code but having spectral acceleration values equal to 75 percent of the code design response spectrum. The spectral acceleration values shall be increased by the occupancy importance factor when required by the building code.

SECTION A505
TIER 1 ANALYSIS PROCEDURE

A505.1 General. Structures conforming to the requirements of the ASCE 31 Tier 1, Screening Phase, are permitted to be shown to be in conformance with this chapter by submission of a report to the building official as described in this section.

A505.2 Evaluation report. The registered design professional shall prepare a report summarizing the analysis conducted in compliance with this section. As a minimum, the report shall include the following items:

1. Building description.

2. Site inspection summary.
3. Summary of reviewed record documents.
4. Earthquake design data used for the evaluation of the building.
5. Completed checklists.
6. Quick-check analysis calculations.
7. Summary of deficiencies.

SECTION A506
TIER 2 ANALYSIS PROCEDURE

A506.1 General. A Tier 2 analysis includes an analysis using the following linear methods: Static or equivalent lateral force procedures. A linear dynamic analysis may be used to determine the distribution of the base shear over the height of the structure. The analysis, as a minimum, shall address all potential deficiencies identified in Tier 1, using procedures specified in this section.

If a Tier 2 analysis identifies a nonconforming condition, such condition shall be modified to conform to the acceptance criteria. Alternatively, the design professional may choose to perform a Tier 3 analysis to verify the adequacy of the structure.

A506.2 Limitations. A Tier 2 analysis procedure may be used if:

1. There is no in-plane offset in the lateral-force-resisting system.
2. There is no out-of-plane offset in the lateral-force-resisting system.
3. There is no torsional irregularity present in any story. A torsional irregularity may be deemed to exist in a story when the maximum story drift, computed including accidental torsion, at one end of the structure transverse to an axis is more than 1.2 times the average of the story drifts at the two ends of the structure.
4. There is no weak story irregularity at any floor level on any axis of the building. A weak story is one in which the story strength is less than 80 percent of that in the story above. The story strength is the total strength of all seismic-resisting elements sharing the story shear for the direction under consideration.

   Exception: Static or equivalent lateral force procedures shall not be used if:

   1. The building is more than 100 feet (30 480 mm) in height.
   2. The building has a vertical mass or stiffness irregularity (soft story). Mass irregularity shall be considered to exist where the effective mass of any story is more than 150 percent of the effective mass of any adjacent story. A soft story is one in which the lateral stiffness is less than 70 percent of that in the story above or less than 80 percent of the average stiffness of the three stories above.
   3. The building has a vertical geometric irregularity. Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral-force-resisting system in any story is more than 130 percent of that in an adjacent story.
   4. The building has a nonorthogonal lateral-force-resisting system.

A506.3 Analysis procedure. A structural analysis shall be performed for all structures in accordance with the requirements of the building code, except as modified in Section A506. The response modification factor, *R*, shall be selected based on the type of seismic-force-resisting system employed and shall comply with the requirements of Section 101.5.4.1.

A506.3.1 Mathematical model. The three-dimensional mathematical model of the physical structure shall represent the spatial distribution of mass and stiffness of the structure to an extent that is adequate for the calculation of the significant features of its distribution of lateral forces. All concrete and masonry elements shall be included in the model of the physical structure.

Exception: Concrete or masonry partitions that are isolated from the concrete frame members and the floor above.

Cast-in-place reinforced concrete floors with span-to-depth ratios less than three-to-one may be assumed to be rigid diaphragms. Other floors, including floors constructed of precast elements with or without a reinforced concrete topping, shall be analyzed in conformance with the building code to determine if they must be considered semi-rigid diaphragms. The effective in-plane stiffness of the diaphragm, including effects of cracking and discontinuity between precast elements, shall be considered. Parking structures that have ramps rather than a single floor level shall be modeled as having mass appropriately distributed on each ramp. The lateral stiffness of the ramp may be calculated as having properties based on the uncracked cross section of the slab exclusive of beams and girders.

A506.3.2 Component stiffness. Component stiffness shall be calculated based on the approximate values shown in Table 6-5 of ASCE 41.

A506.4 Design, detailing requirements and structural component load effects. The design and detailing of new components of the seismic-force-resisting system shall comply with the requirements of the *International Building Code*, unless specifically modified herein.

A506.5 Acceptance criteria. The calculated strength of a member shall not be less than the load effects on that member.

A506.5.1 Load combinations. For load and resistance factor design (strength design), structures and all portions thereof shall resist the most critical effects from the combinations of factored loads prescribed in the building code.

Exception: For concrete beams and columns, the shear effect shall be determined based on the most critical load combinations prescribed in the building code. The shear load effect, because of seismic forces, shall be multiplied

by a factor of *Cd,* but combined shear load effect need not be greater than *Ve*, as calculated in accordance with Equation (A5-4). M_{pr1} and M_{pr2} are the end moments, assumed to be in the same direction (clockwise or counter clockwise), based on steel tensile stress being equal to 1.25 f_y, where f_y is the specified yield strength.

$$V_e = \frac{M_{pr1} + M_{pr2}}{L} \pm \frac{W_g}{2} \qquad \textbf{(Equation A5-4)}$$

where:

W_g = Total gravity loads on the beam.

A506.5.2 Determination of the strength of members. The strength of a member shall be determined by multiplying the nominal strength of the member by a strength reduction factor, ϕ. The nominal strength of the member shall be determined in accordance with the building code.

SECTION A507
TIER 3 ANALYSIS PROCEDURE

A507.1 General. A Tier 3 evaluation shall be performed using the nonlinear procedures of Section 6.3.1.2.2. of ASCE 41. The general assumptions and requirements of Section 6.0, excluding concrete frames with infills shall be used in the evaluation. Site-ground motions in accordance with Section A504.3 are permitted for this evaluation.