ALTERNATIVE SIMPLIFIED CHAPTER 4:

ALTERNATIVE STRUCTURAL DESIGN CRITERIA FOR SIMPLE BEARING WALL OR BUILDING FRAME SYSTEMS

Alt.4.1 GENERAL

Alt. 4.1.1 Simplified design procedure. Simple bearing wall and building frame systems and their components meeting the qualifications of this section shall be permitted to be designed as prescribed in this chapter as an alternative to the Provisions of Chapter 4, and 5. This chapter also provides alternative procedures for determining site class and site coefficients. The Seismic Design Category shall be determined from Table 1.4-1 using the value of S_{DS} from Section Alt. 4.6.1. Application of this Alternative Simplified Chapter is subject to all of the following limitations:

1. Structure shall qualify for Seismic Use Group I.
2. The Site Class, defined in Sec. 3.5, shall not be Class E or F.
3. Structure shall not exceed three stories in height above grade.
4. Seismic-force resisting system shall be either a Bearing Wall System or Building Frame System, as indicated in Alt. Table 4.3.1
5. The structure shall have at least two lines of lateral resistance in each of two major axis directions.
6. At least one line of resistance shall be provided on each side of the center of mass in each direction.
7. The sum of the strengths of the lines of resistance on each side of the center of mass shall equal at least 40 percent of the story shear.
8. For buildings with a diaphragm that is not flexible, the distance between the center of rigidity and the center of mass parallel to each major axis shall not exceed 15 percent of the greatest width of the diaphragm parallel to that axis.
9. Lines of resistance of the lateral-force-resisting system shall be oriented at angles of no more than 15 degrees from alignment with the major orthogonal horizontal axes of the building.
10. The alternative simplified design procedure shall be used for each major orthogonal horizontal axis direction of the building.
11. System irregularities caused by in-plane or out-of-plane offsets of lateral force-resisting elements shall not be permitted.
12. The lateral-load-resistance of any story shall not be less than 80 percent of the story above.

Alt. 4.1.2 References. The reference documents listed in Sec 4.1.2 shall be used as indicated in this Simplified Alternate Chapter 4.

Alt. 4.1.3 Definitions. The definitions listed in Sec. 4.1.3 shall be used for this Alternative Simplified Chapter 4 in addition to the following:

Major orthogonal horizontal directions: The orthogonal directions that overlay the majority of lateral force resisting elements.

Alt. 4.1.4 Notation

D	The effect of dead load.
E	The effect of horizontal and vertical earthquake-induced forces.
F_i	The portion of the seismic base shear, V, induced at Level i.
F_p	The seismic design force applicable to a particular structural component.
F_x	See Sec. 1.1.5.
h_i	The height above the base to Level i.
h_x	The height above the base to Level x.
I	See Sec. 1.1.5.
Level i	The building level referred to by the subscript i; i = 1 designates the first level above the base.
Level n	The level that is uppermost in the main portion of the of the building.
Level x	See Sec. 1.1.5.
Q_E	The effect of horizontal seismic forces.
R	The response modification coefficient as given in Table 4.3-1.
S_{DS}	See Sec. 3.1.4.
S_S	*See Sec 3.3.1.*
V	The total design shear at the base of the structure in the direction of interest, as determined using the procedure of A4.6.1
V_x	The seismic design shear in Story x. See Sec. A4.6.3.
W	See Sec. 1.1.5.
W_c	Weight of wall.
W_p	Weight of structural component.
w_i	The portion of the seismic weight, W, located at or assigned to Level i.
w_x	See Sec. 1.1.5.

Alt. 4.2 DESIGN BASIS

Alt. 4.2.1 General. The structure shall include complete lateral and vertical-force-resisting systems capable of providing adequate strength, stiffness, and energy dissipation capacity to withstand the design ground motions within the prescribed limits of strength demand. The adequacy of the structural systems shall be demonstrated through construction of a mathematical model and evaluation of this model for the effects of the design ground motions. This evaluation shall consist of a linear elastic analysis in which design seismic forces are distributed and applied throughout the height of the structure in accordance with the procedures of Sec. Alt. 4.6. The corresponding internal forces in all members of the structure shall be determined and evaluated against acceptance criteria contained in these *Provisions*.

Individual members shall be provided with adequate strength to resist the shears, axial forces, and moments determined in accordance with these *Provisions*. A continuous load path, or paths, with adequate strength and stiffness shall be provided to transfer all forces from the point of application to the final point of resistance. The foundation shall be designed to accommodate the forces developed or the movements imparted to the structure by the design ground motions.

Alt. 4.2.2 Combination of Load Effects. The effects on the structure and its components due to gravity loads and seismic forces shall be combined in accordance with the factored load combinations as presented in ASCE 7-02, except that the effect of seismic loads, *E*, shall be as defined herein.

Alt. 4.2.2.1 Seismic load effect. The effect of seismic load *E* shall be defined by Eq. Alt. 4.2-1 as follows for load combinations in which the effects of gravity loads and seismic loads are additive:

$$E = Q_E + 0.2S_{DS}D \qquad \text{(Alt. 4.2-1)}$$

where:

E = the effect of horizontal and vertical earthquake-induced forces,

S_{DS} = the design spectral response acceleration at short periods obtained from Sec. Alt. 4.6.1

D = the effect of dead load, and

Q_E = the effect of horizontal seismic forces.

The effect of seismic load *E* shall be defined by Eq. Alt. 4.2-2 as follows for load combinations in which the effects of gravity counteract seismic load:

$$E = Q_E - 0.2S_{DS}D \qquad \text{(Alt.4.2-2)}$$

where E, Q_E, S_{DS}, and D are as defined above.

Alt. 4.2.2.2 Seismic load effect with overstrength. Where specifically required by these *Provisions*, the design seismic force on components sensitive to the effects of structural overstrength shall be as defined by Eq. 4.2-3 and 4.2-4 for load combinations in which the effects of gravity are respectively additive with or counteractive to the effect of seismic loads:

$$E = \Omega_0 Q_E + 0.2S_{DS}D \qquad \text{(Alt. 4.2-3)}$$

$$E = \Omega_0 Q_E - 0.2S_{DS}D \qquad \text{(Alt. 4.2-4)}$$

where E, Q_E, S_{DS}, and D are as defined above. Ω_0 shall be taken as 2-1/2.

Alt. 4.3 SEISMIC-FORCE-RESISTING SYSTEM

Alt. 4.3.1 Selection and Limitations. The basic lateral and vertical seismic-force-resisting system shall conform to one of the types indicated in Alt. Table 4.3.1. Each type is subdivided by the type of vertical element used to resist lateral seismic forces. The appropriate response modification coefficient, *R*, indicated in Alt.Table 4.3.1 shall be used in determining the base shear and element design forces as indicated in these *Provisions*.

Special framing and detailing requirements are indicated in Sec. Alt. 4.5 and in Chapters 8, 9, 10, 11, and 12 for structures assigned to the various Seismic Design Categories.

Alt. Table 4.3-1 Design Coefficients and Factors for Basic Seismic-Force-Resisting Systems

Basic Seismic-Force-Resisting System	**Detailing Reference Section**	***R*** [a]	**System Limitations by Seismic Design Category** [b]		
			B	**C**	**D,E**
Bearing Wall Systems					
Special reinforced concrete shear walls	9.2.1.6	5	P	P	P
Ordinary reinforced concrete shear walls	9.2.1.4	4	P	P	NP
Detailed plain concrete shear walls	9.2.1.2	2	P	NP	NP
Ordinary plain concrete shear walls	9.2.1.1	1½	P	NP	NP
Intermediate precast shear walls	9.2.1.5	4	P	P	P
Ordinary precast shear walls	9.2.1.3	3	P	NP	NP
Special reinforced masonry shear walls	11.5.6.3	3½	P	P	P
Intermediate reinforced masonry shear walls	11.5.6.2	2½	P	P	NP
Ordinary reinforced masonry shear walls	11.5.6.1	2	P	NP	NP
Detailed plain masonry shear walls	11.4.4.2	2	P	NP	NP
Ordinary plain masonry shear walls	11.4.4.1	1½	P	NP	NP
Prestressed masonry shear walls	11.9	1½	P	NP	NP
Light-frame walls with shear panels	8.4, 12.3.3, 12.4	6½	P	P	P
Light-frame walls with diagonal braces	8.4.2	4	P	P	P
Building Frame Systems					
Special steel concentrically braced frames	AISC Seismic, Part I, Sec. 13	6	P	P	P
Ordinary steel concentrically braced frames	AISC Seismic, Part I, Sec. 14	5	P	P	P
Special reinforced concrete shear walls	9.2.1.6	6	P	P	P

Ordinary reinforced concrete shear walls	9.2.1.4	5	P	P	NP
Detailed plain concrete shear walls	9.2.1.2	2½	P	NP	NP
Ordinary plain concrete shear walls	9.2.1.1	1½	P	NP	NP
Intermediate precast shear walls	9.2.1.5	5	P	P	P
Ordinary precast shear walls	9.2.1.3	4	P	NP	NP
Composite concentrically braced frames	AISC Seismic, Part II, Sec. 12	5	P	P	P
Ordinary composite braced frames	AISC Seismic, Part II, Sec. 13	3	P	P	NP
Composite steel plate shear walls	AISC Seismic, Part II, Sec. 17	6½	P	P	P
Special steel plate shear walls		7	P	P	P
Special composite reinforced concrete shear walls with steel elements	AISC Seismic, Part II, Sec. 16	6	P	P	P
Ordinary composite reinforced concrete shear walls with steel elements	AISC Seismic, Part II, Sec. 15	5	P	P	NP
Special reinforced masonry shear walls	11.5.6.3	4½	P	P	P
Intermediate reinforced masonry shear walls	11.5.6.2	3	P	P	NP
Ordinary reinforced masonry shear walls	11.5.6.1	2	P	NP	NP
Detailed plain masonry shear walls	11.4.4.2	2	P	NP	Np
Ordinary plain masonry shear walls	11.4.4.1	1½	P	NP	NP
Prestressed masonry shear walls	11.9	1½	P	NP	NP
Light-frame walls with shear panels	8.4, 12.3.3, 12.4	7	P	P	P
Steel Systems Not Specifically Detailed for Seismic Resistance (Concentric Braced Frame systems only)	AISC ASD, AISC LRFD, AISI	3	P	P	NP

[a] Response modification coefficient, R, for use throughout these *Provisions*.

[b] P = Permitted and NP = Not Permitted.

Alt. 4.3.1.1 Combinations of Framing Systems. A combination of different structural systems shall not be utilized to resist lateral forces in the same direction. Seismic-force-resisting systems are permitted to differ between the two major horizontal axes of the structure, provided that systems shall not be vertically combined from story to story.

> **Exception:** Penthouses and other rooftop-supported structures weighing less than 25% of the roof level need not be considered a story. The limitations of Sec 4.1.1 do not apply to these structures. The value of *R* used for combinations of different systems shall not be greater than the least value of any of the systems utilized in the same direction. The systems utilized may differ from those of the supporting structure below.

Alt. 4.3.1.1.2 Combination Framing Detailing Requirements. The detailing requirements of Sec. Alt. 4.5 required by the higher response modification coefficient, *R*, shall be used for structural components common to systems having different response modification coefficients.

Alt. 4.3.2 Diaphragm Flexibility. Diaphragms constructed of untopped steel decking, wood structural panels or similar panelized construction may be considered flexible.

Alt. 4.4 APPLICATION OF LOADING The effects of the combination of loads shall be considered as prescribed in Sec. Alt. 4.2.2. The design seismic forces are permitted to be applied separately in each orthogonal direction and the combination of effects from the two directions need not be considered. Reversal of load shall be considered.

Alt. 4.5 DESIGN AND DETAILING REQUIREMENTS The design and detailing of the components of the seismic-force-resisting system shall comply with the requirements of this section. Foundation design shall conform to the applicable requirements of Chapter 7. The materials and the systems composed of those materials shall conform to the applicable requirements and limitations found elsewhere in these Provisions.

Alt. 4.5.1 Connections. All parts of the structure between separation joints shall be inter-connected, and the connection shall be capable of transmitting the seismic force, F_p, induced by the parts being connected. Any smaller portion of the structure shall be tied to the remainder of the structure with elements having a strength of 0.20 times the short period design spectral response acceleration coefficient, S_{DS}, times the weight of the smaller portion or 5 percent of the portion's weight, whichever is greater.

A positive connection for resisting a horizontal force acting parallel to the member shall be provided for each beam, girder, or truss to its support. The connections shall have a minimum strength of 5 percent of the dead load and live load reaction.

Alt. 4.5.2 Openings or Re-entrant Building Corners. Except where as otherwise specifically provided for in these provisions, openings in shear walls, diaphragms or other plate-type elements, shall be provided with reinforcement at the edges of the openings designed to transfer the stresses into the structure. The edge reinforcement shall extend into the body of the wall or diaphragm a distance sufficient to develop the force in the reinforcement.

Alt. 4.5.3 Collector Elements. Collector elements shall be provided with adequate strength to transfer the seismic forces originating in other portions of the structure to the element providing the resistance to those forces. Collector elements, splices, and their connections to resisting elements shall be designed to resist the forces defined in Sec. Alt. 4.2.2.2.

> **Exception**: In structures or portions thereof braced entirely by light-frame shear walls, collector elements, splices, and connections to resisting elements are permitted to be designed to resist forces in accordance with Sec. Alt. 4.5.4.

Alt. 4.5.4 Diaphragms. Floor and roof diaphragms shall be designed to resist the design seismic forces at each level, F_x, calculated in accordance with Sec. Alt. 4.6.2. When the diaphragm is required to transfer design seismic forces from the vertical-resisting elements above the diaphragm to other vertical-resisting elements below the diaphragm due to changes in relative lateral stiffness in the vertical elements, the transferred portion of the seismic shear force at that level, V_x, shall be added to the diaphragm design force. Diaphragms shall provide for both the shear and bending stresses resulting from these forces. Diaphragms shall have ties or struts to distribute the wall anchorage forces into the diaphragm. Diaphragm connections shall be positive, mechanical or welded type connections.

Alt. 4.5.5 Anchorage of Concrete or Masonry Walls

Alt. 4.5.5.1 Seismic Design Category B. Concrete or masonry walls shall be connected, using reinforcement or anchors, to the roof and all floors and members that provide lateral support for the wall or that are supported by the wall. The connection shall be capable of resisting a seismic lateral force induced by the wall of 100 pounds per lineal foot (1500 K/m). Walls shall be designed to resist bending between connections where the spacing exceeds 4 ft (1.2 m).

Alt. 4.5.5.2 Seismic Design Category C and D. In addition to the requirements of Sec. Alt 4.5.5.1, concrete or masonry walls shall be anchored in accordance with this section.. The anchorage shall provide a positive direct connection between the wall and floor, roof, or supporting member capable of resisting horizontal forces specified in this section for structures with flexible diaphragms or of Sec. 6.2.2 (using a_p equal to 1.0 and R_p equal to 2.5) for structures with diaphragms that are not flexible.

Anchorage of walls to flexible diaphragms shall have the strength to develop the out-of-plane force given by Eq. A4.5-1:

$$F_p = 0.8 S_{DS} W p \qquad \text{(Alt. 4.5-1)}$$

where:

F_p = the design force in the individual anchors,

S_{DS} = the design spectral response acceleration at short periods per Sec. Alt. 4.6.1, and

W_p = the weight of the wall tributary to the anchor

Diaphragms shall be provided with continuous ties or struts between diaphragm chords to distribute these anchorage forces into the diaphragms. Added chords are permitted to be used to form subdiaphragms to transmit the anchorage forces to the main continuous cross ties. The maximum length to width ratio of the structural subdiaphragm shall be 2-1/2 to 1. Connections and anchorages capable of resisting the prescribed forces shall be provided between the diaphragm and the attached components. Connections shall extend into the diaphragm a sufficient distance to develop the force transferred into the diaphragm.

In wood diaphragms, the continuous ties shall be in addition to the diaphragm sheathing. Anchorage shall not be accomplished by use of toe nails or nails subject to withdrawal nor shall wood ledgers of framing be used in cross-grain bending or cross-grain tension. The diaphragm sheathing shall not be considered effective as providing the ties or struts required by this section.

In metal deck diaphragms, the metal deck shall not be used as the continuous ties required by this section in the direction perpendicular to the deck span.

Diaphragm to wall anchorage using embedded straps shall be attached to or hooked around the reinforcing steel or otherwise terminated so as to effectively transfer forces to the reinforcing steel.

Alt. 4.5.6 Bearing Walls. Exterior and interior bearing walls and their anchorage shall be designed for a force equal to 40 percent of the short period design spectral response acceleration S_{DS} times the weight of wall, W_c, normal to the surface, with a minimum force of 10 percent of the weight of the wall. Interconnection of wall elements and connections to supporting framing systems shall have sufficient ductility, rotational capacity, or sufficient strength to resist shrinkage, thermal changes, and differential foundation settlement when combined with seismic forces.

Alt. 4.5.7 Anchorage of Nonstructural Systems. When required by Chapter 6, all portions or components of the structure shall be anchored for the seismic force, F_p, prescribed therein.

Alt. 4.6 SIMPLIFIED LATERAL FORCE ANALYSIS PROCEDURE

An equivalent lateral force analysis shall consist of the application of equivalent static lateral forces to a linear mathematical model of the structure. The lateral forces applied in each direction shall sum to a total seismic base shear given by Sec. Alt. 4.6.1 and shall be distributed vertically in accordance with Sec. Alt. 4.6.2. For purposes of analysis, the structure shall be considered fixed at the base.

Alt. 4.6.1 Seismic Base Shear

The seismic base shear, V, in a given direction shall be determined in accordance with formula Alt. 4.6-1:

$$V = \frac{1.25 S_{DS}}{R} W \qquad \text{(Alt. 4.6-1)}$$

where:

S_{DS} = $2/3 F_a S_s$, where F_a may be taken as 1.0 for rock sites, 1.4 for soil sites, or determined in accordance with Section 3.3.2. For the purpose of this section, sites may be considered to be rock if there is no more than 10 ft (3 m) of soil between the rock surface and the bottom of spread footing or mat foundation. In calculating S_{DS}, S_s need not be taken larger than 1.5.

R = the response modification factor from Table A4.3.1 and

W = the total dead load and applicable portions of other loads listed below:

1. In areas used for storage, a minimum of 25 percent of the floor live load shall be applicable. The live load may be reduced for tributary area as permitted by the structural code administered by the authority having jurisdiction. Floor live load in public garages and open parking structures is not applicable.
2. Where an allowance for partition load is included in the floor load design, the actual partition weight or a minimum weight of 10 psf (500 Pa/m^2) of floor area, whichever is greater, shall be applicable.
3. Total operating weight of permanent equipment.
4. In areas where the design flat roof snow load does not exceed 30 pounds per square foot, the effective snow load is permitted to be taken as zero. In areas where the design snow load is greater than 30 pounds per square foot and where siting and load duration conditions warrant and when approved by the authority having jurisdiction, the effective snow load is permitted to be reduced to not less than 20 percent of the design snow load.

Alt. 4.6.2 Vertical distribution. The forces at each level shall be calculated using the following formula:

$$F_x = \frac{1.25 S_{DS}}{R} w_x \qquad \text{(Alt. 4.6-2)}$$

where w_x = the portion of the effective seismic weight of the structure, W at Level x.

Alt. 4.6.3 Horizontal Shear Distribution. The seismic design story shear in any story, V_x (kip or kN), shall be determined from the following equation:

$$V_x = \sum_{i=x}^{n} F_i \qquad \text{(Alt. 4.6-3)}$$

where F_i = the portion of the seismic base shear, V (kip or kN) induced at Level i.

Alt. 4.6.3.1 Flexible Diaphragm Structures. The seismic design story shear in stories of structures with flexible diaphragms, as defined in Sec. Alt. 4.3.2, shall be distributed to the vertical elements of the lateral force resisting system using tributary area rules. Two- dimensional analysis shall be permitted where diaphragms are flexible.

Alt. 4.6.3.2 Structures with Diaphragms that are not Flexible. For structures with diaphragms that are not flexible, as defined in Sec. Alt. 4.3.2, the seismic design story shear, V_x, (kip or kN) shall be distributed to the various vertical elements of the seismic-force-resisting system in the story under consideration based on the relative lateral stiffnesses of the vertical elements and the diaphragm.

Alt. 4.6.3.2.1 Torsion. The design of structures with diaphragms that are not flexible shall include the torsional moment, M_t (kip-ft or KN-m) resulting from eccentric location of the masses.

Alt. 4.6.4 Overturning. The structure shall be designed to resist overturning effects caused by the seismic forces determined in Sec. Alt. 4.6.2. At any story, the increment of overturning moment in the story under consideration shall be distributed to the various vertical force-resisting elements in the same proportion as the distribution of the horizontal shears to those elements.

The overturning moments at Level x, M_x (kip-ft or kN-m) shall be determined from the following equation:

$$M_x = \sum_{i=x}^{n} F_i \left(h_i - h_x\right) \qquad \text{(Alt.4.6-4)}$$

where:

F_i = the portion of the seismic base shear, V, induced at Level i, and

h_i and h_x = the height (ft or m) from the base to Level i or x.

The foundations of structures shall be designed for 75% of the foundation overturning design moment, M_f (kip-ft or kN-m) at the foundation-soil interface.

Alt. 4.6.5 Drift Limits and Building Separation. Structural drift need not be calculated. When a drift value is needed for use in material standards to determine structural separations between buildings, for design of cladding, or for other design requirements, it shall be taken as 1% of building height. All portions of the structure shall be designed to act as an integral unit in resisting seismic forces unless separated structurally by a distance sufficient to avoid damaging contact under the total deflection, δ_X,, as defined in Sec 5.2.6.1.

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