CHAPTER A4

EARTHQUAKE HAZARD REDUCTION IN EXISTING WOOD-FRAME RESIDENTIAL BUILDINGS WITH SOFT, WEAK OR OPEN-FRONT WALLS

SECTION A401 GENERAL

A401.1 Purpose. The purpose of this chapter is to promote public welfare and safety by reducing the risk of death or injury that may result from the effects of earthquakes on existing wood-frame, multiunit residential buildings. The ground motions of past earthquakes have caused the loss of human life, personal injury and property damage in these types of buildings. This chapter creates minimum standards to strengthen the more vulnerable portions of these structures. When fully followed, these minimum standards will improve the performance of these buildings but will not necessarily prevent all earthquake-related damage.

A401.2 Scope. The provisions of this chapter shall apply to all existing Occupancy Group R-1 and R-2 buildings of wood construction or portions thereof where:

1. The ground floor portion of the wood-frame structure contains parking or other similar open floor space, which causes soft, weak or open-front wall lines as defined in this chapter, and there exists one or more stories above, or
2. The walls of any story or basement of wood construction are laterally braced with nonconforming structural materials as defined in this chapter, a soft or weak wall line exists as defined in this chapter and there exist two or more stories above.
3. The structure is assigned to Seismic Design Category C, D or E.

SECTION A402 DEFINITIONS

Notwithstanding the applicable definitions, symbols and notations in the building code, the following definitions shall apply for the purposes of this chapter:

APARTMENT HOUSE. Any building or portion thereof that contains three or more dwelling units. For the purposes of this chapter, "apartment house" includes residential condominiums.

ASPECT RATIO. The span-width ratio for horizontal diaphragms and the height-length ratio for vertical diaphragms.

CONGREGATE RESIDENCE. A congregate residence is any building or portion thereof for occupancy by other than a family that contains facilities for living, sleeping and sanitation as required by the building code and that may include facilities for eating and cooking. A congregate residence may be a shelter, convent, monastery, dormitory, fraternity or sorority house, but does not include jails, hospitals, nursing homes, hotels or lodging houses.

CRIPPLE WALL. A wood-frame stud wall extending from the top of the foundation wall to the underside of the lowest floor framing.

DWELLING UNIT. Any building or portion thereof for not more than one family that contains living facilities, including provisions for sleeping, eating, cooking and sanitation as required by the building code or congregate residence for 10 or fewer persons.

EXPANSION ANCHOR. An approved mechanical fastener placed in hardened concrete that is designed to expand in a self-drilled or pre-drilled hole of a specified size and engage the sides of the hole in one or more locations to develop shear and/or tension resistance to applied loads without grout, adhesive or drypack.

GROUND FLOOR. Any floor whose elevation is immediately accessible from an adjacent grade by vehicles or pedestrians. The ground floor portion of the structure does not include any floor that is completely below adjacent grades.

GUESTROOM. Any room or rooms used or intended to be used by a guest for sleeping purposes. Every 100 square feet (9.3 m^2) of superficial floor area in a congregate residence shall be considered a guestroom.

HOTEL. Any building containing six or more guestrooms intended or designed to be used, rented, hired out to be occupied, or that are occupied, for sleeping purposes by guests.

LIFE SAFETY PERFORMANCE LEVEL. The building performance level that includes significant damage to both structural and nonstructural components during a design earthquake, though at least some margin against either partial or total structural collapse remains. Injuries may occur, but the level of risk for life-threatening injury and entrapment is low.

LODGING HOUSE. Any building or portion thereof containing at least one but not more than five guest rooms where rent is paid in money, goods, labor or otherwise.

MOTEL. Motel shall mean a hotel as defined in this chapter.

MULTIUNIT RESIDENTIAL BUILDINGS. Hotels, lodging houses, congregate residences and apartment houses.

NONCONFORMING STRUCTURAL MATERIALS. Wall bracing materials other than wood structural panels or diagonal sheathing.

OPEN-FRONT WALL LINE. An exterior wall line, without vertical elements of the lateral-force-resisting system, that requires tributary seismic forces to be resisted by diaphragm rotation or excessive cantilever beyond parallel lines of shear walls. Diaphragms that cantilever more than 25 percent of the distance between lines of lateral-force-resisting elements from which the diaphragm cantilevers shall be considered excessive.

Exterior exit balconies of 6 feet (1829 mm) or less in width shall not be considered excessive cantilevers.

RETROFIT. An improvement of the lateral-force-resisting system by alteration of existing structural elements or addition of new structural elements.

SOFT WALL LINE. A wall line whose lateral stiffness is less than that required by story drift limitations or deformation compatibility requirements of this chapter. In lieu of analysis, a soft wall line may be defined as a wall line in a story where the story stiffness is less than 70 percent of the story above for the direction under consideration.

STORY. A story as defined by the building code, including any basement or underfloor space of a building with cripple walls exceeding 4 feet (1219 mm) in height.

STORY STRENGTH. The total strength of all seismic-resisting elements sharing the same story shear in the direction under consideration.

WALL LINE. Any length of wall along a principal axis of the building used to provide resistance to lateral loads. Parallel wall lines separated by less than 4 feet (1219 mm) shall be considered one wall line for the distribution of loads.

WEAK WALL LINE. A wall line in a story where the story strength is less than 80 percent of the story above in the direction under consideration.

SECTION A403
ANALYSIS AND DESIGN

A403.1 General. Buildings within the scope of this chapter shall be analyzed, designed and constructed in conformance with the building code, except as modified in this chapter.

Exception: Buildings for which the prescriptive measures provided in Section A405 apply and are used.

No alteration of the existing lateral-force-resisting or vertical-load-carrying system shall reduce the strength or stiffness of the existing structure. When any portion of a building within the scope of this chapter is constructed on or into a slope steeper than one unit vertical in three units horizontal, the lateral-force-resisting system at and below the base level diaphragm shall be analyzed for the effects of concentrated lateral forces at the base caused by this hillside condition.

A403.2 Scope of analysis. This chapter requires the alteration, repair, replacement or addition of structural elements and their connections to meet the strength and stiffness requirements herein. The lateral-load-path analysis shall include the resisting elements and connections from the wood diaphragm immediately above any soft, weak or open-front wall lines to the foundation soil interface or to the uppermost floor or roof of a Type I structure below. Stories above the uppermost story with a soft, weak or open-front wall line need not be modified. The lateral-load-path analysis for added structural elements shall also include evaluation of the allowable soil-bearing and lateral pressures in accordance with the building code.

Exception: When an open-front, weak or soft wall line exists because of parking at the ground floor of a two-story building and the parking area is less than 20 percent of the ground floor area, then only the wall lines in the open, weak or soft directions of the enclosed parking area need comply with the provisions of this chapter.

A403.3 Design base shear. The design base shear in a given direction shall be 75 percent of the value required for similar new construction in accordance with the building code.

A403.4 Vertical distribution of forces. The total seismic force shall be distributed over the height of the structure as for new construction in accordance with the building code. Distribution of force by story weight shall be permitted for two-story buildings. The value of R used in the design of any story shall be less than or equal to the value of R used in the given direction for the story above.

A403.5 Weak story limitation. Every weak story shall be strengthened to the lesser of:

1. Ω_0 times the story shear prescribed by Sections A403.3 and A403.4.
2. In two-story buildings up to 30 feet (9144 mm) in height, 65 percent of the strength of the story above. In all other buildings, 80 percent of the strength of the story above.

A403.6 Story drift limitation. The calculated story drift for each retrofitted story shall not exceed the allowable deformation compatible with all vertical-load-resisting elements and 0.025 times the story height. The calculated story drift shall not be reduced by the effects of horizontal diaphragm stiffness but shall be increased when these effects produce rotation. Drift calculations shall be in accordance with the building code.

The effects of rotation and soil stiffness shall be included in the calculated story drift when lateral loads are resisted by vertical elements whose required depth of embedment is determined by pole formulas. The coefficient of subgrade reaction used in the deflection calculations shall be provided from an approved geotechnical engineering report or other approved methods.

A403.7 P Δ effects. The requirements of the building code shall apply, except as modified herein. All structural framing elements and their connections not required by design to be part of the lateral-force-resisting system shall be designed and/or detailed to be adequate to maintain support of design dead plus live loads when subjected to the expected deformations caused by seismic forces. The stress analysis of cantilever columns shall use a buckling factor of 2.1 for the direction normal to the axis of the beam.

A403.8 Ties and continuity. All parts of the structure included in the scope of Section A403.2 shall be interconnected as required by the building code.

A403.8.1 Cripple walls. Cripple walls braced with nonconforming structural materials shall be braced in accordance with this chapter. When a single top plate exists in the cripple wall, all end joints in the top plate shall be tied.

Ties shall be connected to each end of the discontinuous top plate and shall be equal to one of the following:

1. Three-inch by 6-inch (76 mm by 152 mm), 18-gage galvanized steel, nailed with six 8d common nails at each end.
2. One and one-fourth-inch by 12-inch (32 mm by 305 mm), 18-gage galvanized steel, nailed with six 16d common nails at each end.
3. Two-inch by 4-inch by 12-inch (51 mm by 102 mm by 305 mm) wood blocking, nailed with six 16d common nails at each end.

A403.9 Collector elements. Collector elements shall be provided that can transfer the seismic forces originating in other portions of the building to the elements within the scope of Section A403.2 that provide resistance to those forces.

A403.10 Horizontal diaphragms. The strength of an existing horizontal diaphragm sheathed with wood structural panels or diagonal sheathing need not be investigated unless the diaphragm is required to transfer lateral forces from vertical elements of the seismic-force-resisting system above the diaphragm to elements below the diaphragm because of an offset in placement of the elements.

Wood diaphragms with stories above shall not be allowed to transmit lateral forces by rotation or cantilever except as allowed by the building code; however, rotational effects shall be accounted for when unsymmetric wall stiffness increases shear demands.

Exception: Diaphragms that cantilever 25 percent or less of the distance between lines of lateral-load-resisting elements from which the diaphragm cantilevers may transmit their shears by cantilever, provided that rotational effects on shear walls parallel and perpendicular to the load are taken into account.

A403.11 Wood-framed shear walls. Wood-framed shear walls shall have strength and stiffness sufficient to resist the seismic loads and shall conform to the requirements of this section.

A403.11.1 Gypsum or cement plaster products. Gypsum or cement plaster products shall not be used to provide lateral resistance in a soft or weak story or in a story with an open-front wall line, whether or not new elements are added to mitigate the soft, weak or open-front condition.

A403.11.2 Wood structural panels.

A403.11.2.1 Drift limit. Wood structural panel shear walls shall meet the story drift limitation of Section A403.6. Conformance to the story drift limitation shall be determined by approved testing or calculation, not by the use of an aspect ratio. Calculated deflection shall be determined according to *International Building Code* Equation 23-1 and shall be increased by 25 percent. Contribution to the shear wall deflection from the anchor or tie-down slippage shall also be included. The slippage contribution shall include the vertical elongation of the connector metal components, the vertical slippage of the connectors to framing members, localized crushing of wood due to bearing loads and shrinkage of the wood elements because of changes in moisture content as a result of aging. The total vertical slippage shall be multiplied by the shear panel aspect ratio and added to the total horizontal deflection. Individual shear panels shall be permitted to exceed the maximum aspect ratio, provided the allowable story drift and allowable shear capacities are not exceeded.

A403.11.2.2 Openings. Shear walls are permitted to be designed for continuity around openings in accordance with the building code. Blocking and steel strapping shall be provided at corners of the openings to transfer forces from discontinuous boundary elements into adjoining panel elements. Alternatively, perforated shear wall provisions of the building code are permitted to be used.

A403.11.2.3 Wood species of framing members. Allowable shear values for wood structural panels shall consider the species of the framing members. When the allowable shear values are based on Douglas fir-larch framing members, and framing members are constructed of other species of lumber, the allowable shear values shall be multiplied by the following factors: 0.82 for species with specific gravities greater than or equal to 0.42 but less than 0.49, and 0.65 for species with specific gravities less than 0.42. Redwood shall use 0.65 and hem fir shall use 0.82, unless otherwise approved.

A403.11.3 Substitution for 3-inch (76 mm) nominal width framing members. Two 2-inch (51 mm) nominal width framing members shall be permitted in lieu of any required 3-inch (76 mm) nominal width framing member when the existing and new framing members are of equal dimensions, when they are connected as required to transfer the in-plane shear between them, and when the sheathing fasteners are equally divided between them.

A403.11.4 Hold-down connectors.

A403.11.4.1 Expansion anchors in tension. Expansion anchors that provide tension strength by friction resistance shall not be used to connect hold-down devices to existing concrete or masonry elements. Expansion anchors that provide tension strength by bearing (commonly referenced as "undercut" anchors) shall be permitted.

A403.11.4.2 Required depth of embedment. The required depth of embedment or edge distance for the anchor used in the hold-down connector shall be provided in the concrete or masonry below any plain concrete slab unless satisfactory evidence is submitted to the building official that shows that the concrete slab and footings are of monolithic construction.

A403.11.4.3 Required preload of bolted hold-down connectors. Bolted hold-down connectors shall be preloaded to reduce slippage of the connector. Preloading shall consist of tightening the nut on the tension anchor after the placement but before the tightening of the shear bolts in the panel boundary flange member. The tension anchor shall be tightened until the shear bolts are in firm contact with the edge of the hole nearest

the direction of the tension anchor. Hold-down connectors with self-jigging bolt standoffs shall be installed in a manner to permit preloading.

SECTION A404
PHASED CONSTRUCTION

The work specified in this chapter shall be permitted to be done in the following phases. Work shall start with Phase 1 unless otherwise approved by the building official. When the building does not contain the conditions associated with the given phase, the work shall proceed to the next phase.

Phase 1 Work. The first phase shall include all work in the lowest story with a soft, weak or open-front wall line and all foundation work.

Phase 2 Work. The second phase shall include wood-framed walls in any story with two or more stories above that are laterally braced with nonconforming structural materials.

Phase 3 Work. The third and final phase shall include all required work not performed in Phase 1 or Phase 2.

SECTION A405
PRESCRIPTIVE MEASURES FOR WEAK STORY

A405.1 Limitation. These prescriptive measures shall apply only to two-story buildings and only when deemed appropriate by the code official. These prescriptive measures rely on rotation of the second floor diaphragm to distribute the seismic load between the side and rear walls of the ground floor open area. In the absence of an existing floor diaphragm of wood structural panel or diagonal sheathing, a new wood structural panel diaphragm of minimum thickness of $^3/_4$ inch (19 mm) and with 10d common nails at 6 inches (152 mm) on center shall be applied.

A405.1.1 Additional conditions. To qualify for these prescriptive measures, the following additional conditions need to be satisfied by the retrofitted structure:

1. Diaphragm aspect ratio L/W is less than 0.67, where W is the diaphragm dimension parallel to the soft, weak or open-front wall line and L is the distance in the orthogoal direction between that wall line and the rear wall of the ground floor open area.
2. Minimum length of side shear walls = 20 feet (6096 mm).
3. Minimum length of rear shear wall = three-fourth of rear wall.
4. No plan or vertical irregularities other than a soft, weak or open-front wall line.
5. Roofing weight less than or equal to 5 pounds per square foot (240 N/m^2).
6. Aspect ratio of the full second floor diaphragm meets the requirements of the building code for new construction.

A405.2 Minimum required retrofit.

A405.2.1 Anchor bolt size and spacing. The anchor bolt size and spacing shall be a minimum of $^3/_4$ inch (19 mm) in diameter at 32 inches (813 mm) on center. Where existing bolts are inadequate, new steel plates bolted to the side of the foundation and nailed to the sill may be used, such as an approved connector.

A405.2.2 Connection to floor above. Shear wall top plates shall be connected to blocking or rim joist at upper floor with a minimum of 18-gage galvanized steel angle clips $4^1/_2$ inches (114 mm) long with 12-8d nails spaced no farther than 16 inches (406 mm) on center, or by equivalent shear transfer methods.

A405.2.3 Shear wall sheathing. The shear wall sheathing shall be a minimum of $^{15}/_{32}$ inch (11.9 mm) 5-Ply Structural I with 10d nails at 4 inches (102 mm) on center at edges and 12 inches (305 mm) on center at field; blocked all edges with 3 by 4 or larger. Where existing sill plates are less than 3-by thick, place flat 2-by on top of sill between studs, with flat 18-gage galvanized steel clips $4^1/_2$ inches (114 mm) long with 12-8d nails or $^3/_8$-inch-diameter (9.5 mm) lags through blocking for shear transfer to sill plate. Stagger nailing from wall sheathing between existing sill and new blocking. Anchor new blocking to foundation as specified above.

A405.2.4 Shear wall hold-downs. Shear walls shall be provided with hold-down anchors at each end. Two hold-down anchors are required at intersecting corners. Hold-downs shall be approved connectors with a minimum $^5/_8$-inch-diameter (15.9 mm) threaded rod or other approved anchor with a minimum allowable load of 4,000 pounds (17.8 kN). Anchor embedment in concrete shall not be less than 5 inches (127 mm). Tie-rod systems shall not be less than $^5/_8$ inch (15.9 mm) in diameter unless using high strength cable. Threaded rod or high strength cable elongation shall not exceed $^5/_8$ inch (15.9 mm) using design forces.

SECTION A406
MATERIALS OF CONSTRUCTION

A406.1 New materials. All materials approved by the building code, including their appropriate allowable stresses and limiting aspect ratios, shall be permitted to meet the requirements of this chapter.

A406.2 Allowable foundation and lateral pressures. The use of default values from the building code for continuous and isolated concrete spread footings shall be permitted. For soil that supports embedded vertical elements, Section A403.6 shall apply.

A406.3 Existing materials. All existing materials shall be in sound condition and constructed in general conformance to the building code before they are permitted to be used to resist the lateral loads prescribed in this chapter. The verification of existing materials conditions and their conformance to these requirements shall be made by physical observation reports, material testing or record drawings as determined by the structural designer and as approved by the building official.

A406.3.1 Horizontal wood diaphragms. Allowable shear values for existing horizontal wood diaphragms that require analysis under Section A403.10 are permitted to be taken from Table A4-A. The values in Table A4-A shall be used for allowable stress design. Design forces based on strength design shall be reduced to allowable stress levels before comparison with the limiting values in the table.

A406.3.2 Wood-structural-panel shear walls.

A406.3.2.1 Allowable nail slip values. The use of box nails and unseasoned lumber are permitted to be assumed. When the required drift calculations of Section A403.11.2.1 rely on the slip values for common nails or surfaced dry lumber, their use in construction shall be verified by exposure. The design value of the box nails shall be assumed to be similar to that of common nails having the same diameter. Verification of surfaced dry lumber shall be by identification conforming to the building code.

A406.3.2.2 Plywood panel construction. When verification of the existing plywood materials is by use of record drawings alone, the panel construction for plywood shall be assumed to be of three plies. The plywood modulus "G" shall be assumed equal to 50,000 pounds per square inch (345 MPa).

A406.3.3 Existing wood framing. Wood framing is permitted to use the design stresses specified in the building code under which the building was constructed or other stress criteria approved by the building official.

A406.3.4 Structural steel. All existing structural steel shall be permitted to use the allowable stresses for Grade A36. Existing pipe or tube columns shall be assumed to be of minimum wall thickness unless verified by testing or exposure.

A406.3.5 Strength of concrete. All existing concrete footings shall be permitted to be assumed to be plain concrete with a compressive strength of 2,000 pounds per square inch (13.8 MPa). Existing concrete compressive strength taken greater than 2,000 pounds per square inch (13.8 MPa) shall be verified by testing, record drawings or department records.

A406.3.6 Existing sill plate anchorage. Existing cast-in-place anchor bolts shall be permitted to use the allowable service loads for bolts with proper embedment when used for shear resistance to lateral loads.

SECTION A407
INFORMATION REQUIRED TO BE ON THE PLANS

A407.1 General. The plans shall show all information necessary for plan review and for construction and shall accurately reflect the results of the engineering investigation and design. The plans shall contain a note that states that this retrofit was designed in compliance with the criteria of this chapter.

A407.2 Existing construction. The plans shall show existing diaphragm and shear wall sheathing and framing materials; fastener type and spacing; diaphragm and shear wall connections; continuity ties; and collector elements. The plans shall also show the portion of the existing materials that needs verification during construction.

A407.3 New construction.

A407.3.1 Foundation plan elements. The foundation plan shall include the size, type, location and spacing of all anchor bolts with the required depth of embedment, edge and end distance; the location and size of all shear walls and all columns for braced frames or moment frames; referenced details for the connection of shear walls, braced frames or moment-resisting frames to their footing; and referenced sections for any grade beams and footings.

A407.3.2 Framing plan elements. The framing plan shall include the length, location and material of shear walls; the location and material of frames; references on details for the column-to-beam connectors, beam-to-wall connections and shear transfers at floor and roof diaphragms; and the required nailing and length for wall top plate splices.

A407.3.3 Shear wall schedule, notes and details. Shear walls shall have a referenced schedule on the plans that includes the correct shear wall capacity in pounds per foot (N/m); the required fastener type, length, gauge and head size; and a complete specification for the sheathing material and its thickness. The schedule shall also show the required location of 3-inch (76 mm) nominal or two 2-inch (51 mm) nominal edge members; the spacing of shear transfer elements such as framing anchors or added sill plate nails; the required hold-down with its bolt, screw or nail sizes; and the dimensions, lumber grade and species of the attached framing member.

Notes shall show required edge distance for fasteners on structural wood panels and framing members; required flush nailing at the plywood surface; limits of mechanical penetrations; and the sill plate material assumed in the design. The limits of mechanical penetrations shall also be detailed showing the maximum notching and drilled hole sizes.

A407.3.4 General notes. General notes shall show the requirements for material testing, special inspection and structural observation.

SECTION A408
QUALITY CONTROL

A408.1 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.

TABLE A4-A—ALLOWABLE VALUES FOR EXISTING MATERIALS

EXISTING MATERIALS OR CONFIGURATIONS OF MATERIALS[a]	ALLOWABLE VALUES × 14.594 for N/m
1. Horizontal diaphragms[b]	
1.1. Roofs with straight sheathing and roofing applied directly to the sheathing	-100 lbs. per ft. for seismic shear
1.2. Roofs with diagonal sheathing and roofing applied directly to the sheathing	250 lbs. per ft. for seismic shear
1.3. Floors with straight tongue-and-groove sheathing	100 lbs. per ft. for seismic shear
1.4. Floors with straight sheathing and finished wood flooring with board edges offset or perpendicular	500 lbs. per ft. for seismic shear
1.5. Floors with diagonal sheathing and finished wood flooring	600 lbs. per ft. for seismic shear
2. Crosswalls[b, c]	Per side:
2.1. Plaster on wood or metal lath	200 lbs. per ft. for seismic shear
2.2. Plaster on gypsum lath	175 lbs. per ft. for seismic shear
2.3. Gypsum wallboard, unblocked edges	75 lbs. per ft. for seismic shear
2.4. Gypsum wallboard, blocked edges	125 lbs. per ft. for seismic shear
3. Existing footings, wood framing, structural steel and reinforced steel	
3.1. Plain concrete footings	f'_c = 1,500 psi (10.3 MPa) unless otherwise shown by tests[d]
3.2. Douglas fir wood	Allowable stress same as D.F. No. 1[d]
3.3. Reinforcing steel	f_s = 18,000 psi (124 MPa) maximum[d]
3.4. Structural steel	f_s = 20,000 psi (138 MPa) maximum[d]

For SI: 1 foot = 304.8 mm.

a. Material must be sound and in good condition.

b. A one-third increase in allowable stress is not allowed.

c. Shear values of these materials may be combined, except the total combined value shall not exceed 300 pounds per foot.

d. Stresses given may be increased for combination of loads as specified in the building code.