

# Chapter A4 Earthquake Risk Reduction in Wood-Frame Residential Buildings With Soft, Weak or Open Front Walls

## Section A401 General

### [BS] 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.

### [BS] 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 the structure has a soft, weak, or open-front wall line, and there exists one or more stories above.

## 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:

**[BS] ASPECT RATIO.** The span-width ratio for horizontal diaphragms and the height-length ratio for shear walls.

**[BS] 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.

**[BS] NONCONFORMING STRUCTURAL MATERIALS.** Wall bracing materials other than wood structural panels or diagonal sheathing.

**[BS] 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.

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

**[BS] 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.

**[BS] 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.

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

**[BS] 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.

**[BS] 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

#### [BS] A403.1 General

All modifications required by the provisions in this chapter shall be designed in accordance with the *California Building Code* provisions for new construction, except as modified by this chapter.

**Exception:** Buildings for which the prescriptive measures provided in Section A404 apply and are used.

No alteration of the existing lateral force-resisting system or vertical load-carrying system shall reduce the strength or stiffness of the existing structure, unless the altered structure would remain in conformance to the building code and this chapter.

### **[BS] 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 story of a podium structure comprised of steel, masonry, or concrete structural systems that supports the upper, wood-framed structure. Stories above the uppermost story with a soft, weak, or open-front wall line shall be considered in the analysis but 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. Where 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 (33-percent slope), 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.

**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.

### **[BS] A403.3 Design base shear and design parameters**

The design base shear in a given direction shall be permitted to be 75 percent of the value required for similar new construction in accordance with the building code. The value of  $R$  used in the design of the strengthening of any story shall not exceed the lowest value of  $R$  used in the same direction at any story above. The system overstrength factor,  $\Delta_0$  and the deflection amplification factor,  $C_d$  shall be not less than the largest respective value corresponding to the  $R$  factor being used in the direction under consideration.

#### **Exceptions:**

1. For structures assigned to Seismic Design Category B, values of  $R$ ,  $\Delta_0$  and  $C_d$  shall be permitted to be based on the seismic force-resisting system being used to achieve the required strengthening.
2. For structures assigned to Seismic Design Category C or D, values of  $R$ ,  $\Delta_0$  and  $C_d$  shall be permitted to be based on the seismic force-resisting system being used to achieve the required strengthening, provided that when the strengthening is complete, the strengthened structure will not have an extreme weak story irregularity defined as Type 5b in ASCE 7 Table 12.3-2.
3. For structures assigned to Seismic Design Category E, values of  $R$ ,  $\Delta_0$  and  $C_d$  shall be permitted to be based on the seismic force-resisting system being used to achieve the required strengthening, provided that when the strengthening is complete, the strengthened structure will not have an extreme soft story, a weak story, or an extreme weak story irregularity defined, respectively, as Types 1b, 5a and 5b in ASCE 7 Table 12.3-2.

### **[BS] A403.4 Story drift**

#### **limitations**

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.

#### **[BS] A403.4.1 Pole structures**

The effects of rotation and soil stiffness shall be included in the calculated story drift where lateral loads are resisted by vertical elements whose required depth of embedment is determined by pole formulas. The coefficient of subgrade reaction used in deflection calculations shall be based on a geotechnical investigation conducted in accordance with the building code.

### **[BS] A403.5 Deformation compatibility and P $\Delta$ 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 expected gravity loads when subjected to the expected deformations caused by seismic forces. Increased demand due to P  $\Delta$  effects and story sidesway stability shall be considered in retrofit stories that rely on the strength and stiffness of cantilever columns for lateral resistance.

### **[BS] A403.6 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.

### **[BS] A403.7 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.

### **[BS] A403.8 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.

Rotational effects shall be accounted for when asymmetric wall stiffness increases shear demands.

#### **[BS] A403.9 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.

##### **[BS] A403.9.1 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.

##### **[BS] A403.9.2 Wood structural panels**

###### **[BS] A403.9.2.1 Drift limit**

Wood structural panel shear walls shall meet the story drift limitation of Section A403.4. Conformance to the story drift limitation shall be determined by approved testing or calculation. Individual shear panels shall be permitted to exceed the maximum aspect ratio, provided the allowable story drift and allowable shear capacities are not exceeded.

###### **[BS] A403.9.2.2 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.

##### **[BS] A403.9.3 Hold-down connectors**

###### **[BS] A403.9.3.1 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.

###### **[BS] A403.9.3.2 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 code official that shows that the concrete slab and footings are of monolithic construction.

#### **Section A404 Prescriptive Measures for Weak Story**

##### **[BS] A404.1**

###### **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  $\frac{3}{4}$  inch (19.1 mm) and with 10d common nails at 6 inches (152 mm) on center shall be applied.

###### **[BS] A404.1.1 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 orthogonal 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-fourths of the total rear wall length.
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<sup>2</sup>).
6. Aspect ratio of the full second floor diaphragm meets the requirements of the building code for new construction.

##### **[BS] A404.2 Minimum required retrofit**

**[BS] A404.2.1 Anchor size and spacing**

The anchor size and spacing shall be a minimum of  $3/4$  inch (19.1 mm) in diameter at 32 inches (813 mm) on center. Where existing anchors are inadequate, supplemental or alternative approved connectors (such as new steel plates bolted to the side of the foundation and nailed to the sill) shall be used.

**[BS] A404.2.2 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  $4\frac{1}{2}$  inches (114 mm) long with 12-8d nails spaced no farther than 16 inches (406 mm) on center, or by equivalent shear transfer methods.

**[BS] A404.2.3 Shear wall sheathing**

The shear wall sheathing shall be a minimum of  $1\frac{5}{32}$  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 board 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  $4\frac{1}{2}$  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.

**[BS] A404.2.4 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 be not less than 5 inches (127 mm). Tie-rod systems shall be not less than  $5/8$  inch (15.9 mm) in diameter unless using high-strength cable. High-strength cable elongation shall not exceed  $5/8$  inch (15.9 mm) under a 4,000 pound (17.8 kN) axial load.

**Section A405 Materials of Construction****[BS] A405.1 New materials**

New materials shall meet the requirements of the *California Building Code*, except where allowed by this chapter.

**[BS] A405.2 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 A403.4.1 shall apply.

**[BS] A405.3 Existing materials**

The physical condition, strengths, and stiffnesses of existing building materials shall be taken into account in any analysis required by this chapter. The verification of existing materials conditions and their conformance to these requirements shall be made by physical observation, material testing or record drawings as determined by the registered design professional subject to the approval of the code official.

**[BS] A405.3.1 Wood-structural-panel shear walls****[BS] A405.3.1.1 Existing nails**

When the required calculations rely on design values for common nails or surfaced dry lumber, their use in construction shall be verified by exposure.

**[BS] A405.3.1.2 Existing plywood**

When verification of the existing plywood is by use of record drawings alone, plywood shall be assumed to be of three plies.

**[BS] A405.3.2 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 code official.

**[BS] A405.3.3 Existing structural steel**

All existing structural steel shall be permitted to be assumed to comply with ASTM A 36. Existing pipe or tube columns shall be assumed to be of minimum wall thickness unless verified by testing or exposure.

**[BS] A405.3.4 Existing 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.

**[BS] A405.3.5 Existing sill plate anchorage**

The analysis of existing cast-in-place anchors shall be permitted to assume proper anchor embedment for purposes of evaluating shear resistance to lateral loads.

**Section A406 Information Required to Be on the Plans**

**[BS] A406.1 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.

**[BS] A406.2 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.

**[BS] A406.3 New construction**

**[BS] A406.3.1 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.

**[BS] A406.3.2 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.

**[BS] A406.3.3 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, gage 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.

**[BS] A406.3.4 General notes**

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

**Section A407 Quality Control**

**[BS] A407.1 Structural observation, testing and inspection**

Structural observation, in accordance with Section 1709 of the *California 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 to 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.