



Vulnerability-Based Seismic Assessment and Retrofit of One- and Two-Family Dwellings

Volume 1 - Prestandard

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Cover photograph – Photographs showing vulnerabilities addressed in prestandard.

Preface

In 2013, the California Earthquake Authority (CEA) and the Federal Emergency Management Agency (FEMA) jointly funded a project with the Applied Technology Council (ATC) to develop a prestandard for the evaluation and retrofit of one- and two-family wood light-frame residential buildings (ATC-110 Project). This class of structure represents the most common type of dwelling in the United States. Although this type of construction has generally provided good performance in past earthquakes, there are well-known vulnerabilities that have led to large numbers of homes being rendered uninhabitable or even unrepairable following an earthquake.

Improved seismic design and seismic retrofitting of vulnerable configurations will increase the probability that homes are available to provide shelter immediately following moderate to large seismic events. The purpose of this prestandard is provide a methodology to identify and retrofit specific known vulnerabilities in wood light-frame dwellings. Development of the assessment and retrofit provisions has included use of the best available seismic numerical modeling tools and engineering practices to assist in development of assessment methods and to identify retrofit criteria to best achieve targeted performance objectives. Use of the provisions is anticipated to improve earthquake performance but is not intended to prevent earthquake damage.

The prestandard builds on the ATC-110 report, *Plan for Development of a Prestandard for Evaluation and Retrofit of Wood Light-Frame Dwellings*, (ATC, 2014) and is expected to serve as a basis for a nationally recognized, ANSI-approved consensus standard that will further help in disseminating and incorporating the approaches and technology of the prestandard into the mainstream of design and construction practices in the United States. This prestandard provides a stand-alone resource for assessment and retrofit, incorporating all provisions required for implementation, and includes figures containing prescriptive, pre-engineered structural drawings and commentary, as well as appendices that are expected to remain non-mandatory.

This prestandard is presented as Volume 1 in the FEMA P-1100 product series and is supported by two additional volumes, currently under

development. Volume 2 includes the FEMA Plan Set, a prescriptive, pre-engineered set of plans that can be adapted to retrofit crawlspace dwelling cripple walls, living-space-over-garage dwelling ground story bracing walls, masonry chimneys and masonry fireplace surrounds in wood light-frame dwellings. Volume 3 consists of a series of products assembled to assist engineers in understanding the technical basis of the prestandard.

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Chapter 1

Scope and Administration

1.1 Prestandard Scope

This prestandard provides minimum criteria for vulnerability-based assessment and retrofit of seismic vulnerabilities in one- and two-family detached wood light-frame *dwelling*s. In addition to one- and two-family detached dwellings, this prestandard is applicable to *townhouses* and to single-family dwellings divided into multiple *dwelling units* since original construction, to the extent that the vulnerabilities and assessment and retrofit provisions are applicable.

The specific seismic vulnerabilities addressed by this prestandard are:

- *Crawlspace dwelling* anchorage to foundation, cripple wall bracing, and connection to the framed floor immediately above
- *Living-space-over-garage dwelling* ground story bracing
- *Hillside dwelling* anchorage to foundation and cripple wall bracing
- Brick masonry *chimneys*
- Anchorage of *masonry fireplace surrounds*

Where more than one of the above vulnerabilities occur in a dwelling, assessment and retrofit can address a single vulnerability or multiple vulnerabilities.

The assessment methods incorporated are:

- Simplified vulnerability-based assessment
- Detailed vulnerability-based assessment
- Engineered vulnerability-based assessment
- General engineered assessment

The retrofit methods incorporated are:

- Prescriptive vulnerability-based retrofit
- Simplified engineered vulnerability-based retrofit
- General engineered retrofit

General engineered assessment and retrofit methods are described in Section 1.7. Other assessment and retrofit methods are described in Chapters 4 through 7.

Compliance with this prestandard is achieved by demonstrating that existing conditions conform to the assessment provisions for an applicable vulnerability, or that non-conforming conditions are retrofitted in accordance with the retrofit provisions for an applicable vulnerability.

1.2 Prestandard Purpose

The purpose of this prestandard is to promote public safety and welfare by reducing earthquake-induced damage to existing wood light-frame dwellings. The seismic assessment and retrofit provisions of this prestandard provide a methodology to identify and retrofit specific known vulnerabilities in wood light-frame dwellings. Use of the provisions of this prestandard is anticipated to improve earthquake performance but is not intended to prevent earthquake damage.

1.3 Alternative Methods

The provisions of this prestandard are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this prestandard, provided that any such alternative has been *approved*. An alternative material, design or method of construction shall be approved where the *building official* finds that the proposed design is satisfactory and complies with the intent of the provisions of this prestandard, and the material, method or work offered is, for the purpose intended, not less than the equivalent of that prescribed in the adopted building or residential code in quality, strength, effectiveness, fire resistance, durability, and safety.

1.4 Use of This Prestandard

This prestandard is permitted to be used to assess and retrofit one or more vulnerabilities occurring in a dwelling. For each vulnerability to be retrofitted, the applicable provisions of this prestandard shall be used as follows:

- The provisions of Chapter 1 and definitions of Chapter 2 shall be applicable to the assessment and retrofit of all vulnerabilities.
- The minimum construction provisions of Chapter 3 shall be applicable to all retrofits addressed by this prestandard.
- Crawlspace dwellings shall be assessed and retrofitted in accordance with Chapter 4.

- Living-space-over-garage dwellings shall be assessed and retrofit in accordance with Chapter 5.
- Hillside dwellings shall be assessed and retrofit in accordance with Chapter 6.
- Masonry chimneys shall be assessed and retrofit in accordance with Chapter 7.
- Masonry fireplace surrounds shall be assessed and retrofit in accordance with Chapter 7.
- The detailed assessment checklists of Chapter 8 shall be used when required by Chapters 4 through 7.

1.4.1 Partial Retrofit

Retrofits that do not address all applicable locations or do not include all applicable retrofit elements for a specific vulnerability being addressed shall not be designated as conforming to this prestandard.

1.4.2 Phased Retrofit

Seismic retrofit is permitted to be phased. When phased construction is used, all *load-path connections* attaching the *retrofit element* into the dwelling shall be provided at the time of *retrofit element* installation. When phased construction is used, the dwelling shall not be designated as conforming to this prestandard until all retrofit construction is complete.

1.4.3 New Work

New work required but not addressed by this prestandard shall be in accordance with the adopted building or residential code.

1.5 Combinations of Seismic Vulnerabilities

Where more than one of the vulnerabilities addressed by this prestandard occur in a dwelling, assessment and retrofit can be of one, multiple, or all applicable vulnerabilities. It is not the intent of this prestandard to require that all potential vulnerabilities be assessed and retrofit.

When a dwelling is identified as complying with the provisions of this prestandard, the vulnerability or vulnerabilities that have been assessed or retrofit and found to conform shall be specifically identified. A dwelling shall only be designated as complying with this prestandard when all aspects and portions of the dwelling are assessed and, where required, retrofit to conform to the provisions of the chapter addressing that vulnerability.

1.6 Site Seismicity

The Seismic Design Category (SDC) of a dwelling shall be determined in accordance with ASCE/SEI 7 Chapter 11, *International Residential Code* (IRC) Section R301.2.2.1, or Figures 1.6-1 through 1.6-6 of this prestandard (reprinted from the IRC, presented at the end of this chapter). A dwelling thus assigned to SDC B through E is eligible for assessment and retrofit using this prestandard.

Engineered retrofit design shall be based on the short-period design spectral response acceleration parameter, S_{DS} , determined in accordance with ASCE/SEI 7. See Chapters 4 through 7 for design provisions.

Prescriptive retrofit designs are provided for S_{DS} values of 1.0, 1.2, and 1.5. The S_{DS} value applicable for seismic retrofit shall be determined based on the mapped SDC from Figures 1.6-1 through 1.6-6 or the web link <https://www.atcouncil.org/fema-p-1100> (last accessed June 29, 2018) and the following:

- For SDC B through D₁, S_{DS} shall be taken as 1.0
- For SDC D₂, S_{DS} shall be taken as 1.2
- SDC E, S_{DS} shall be taken as 1.5

Alternatively, S_{DS} shall be permitted to be determined in accordance with ASCE/SEI 7.

Where S_{DS} falls below 1.0 or between the values of 1.0, 1.2, and 1.5, the prescriptive retrofit design shall use the next higher S_{DS} value for which prescriptive designs are provided. Where S_{DS} falls above 1.5, the prescriptive design for 1.5 is permitted to be used. Interpolation of prescriptive retrofit provisions between S_{DS} levels is not permitted.

1.7 Assessment and Retrofit Methodologies

The methodologies for seismic assessment and retrofit are listed in Section 1.1. This section discusses use.

1.7.1 Assessment Methodologies

Assessment is performed to determine whether seismic retrofit is needed for compliance. Assessment shall be by one of the four methods identified in Section 1.1. Where vulnerability-based assessment is used, assessment scope is limited to the vulnerable elements and their load path connections to the dwelling, in accordance with applicable provisions of Chapters 4 through 7.

General engineered assessment scope shall include the entire dwelling *seismic force-resisting system*, and be in accordance with other approved code or standard provisions.

1.7.2 Retrofit Methodologies

Retrofit shall be by one of the three methods identified in Section 1.1. Where vulnerability-based retrofit is used, retrofit scope is limited to the vulnerable elements and their load path connections to the dwelling, in accordance with the applicable provisions of Chapters 4 through 7.

General engineered retrofit scope shall include the entire dwelling seismic force-resisting system, and be in accordance with other approved code or standard provisions supplemented by the following additional retrofit provisions:

- For retrofit of crawlspace dwellings and living-space-over-garage dwellings, the cripple wall or garage stories shall be recognized as a soft and weak story due to the reduced strength and stiffness of finish materials, and shall be identified as a vertical irregularity for purposes of seismic design. Unless otherwise accounted for in the retrofit design methodology, the cripple wall or garage story shall be designed for 1.5 times the seismic story shear force otherwise required.
- For retrofit of hillside dwellings, the base level diaphragm shall be idealized as rigid or modeled as semi-rigid, and the relative stiffness of vertical elements shall be considered in determining distribution of seismic forces and detailing of load path connections. Modeling shall include as a minimum the story (including finish materials) above the base level diaphragm as well as the bracing elements at and below the base level diaphragm.

1.8 Limitations of Use

Use of this prestandard is limited to dwellings that are compliant with all of the eligibility statements of Table 1.8-1. Where one or more statements are identified as non-compliant, general engineered assessment and retrofit methods, as described in Section 1.7.2, are required.

Table 1.8-1 Eligibility Criteria for Use of the Prestandard

	Eligibility Criteria	Compliant	Non-Compliant
1	The dwelling is a detached <i>one- or two-family dwelling</i> or the dwelling is a unit in a <i>townhouse</i> and assessment and retrofit will occur for each attached <i>townhouse unit (the full townhouse structure)</i> .		
2	The dwelling is of wood <i>light-frame construction</i> .		
3	The weight of the exterior wall finish does not exceed 10 psf, except that masonry veneer wainscots supported on concrete or masonry foundations are permitted to extend up to four feet above the top of foundation.		

1.9 Conditions Beyond the Scope of this Prestandard

This prestandard addresses the assessment and retrofit of seismic vulnerabilities identified in Section 1.1. Additional seismic vulnerabilities might exist, but are beyond the scope of this prestandard.

The vulnerability-based methods of this prestandard do not require assessment or mitigation of site soil hazards including but not limited to: liquefaction, landslide, surface fault rupture or densification. See non-mandatory Appendix S for descriptions of these hazards and seismic performance implications.

1.10 Administrative Provisions

The following administrative provisions shall apply in addition to the provisions of the adopted building or residential code:

Construction documents are required to be developed in enough detail to communicate the extent, locations, and details of retrofit work to be constructed in order to comply with this prestandard.

See Chapters 4 through 7 for inspection and verification of retrofit installation.

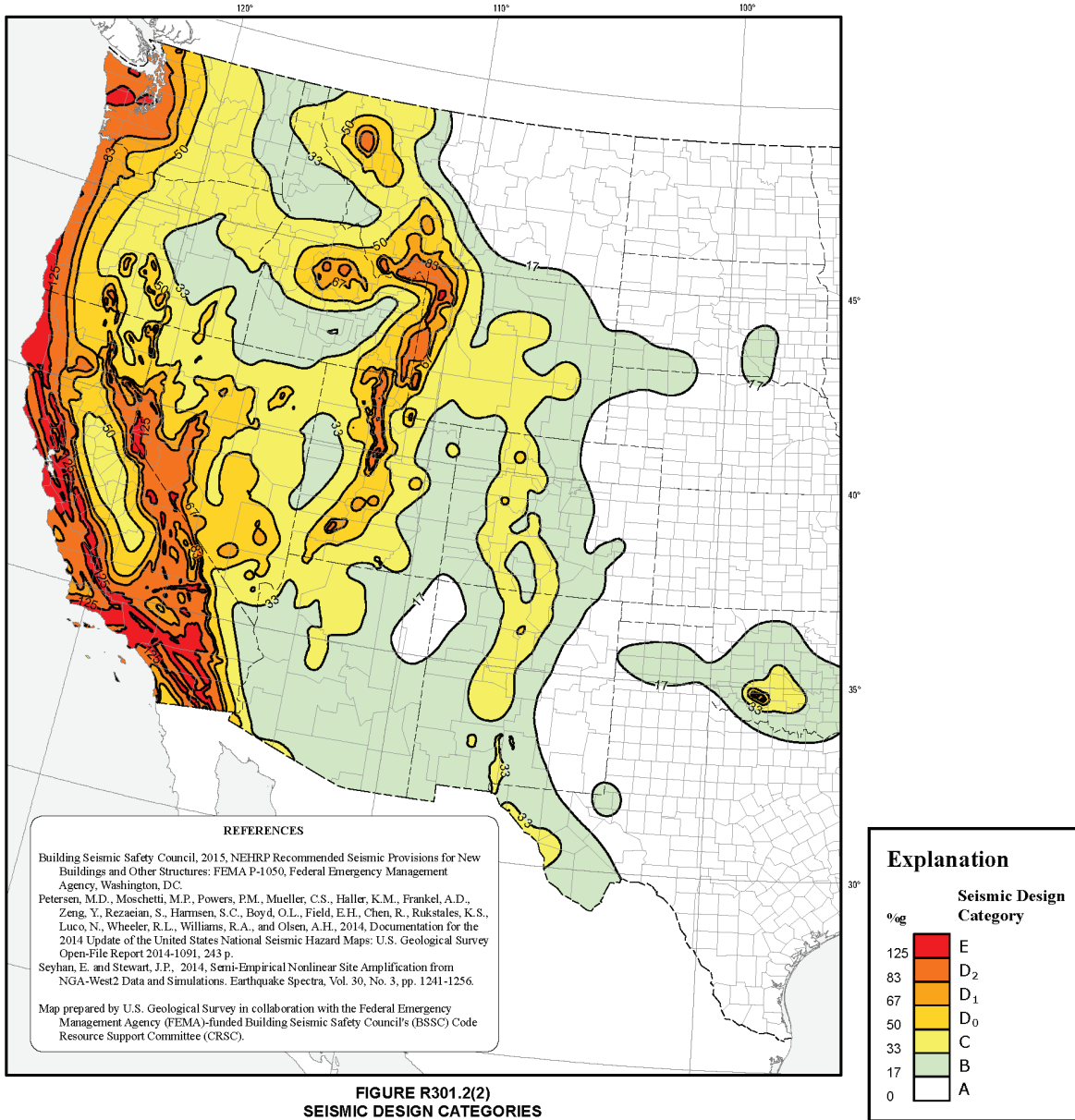


FIGURE R301.2(2)
SEISMIC DESIGN CATEGORIES

Figure 1.6-1 Seismic Design Category (SDC) map, western conterminous states (reprinted from the IRC).

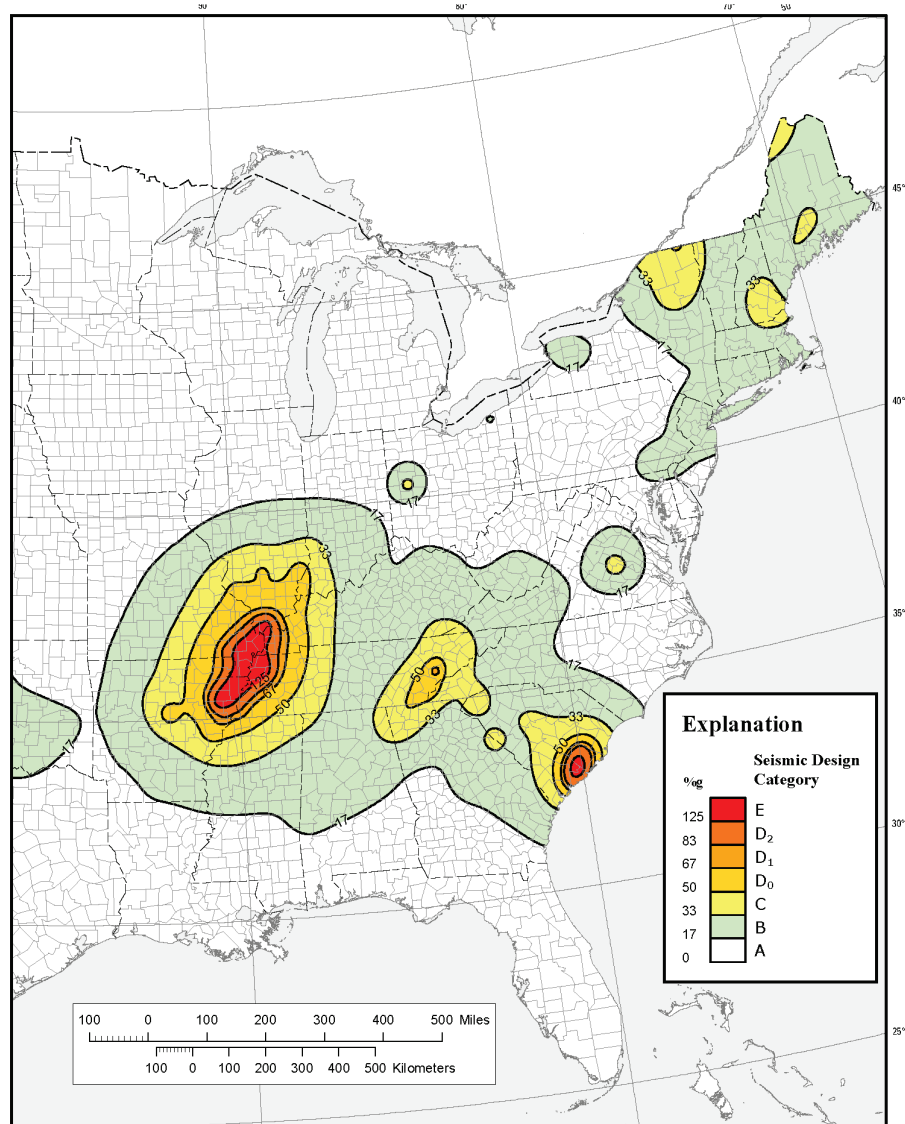
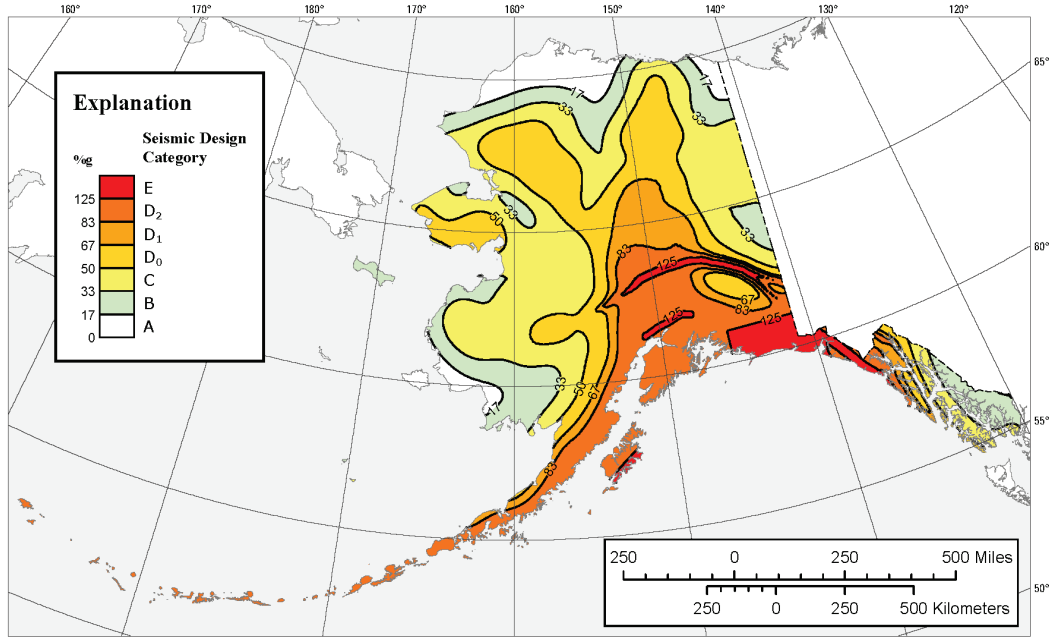


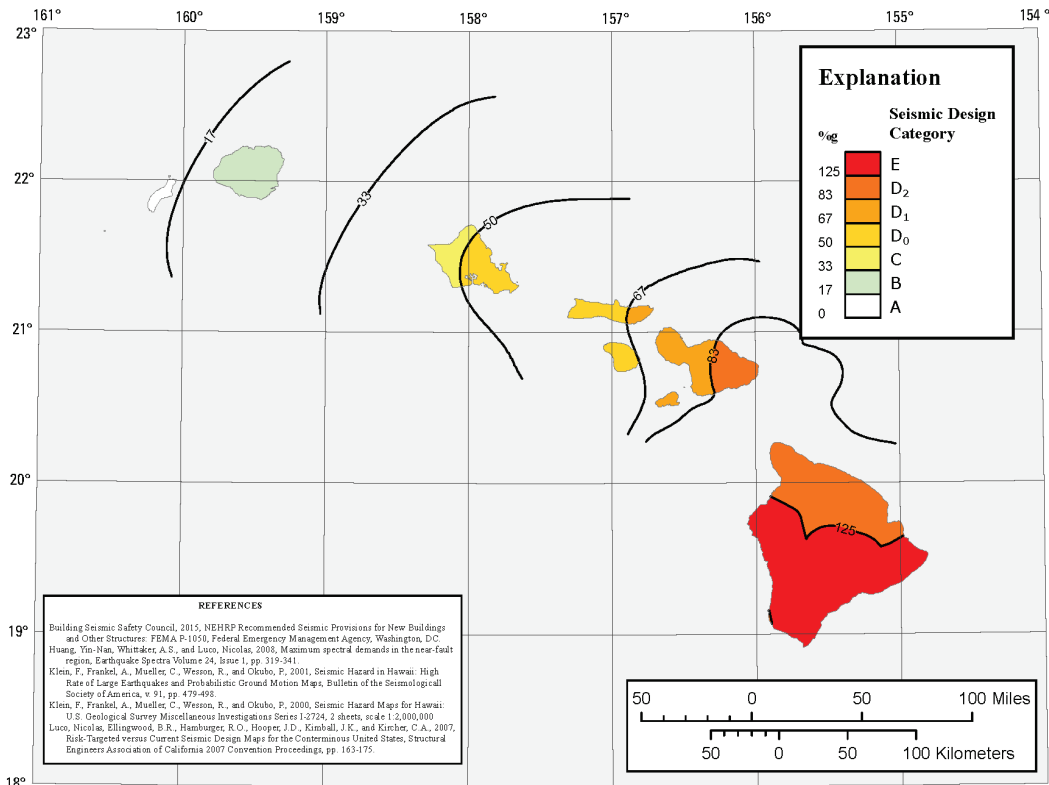
Figure 1.6-2 Seismic Design Category (SDC) map, eastern conterminous states (reprinted from the IRC).



Map prepared by U.S. Geological Survey in collaboration with the Federal Emergency Management Agency (FEMA), Federal Building Seismic Safety Council's (BSSC) Code Resource Support Committee (CRSC).

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 Building Seismic Safety Council, 2015, NEHRP Recommended Seismic Provisions for New Buildings and Other Structures, FEMA P-1050, Federal Emergency Management Agency, Washington, DC.
 Huang, Yin-Nan, Whitaker, A.S., and Luco, Nicolas, 2008, Maximum spectral demands in the near-fault region, Earthquake Spectra Volume 24, Issue 1, pp. 319-341.
 Luco, Nicolas, Ellingwood, B.R., Hamburger, R.O., Hooper, J.D., Kimball, J.K., and Kircher, C.A., 2007, Risk-Targeted versus Current Seismic Design Maps for the Conterminous United States, Structural Engineers Association of California 2007 Convention Proceedings, pp. 143-175.
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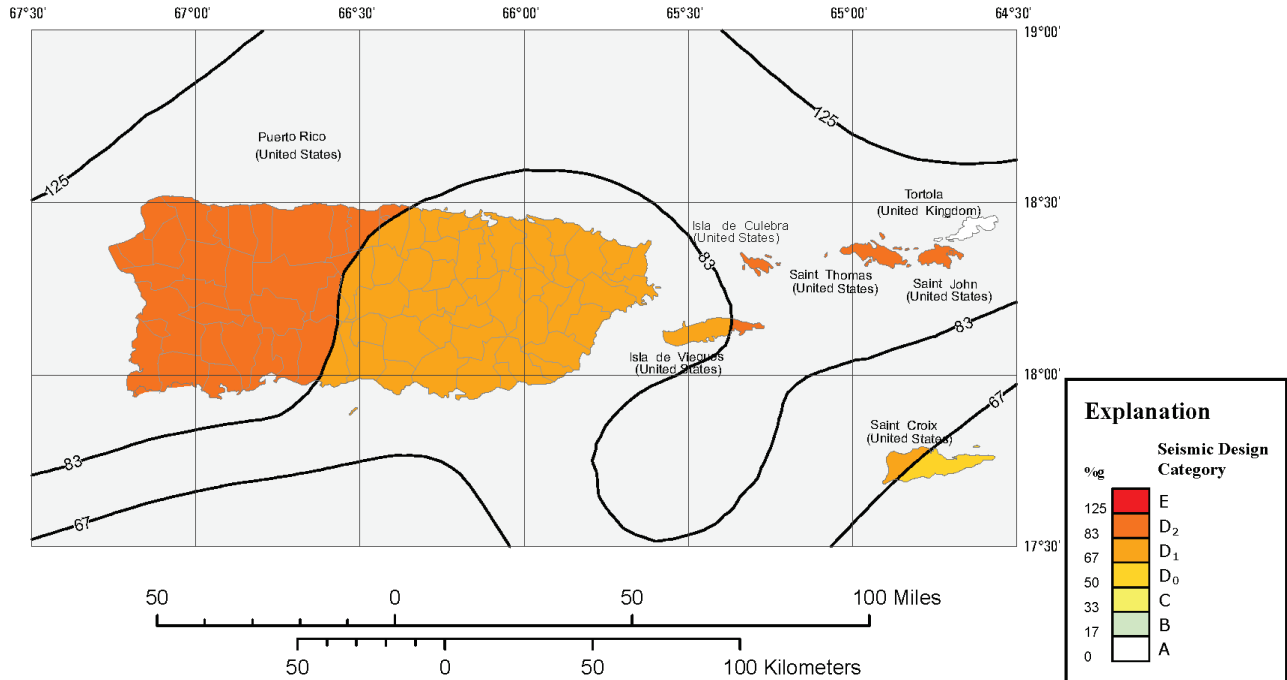
Figure 1.6-3 Seismic Design Category (SDC) map, Alaska (reprinted from the IRC).



REFERENCES
 Building Seismic Safety Council, 2015, NEHRP Recommended Seismic Provisions for New Buildings and Other Structures, FEMA P-1050, Federal Emergency Management Agency, Washington, DC.
 Huang, Yin-Nan, Whitaker, A.S., and Luco, Nicolas, 2008, Maximum spectral demands in the near-fault region, Earthquake Spectra Volume 24, Issue 1, pp. 319-341.
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 Klein, F., Frankel, A., Mueller, C., Wesson, R., and Okubo, P., 2000, Seismic Hazard Maps for Hawaii: U.S. Geological Survey Miscellaneous Investigations Series 1-2724, 2 sheets, scale 1:2,000,000.
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Map prepared by U.S. Geological Survey in collaboration with the Federal Emergency Management Agency (FEMA), Federal Building Seismic Safety Council's (BSSC) Code Resource Support Committee (CRSC).

Figure 1.6-4 Seismic Design Category (SDC) map, Hawaii (reprinted from the IRC).



REFERENCES

Building Seismic Safety Council, 2015, NEHRP Recommended Seismic Provisions for New Buildings and Other Structures: FEMA P-1050, Federal Emergency Management Agency, Washington, DC.

Huang, Yin-Nan, Whittaker, A.S., and Luco, Nicolas, 2008, Maximum spectral demands in the near-fault region, Earthquake Spectra Volume 24, Issue 1, pp. 319-341.

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Mueller, C., Frankel, A., Petersen, M., and Leyendecker, E., 2003, Documentation for 2003 USGS Seismic Hazard Maps for Puerto Rico and the U.S. Virgin Islands, U.S. Geological Survey Open-File Report 03-379.

Map prepared by U.S. Geological Survey in collaboration with the Federal Emergency Management Agency (FEMA)-funded Building Seismic Safety Council's (BSSC) Code Resource Support Committee (CRSC).

Figure 1.6-5 Seismic Design Category (SDC) map, Puerto Rico (reprinted from the IRC).

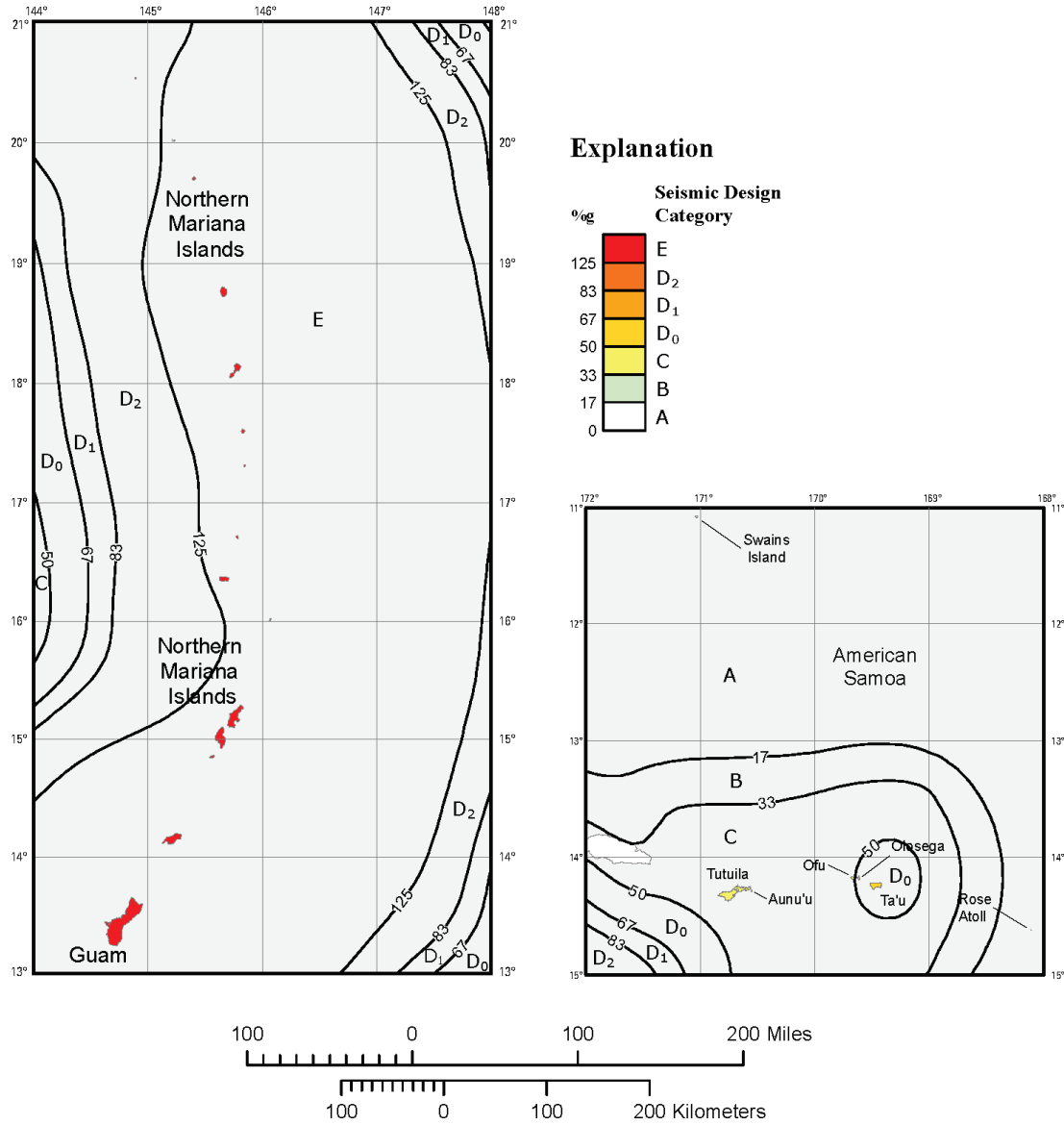


Figure 1.6-6 Seismic design category (SDC) map, Northern Mariana Islands and American Samoa (reprinted from the IRC).

Chapter 2

Definitions, Notation, and Abbreviations

2.1 Definitions

Unless otherwise expressly stated, the following words and terms shall, for the purposes of this prestandard, have the meanings indicated below. See Section 2.3 for reference to sources noted in brackets.

ADHERED STONE OR MASONRY VENEER [IRC]. Stone or masonry veneer secured and supported through the adhesion of an *approved* bonding material applied to an *approved* backing.

ADHESIVE ANCHOR [IEBC Appendix Chapter A3]. An assembly consisting of a threaded rod, washer, nut, and chemical adhesive approved by the *building official* for installation in existing concrete or masonry.

ANCHORED STONE OR MASONRY VENEER [IRC]. Stone or masonry veneer secured with *approved* mechanical fasteners to an *approved* backing.

ANCHOR STRAP. Structural steel tie that anchors the chimney to the dwelling framing or wood framed walls to concrete foundations.

APPROVED. Acceptable to the *building official*.

ATTIC [IRC]. The unfinished space between the ceiling assembly and the roof assembly.

BASE-LEVEL DIAPHRAGM. In a *hillside dwelling*, the framed floor at or closest in elevation to the level of the *uphill foundation*.

BRACED WALL LINE [UBC]. A straight line through the building plan that represents the location of the lateral resistance provided by that wall line.

BRACED WALL PANEL [UBC]. A full-height section of wall constructed to resist in-plane shear loads through interaction of framing members, sheathing material, shear nailing, and anchors.

BRACING WALL. A wood light-frame shear wall, cripple wall, or braced wall panel serving as part of the *seismic force-resisting system*: wood

structural panel sheathed *cripple walls* at the perimeter of the crawlspace in *crawlspace dwellings* and *hillside dwellings* or ground story shear walls at *living-space-over-garage dwellings*.

BUILDING OFFICIAL. The officer or other designated authority charged with the administration of adopted building and residential codes, or a duly authorized representative.

CHIMNEY [IRC]. A primary vertical structure containing one or more *flues*, for the purpose of carrying gaseous products of combustion and air from a fuel-burning appliance to the outside atmosphere.

CHIMNEY, EXTERIOR. A chimney located on an outside wall with at least one face of masonry exposed to the exterior for at least one complete story.

CHIMNEY, FACTORY BUILT [IRC]. A *listed* and *labeled chimney* composed of factory-made components assembled in the field in accordance with the manufacturer's instructions and conditions of the listing.

CHIMNEY, INTERIOR. *Chimneys* not meeting the criteria for exterior chimneys.

CHIMNEY, MASONRY [IRC]. A field-constructed *chimney* composed of *solid masonry* units, bricks, stones or concrete.

CHIMNEY CAP. A concrete, metal, or stone cover for the *chimney* intended to prevent entry of snow and pests, and sloped to shed water.

CONNECTOR. A device used to provide load-path attachment for elements resisting seismic forces, including anchors to the foundation and custom or prefabricated steel clips for attachment between framing elements (sometimes referred to as a shear clip).

CRAWLSPACE DWELLING. A dwelling in which: (1) the space below the lowest framed floor is predominantly unoccupied, including area enclosed by crawlspace walls, open areas, or a combination of the two; (2) the tallest crawlspace *cripple wall clear height* does not exceed 7'-0"; and (3) when averaged across the full length or width of the dwelling the grade slope does not exceed 1 vertical in 5 horizontal.

CRAWLSPACE WALL. A framed wall, concrete wall or masonry wall extending from the top of the foundation to the underside of the floor framing of the first floor above the grade plane.

CRIPPLE WALL [IRC]. A framed wall extending from the top of the foundation to the underside of the floor framing of the first floor above grade plane.

CRIPPLE WALL CLEAR HEIGHT. The vertical height of a *cripple wall* from the top of the foundation to the underside of floor framing above.

CROSS-SLOPE LOADING. In a *hillside dwelling*, horizontal seismic loading in the direction parallel to the uphill foundation and generally parallel to grade elevation contours. *Cross-slope loading* is perpendicular to *out-of-hill loading*.

DESIGN PROFESSIONAL [IRC]. See *registered design professional*.

DWELLING [IRC]. Any building that contains one or two *dwelling units* used, intended, or designed to be built used, rented, leased, let or hired out to be occupied, or that are occupied for living purposes.

DWELLING UNIT [IRC]. A single unit providing complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking, and sanitation.

FIREBOX. An assembly consisting of a hearth and fire chamber of noncombustible material and provided with a *chimney*, for use with solid fuels.

FIREPLACE, FACTORY-BUILT [IRC]. A *listed* and *labeled* fireplace and chimney system composed of factory-made components and assembled in the field in accordance with manufacturer's instructions and the conditions of the listing.

FIREPLACE, MASONRY [IRC]. A field-constructed fireplace composed of *solid masonry* units, bricks, stones, or concrete.

FIREPLACE INSERT, FACTORY-BUILT. A *listed* and *labeled* fireplace composed of factory-made components and assembled in the field within an existing masonry fireplace in accordance with manufacturer's instructions and the conditions of the listing.

FLUE [IRC]. See *vent*.

FLUE CAP. A protective covering or housing attached to the *flue* termination intended to prevent downdrafts and entry of rain, snow or pests while allowing venting of exhaust gasses. For factory installations, the flue cap shall be part of the UL *listed* system.

FOUNDATION SILL PLATE. A wood framing member providing support to a structure above and bearing on a foundation.

GROUND STORY RESIDENTIAL UNIT. In a *living-space-over-garage* dwelling, a residential unit at the garage level with interior wall finishes and interior walls.

HEIGHT ABOVE ROOF. The vertical distance from the lowest roof surface along the chimney perimeter to the top of the highest masonry unit.

HILLSIDE DWELLING. A dwelling in which: (1) the space below the lowest framed floor is predominantly unoccupied, including area enclosed by *crawlspace walls*, open areas, or a combination of the two; (2) the tallest crawlspace *cripple wall clear height* exceeds 7'-0" (or post and beam system post height exceeds 7'-0" when underfloor area is not enclosed); (3) when averaged across the full length or width of the *dwelling* the grade slope exceeds 1 vertical in 5 horizontal; and (4) where a wood light-frame crawlspace wall occurs between the base-level diaphragm and uphill foundation, the height of this crawlspace wall does not exceed 2'-0".

LABELED [IRC]. Equipment, materials or products to which have been affixed a label, seal, symbol, or other identifying mark of a nationally recognized testing laboratory, approved agency, or other organization concerned with product evaluation that maintains periodic inspection of the production of the labeled items and whose labeling indicates either that the equipment, material, or product meets identified standards or has been tested and found suitable for a specified purpose.

LIGHT-FRAME CONSTRUCTION [IRC]. Construction whose vertical and horizontal structural elements that are primarily formed by a system of repetitive wood or cold-formed steel framing members.

LISTED [IRC]. Equipment, materials, products, or services included in a list published by an organization acceptable to the code official and concerned with evaluation of products or services that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services and whose listing states either that the equipment, material, product, or service meets identified standards or has been tested and found suitable for a specified purpose.

LIVING-SPACE-OVER-GARAGE DWELLING. A dwelling in which a primary occupied living space occurs in an upper story that extends substantially or completely over a ground story constructed primarily as a garage, including utility and storage uses.

LOAD PATH CONNECTION. A connection between a retrofit element and the dwelling, intended to transmit seismic forces into and out of the retrofit element.

MASONRY FIREPLACE SURROUND. A decorative stone or masonry wall finish element that borders the fireplace on the sides or above (including the mantelpiece), extending beyond the *firebox*.

MASONRY FIREPLACE SURROUND, ADHERED STONE OR MASONRY. A surround constructed of *adhered stone or masonry veneer*.

MASONRY FIREPLACE SURROUND, ANCHORED STONE OR MASONRY. A surround constructed of *anchored stone or masonry veneer*.

MASONRY, SOLID [IRC]. Masonry consisting of solid masonry units laid contiguously with the joints between the units filled with mortar.

NATURALLY DURABLE WOOD [IRC]. The heartwood of the following species with the exception that an occasional piece with corner sapwood is permitted if 90 percent or more of the width of each side on which it occurs is heartwood.

DECAY RESISTANT. Redwood, cedar, black locust, and black walnut.

TERMITE RESISTANT. Redwood, Alaska yellow cedar, Eastern red cedar, and Western red cedar, including all sapwood of Western red cedar.

OUT-OF-HILL LOADING (Down-hill loading). In a *hillside dwelling*, horizontal seismic loading parallel to the direction of descending grade, acting into or away from the hillside.

PERIMETER FOUNDATION. A foundation system that is located under the dwelling perimeter walls.

POST-INSTALLED ANCHOR. An anchor installed into existing already placed or cast concrete or masonry. Post-installed anchors for purposes of this standard include *approved adhesive anchors* and concrete screws.

PRESERVATIVE TREATED WOOD [IRC]. Wood treated in conformance with the applicable requirements of AWP A U1 and AWP A M4.

PRIMARY ANCHOR [LABC, modified]. In hillside dwellings, an anchor located at *base level diaphragm* ends and offsets or transitions and providing direct connection between the *base-level diaphragm* and the *uphill foundation*. Primary loading is tension in the out-of-hill direction, due to either to direct tension or torsion from cross-hill loading.

PROPRIETARY SHEAR WALL. A pre-engineered, pre-fabricated wood or cold-formed steel load-bearing or non-load-bearing wall assembly with sheathing or bracing, serving as a vertical element of the seismic force-resisting system in place of site-built shear walls. Also known as lateral force-resisting vertical assembly (LFRVA).

REGISTERED DESIGN PROFESSIONAL [IRC]. An individual who is registered or licensed to practice their respective design profession as defined by the statutory requirements of the professional registration laws of the state or jurisdiction in which the project is to be constructed.

REPOINTING. The partial reconstruction of cracked or deteriorated mortar joints between solid brick masonry units by removing unsound mortar and replacing it with new mortar.

RETROFIT ELEMENT. A primary element of the seismic force-resisting system, including *cripple walls* in *crawlspace dwellings*, ground story *bracing walls* in *living-space-over-garage dwellings*, and *crawlspace walls* and *base-level diaphragm* anchorage to the uphill foundation in *hillside dwellings*.

SECONDARY ANCHOR [LABC, modified]. In *hillside dwellings*, regularly spaced anchors providing redundant, distributed connections between the *base-level diaphragm* and the *uphill foundation*.

SEISMIC DESIGN CATEGORY (SDC) [IRC]. A classification assigned to a structure based on its occupancy category and the severity of the design earthquake ground motion at the site.

SEISMIC FORCE-RESISTING SYSTEM [IBC]. That part of the structural system that has been considered in the design to provide the required resistance to seismic forces.

SHEAR WALL [IRC]. A general term for walls that are designed and constructed to resist racking from seismic and wind loads by use of masonry concrete, cold-formed steel or wood framing.

SILL PLATE. See *foundation sill plate*.

SITE CLASS [IBC, modified]. A classification assigned to a site based on the types of soils present and their engineering properties, as defined in IBC Section 1613.3.2 (also ASCE/SEI 7, Chapters 11 and 20).

SLAB-ON-GROUND. A concrete slab supported directly on grade over its full extent, cast monolithically with continuous thickened slab footings, or as a floating slab, independent of surrounding footings. Also referred to as slab-on-grade.

SMOKE CHAMBER. The enlarged vent space immediately above the *firebox* and below the chimney *flue*.

SNUG TIGHT [IEBC]. As tight as an individual can torque a nut on a bolt by hand, using a wrench with a 10-inch long handle, and the point at which the full surface of the plate washer is contacting the wood member and slightly indenting the wood surface.

SPLIT LEVEL [IRC Section R301.2.2.6, Item 5, modified]. Where portions of a floor level are vertically offset, except where framing at each level is supported directly on a continuous foundation or stem wall or where the floor framing on either side of the offset is tied together to not move differentially.

STEM WALL. A concrete or masonry wall bearing on a foundation and supporting structure above. For purposes of cripple wall and crawlspace wall retrofits, the stem wall acts as an extension of the foundation.

TIE-DOWNS. A device used in framed bracing walls or cripple walls to resist uplift through the combination of a threaded rod, anchors, and pre-manufactured metal components.

TOWNHOUSE [IRC]. A single-family *dwelling unit* constructed in a group of three or more attached units in which each unit extends from foundation to roof and with a yard or public way on not less than two sides.

TOWNHOUSE STRUCTURE. A structure comprising three or more attached *townhouse* units.

UPHILL FOUNDATION. In a *hillside dwelling*, the foundation at the side of the dwelling that has the highest top of foundation elevation.

VENT [IRC]. A passageway for conveying flue gases from fuel-fired appliances, or their vent connectors, to the outside atmosphere.

WEIGHT CLASSIFICATION. The classification of light, medium, or heavy construction as a measure of a dwelling's overall seismic mass, for use in applicable prescriptive retrofit design procedures.

WOOD STRUCTURAL PANEL [IRC, modified]. A panel manufactured from veneers or wood strands or wafers bonded together with waterproof synthetic resins or other suitable bonding systems. For purposes of this prestandard, wood structural panels include plywood and oriented strand board (OSB).

2.2 Notation

Unless otherwise expressly stated, the following notation, for the purposes of this prestandard, have the meanings indicated below.

ASD = Allowable stress design

C_d = Deflection amplification factor

CMU = Concrete masonry unit

f'_c = Compressive strength of concrete

F = Seismic base shear parameter, varying with the number of stories

F_R = Loading at roof level

F_y = Yield strength of steel

F_{2nd} = Load at the second level

h_{sx} = The story height below level x

MCE_R = Maximum considered risk targeted earthquake

R = Response modification coefficient

S_{DS} = Design, five percent damped, spectral response acceleration parameter at short periods

SDC = Seismic Design Category

V = Total design lateral force or shear at the base of a structure

W = Effective seismic weight of the structure

Ω_0 = Overstrength factor

2.3 Sources of Definitions

The following are sources of text noted in this prestandard:

[ASCE/SEI 7] Minimum Design Loads and Associated Criteria for Buildings and other Structures, 2016 Edition

[IBC] International Building Code, 2018 Edition

[IEBC] International Existing Building Code, 2018 Edition

[IRC] International Residential Code, 2018 Edition

[LABC] City of Los Angeles Building Code, 2016 Edition

[UBC] Uniform Building Code, 1994 and 1997 Editions

2.4 Abbreviations

The following are abbreviations incorporated into prestandard figures.

(E) Existing

(N) New

blkg Blocking

btm Bottom

clr Clear

Dia Diameter

ea Each

EMB Embed

Gr Grade

Hgr Hanger

l.s.h Long slotted hole

Max. Maximum

Min. Minimum

m.b. Bolt

NTS Not to scale

o.c. On center

s.o.g. Slab-on-ground

Typ. Typical

WF Wide flange

Chapter 3

Minimum Construction Requirements

This chapter provides minimum requirements for materials and construction of retrofits designed in accordance with this prestandard.

Exception. Minimum material and construction requirements shall be permitted to be in accordance with the adopted building or residential code in lieu of this chapter.

3.1 General

3.1.1 Existing Conditions

No retrofit work shall be directly attached to or enclose existing elements that are damaged or deteriorated to an extent that could significantly affect gravity or seismic load-carrying capacity. Any such existing elements shall be addressed prior to or at the time of retrofit construction. Where possible, damaged or deteriorated elements shall be repaired in place or supplemented with new elements. Otherwise, damaged or deteriorated members shall be replaced.

3.1.2 Shoring and Bracing

Shoring and bracing shall be provided, as required, to temporarily support existing *dwelling* elements to remain and to safely install new work.

3.2 Materials

Material newly incorporated into retrofit work shall comply with the building code, but not less than the following.

3.2.1 Sawn Lumber

Sawn lumber shall be identified by a grade mark of an accredited lumber grading or inspection agency and shall have design values certified by an accreditation body that complies with Department of Commerce (DOC) Standard PS 20. In lieu of a grade mark, a certification of inspection shall be issued by a lumber grading or inspection agency. Unless otherwise noted,

framing required by this prestandard shall be of Douglas fir-Larch species, or a species of equal or greater specific gravity.

3.2.2 Preservative Treated Lumber

All lumber and wood structural panels in contact with foundations or exposed to weather shall be pressure-*preservative treated* and dried after treatment in accordance with AWWA U1 (Commodity specification A, Use Category 4B and Section 5.2) and shall bear the label of an accredited agency. Where lumber and/or wood structural wall panels are cut or drilled after treatment, the cut or drilled surface shall be treated in accordance with copper naphthenate in accordance with AWWA M4.

3.2.3 Wood Structural Panel Sheathing

Wood structural panel sheathing shall conform to Department of Commerce Voluntary Product Standard DOC PS1 or PS2. Sheathing shall be Exposure 1 or Exterior Exposure, manufactured with exterior glue, and shall be of minimum 4-ply. Panels shall be identified for grade, bond, classification, and performance category by a grade mark of certification of inspection issued by an *approved* agency. Wood structural panels permitted for use in this prestandard are limited to plywood and oriented strand board (OSB).

3.2.4 Cold-Formed Steel

Sheet steel shall conform to ASTM A1003, Structural Grade 33 Type H or Grade 50 Type H.

Cold-formed steel framing members shall be cold formed to shape from structural quality sheet steel. Wall studs shall be C-shaped sections with a minimum thickness of 43 mil (18 gage), a minimum flange width of 1-5/8 inches and a minimum depth of 2-1/2 inches.

3.2.5 Minimum Fastening

Nails specified in this prestandard shall be common nails conforming to ASTM F1667. Eight-penny (8d) common nails shall be 2-1/2" × 0.131" common nails. Fastening not otherwise specified shall meet the minimum requirements of IRC Table R602.3(1), reprinted here as Table 3.2-1, or the adopted building or residential code. Alternate fastening shall be as specifically approved.

Fasteners in contact with preservative treated lumber or wood structural panels exposed to weather shall be Type 304 or 316 stainless steel, hot-dipped galvanized or hot-tumbled galvanized. Electro galvanized steel nails and steel staples with any coating shall not be permitted.

Table 3.2-1 Minimum Fastening Requirements, IRC Table R602.3(1)

**TABLE R602.3(1)
FASTENING SCHEDULE**

ITEM	DESCRIPTION OF BUILDING ELEMENTS	NUMBER AND TYPE OF FASTENER ^{a,b,c}	SPACING AND LOCATION
Roof			
1	Blocking between ceiling joists or rafters to top plate	4-8d box (2½" × 0.113") or 3-8d common (2½" × 0.131"); or 3-10d box (3" × 0.128"); or 3-3" × 0.131" nails	Toe nail
2	Ceiling joists to top plate	4-8d box (2½" × 0.113"); or 3-8d common (2½" × 0.131"); or 3-10d box (3" × 0.128"); or 3-3" × 0.131" nails	Per joist, toe nail
3	Ceiling joist not attached to parallel rafter, laps over partitions (see Section R802.5.2 and Table R802.5.2)	4-10d box (3" × 0.128"); or 3-16d common (3½" × 0.162"); or 4-3" × 0.131" nails	Face nail
4	Ceiling joist attached to parallel rafter (heel joint) (see Section R802.5.2 and Table R802.5.2)	Table R802.5.2	Face nail
5	Collar tie to rafter, face nail or 1¼" × 20 ga. ridge strap to rafter	4-10d box (3" × 0.128"); or 3-10d common (3" × 0.148"); or 4-3" × 0.131" nails	Face nail each rafter
6	Rafter or roof truss to plate	3-16d box nails (3½" × 0.135"); or 3-10d common nails (3" × 0.148"); or 4-10d box (3" × 0.128"); or 4-3" × 0.131" nails	2 toe nails on one side and 1 toe nail on opposite side of each rafter or truss ¹
7	Roof rafters to ridge, valley or hip rafters or roof rafter to minimum 2" ridge beam	4-16d (3½" × 0.135"); or 3-10d common (3" × 0.148"); or 4-10d box (3" × 0.128"); or 4-3" × 0.131" nails	Toe nail
		3-16d box 3½" × 0.135"); or 2-16d common (3½" × 0.162"); or 3-10d box (3" × 0.128"); or 3-3" × 0.131" nails	End nail
Wall			
8	Stud to stud (not at braced wall panels)	16d common (3½" × 0.162")	24" o.c. face nail
		10d box (3" × 0.128"); or 3" × 0.131" nails	16" o.c. face nail
9	Stud to stud and abutting studs at intersecting wall corners (at braced wall panels)	16d box (3½" × 0.135"); or 3" × 0.131" nails	12" o.c. face nail
		16d common (3½" × 0.162")	16" o.c. face nail
10	Built-up header (2" to 2" header with ½" spacer)	16d common (3½" × 0.162")	16" o.c. each edge face nail
		16d box (3½" × 0.135")	12" o.c. each edge face nail
11	Continuous header to stud	5-8d box (2½" × 0.113"); or 4-8d common (2½" × 0.131"); or 4-10d box (3" × 0.128")	Toe nail
12	Top plate to top plate	16d common (3½" × 0.162")	16" o.c. face nail
		10d box (3" × 0.128"); or 3" × 0.131" nails	12" o.c. face nail
13	Double top plate splice	8-16d common (3½" × 0.162"); or 12-16d box (3½" × 0.135"); or 12-10d box (3" × 0.128"); or 12-3" × 0.131" nails	Face nail on each side of end joint (minimum 24" lap splice length each side of end joint)

(continued)

Table 3.2-1 Minimum Fastening Requirements, IRC Table R602.3(1) (continued)

**TABLE R602.3(1)—continued
FASTENING SCHEDULE**

ITEM	DESCRIPTION OF BUILDING ELEMENTS	NUMBER AND TYPE OF FASTENER ^{a, b, c}	SPACING AND LOCATION
14	Bottom plate to joist, rim joist, band joist or blocking (not at braced wall panels)	16d common (3½" × 0.162")	16" o.c. face nail
		16d box (3½" × 0.135"); or 3" × 0.131" nails	12" o.c. face nail
15	Bottom plate to joist, rim joist, band joist or blocking (at braced wall panel)	3-16d box (3½" × 0.135"); or 2-16d common (3½" × 0.162"); or 4-3" × 0.131" nails	3 each 16" o.c. face nail 2 each 16" o.c. face nail 4 each 16" o.c. face nail
16	Top or bottom plate to stud	4-8d box (2½" × 0.113"); or 3-16d box (3½" × 0.135"); or 4-8d common (2½" × 0.131"); or 4-10d box (3" × 0.128"); or 4-3" × 0.131" nails	Toe nail
		3-16d box (3½" × 0.135"); or 2-16d common (3½" × 0.162"); or 3-10d box (3" × 0.128"); or 3-3" × 0.131" nails	End nail
17	Top plates, laps at corners and intersections	3-10d box (3" × 0.128"); or 2-16d common (3½" × 0.162"); or 3-3" × 0.131" nails	Face nail
18	1" brace to each stud and plate	3-8d box (2½" × 0.113"); or 2-8d common (2½" × 0.131"); or 2-10d box (3" × 0.128"); or 2 staples 1¾"	Face nail
19	1" × 6" sheathing to each bearing	3-8d box (2½" × 0.113"); or 2-8d common (2½" × 0.131"); or 2-10d box (3" × 0.128"); or 2 staples, 1" crown, 16 ga., 1¾" long	Face nail
20	1" × 8" and wider sheathing to each bearing	3-8d box (2½" × 0.113"); or 3-8d common (2½" × 0.131"); or 3-10d box (3" × 0.128"); or 3 staples, 1" crown, 16 ga., 1¾" long	Face nail
		Wider than 1" × 8" Face nail 4-8d box (2½" × 0.113"); or 3-8d common (2½" × 0.131"); or 3-10d box (3" × 0.128"); or 4 staples, 1" crown, 16 ga., 1¾" long	
Floor			
21	Joist to sill, top plate or girder	4-8d box (2½" × 0.113"); or 3-8d common (2½" × 0.131"); or 3-10d box (3" × 0.128"); or 3-3" × 0.131" nails	Toe nail
22	Rim joist, band joist or blocking to sill or top plate (roof applications also)	8d box (2½" × 0.113")	4" o.c. toe nail
		8d common (2½" × 0.131"); or 10d box (3" × 0.128"); or 3" × 0.131" nails	6" o.c. toe nail
23	1" × 6" subfloor or less to each joist	3-8d box (2½" × 0.113"); or 2-8d common (2½" × 0.131"); or 3-10d box (3" × 0.128"); or 2 staples, 1" crown, 16 ga., 1¾" long	Face nail

(continued)

Table 3.2-1 Minimum Fastening Requirements, IRC Table R602.3(1) (continued)

**TABLE 602.3(1)
FASTENING SCHEDULE—continued**

ITEM	DESCRIPTION OF BUILDING ELEMENTS	NUMBER AND TYPE OF FASTENER ^{a,b,c}	SPACING AND LOCATION	
Floor				
24	2" subfloor to joist or girder	3-16d box (3½" × 0.135"); or 2-16d common (3½" × 0.162")	Blind and face nail	
25	2" planks (plank & beam—floor & roof)	3-16d box (3½" × 0.135"); or 2-16d common (3½" × 0.162")	At each bearing, face nail	
26	Band or rim joist to joist	3-16d common (3½" × 0.162") 4-10 box (3" × 0.128"), or 4-3" × 0.131" nails; or 4-3" × 14 ga. staples, 7/16" crown	End nail	
27	Built-up girders and beams, 2-inch lumber layers	20d common (4" × 0.192"); or	Nail each layer as follows: 32" o.c. at top and bottom and staggered.	
		10d box (3" × 0.128"); or 3" × 0.131" nails	24" o.c. face nail at top and bottom staggered on opposite sides	
		And: 2-20d common (4" × 0.192"); or 3-10d box (3" × 0.128"); or 3-3" × 0.131" nails	Face nail at ends and at each splice	
28	Ledger strip supporting joists or rafters	4-16d box (3½" × 0.135"); or 3-16d common (3½" × 0.162"); or 4-10d box (3" × 0.128"); or 4-3" × 0.131" nails	At each joist or rafter, face nail	
29	Bridging or blocking to joist	2-10d box (3" × 0.128"), or 2-8d common (2½" × 0.131"); or 2-3" × 0.131" nails	Each end, toe nail	
ITEM	DESCRIPTION OF BUILDING ELEMENTS	NUMBER AND TYPE OF FASTENER ^{a,b,c}	SPACING AND LOCATION	
Wood structural panels, subfloor, roof and interior wall sheathing to framing and particleboard wall sheathing to framing [see Table R602.3(3) for wood structural panel exterior wall sheathing to wall framing]				
30	¾" – ½"	6d common (2" × 0.113") nail (subfloor, wall) ⁱ 8d common (2½" × 0.131") nail (roof); or RSRS-01 (2¾" × 0.113") nail (roof) ^j	6	12 ^f
31	19/32" – 1"	8d common nail (2½" × 0.131"); or RSRS-01; (2¾" × 0.113") nail (roof) ^j	6	12 ^f
32	1⅛" – 1¼"	10d common (3" × 0.148") nail; or 8d (2½" × 0.131") deformed nail	6	12 ^f
Other wall sheathing^g				
33	½" structural cellulosic fiberboard sheathing	1½" galvanized roofing nail, 7/16" head diameter, or 1¼" long 16 ga. staple with 7/16" or 1" crown	3	6
34	25/32" structural cellulosic fiberboard sheathing	1¾" galvanized roofing nail, 7/16" head diameter, or 1½" long 16 ga. staple with 7/16" or 1" crown	3	6
35	½" gypsum sheathing ^d	1½" galvanized roofing nail; staple galvanized, 1½" long; 1¼" screws, Type W or S	7	7
36	5/8" gypsum sheathing ^d	1¾" galvanized roofing nail; staple galvanized, 1⅝" long; 1⅝" screws, Type W or S	7	7
Wood structural panels, combination subfloor underlayment to framing				
37	¾" and less	6d deformed (2" × 0.120") nail; or 8d common (2½" × 0.131") nail	6	12
38	7/8" – 1"	8d common (2½" × 0.131") nail; or 8d deformed (2½" × 0.120") nail	6	12
39	1⅛" – 1¼"	10d common (3" × 0.148") nail; or 8d deformed (2½" × 0.120") nail	6	12

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 mile per hour = 0.447 m/s; 1 ksi = 6.895 MPa.

(continued)

Screws for steel-to-steel connections shall be No. 8 self-drilling tapping screws that conform to ATSM C1513. Screws for attaching structural sheathing to cold-formed steel wall framing shall have a minimum head diameter of 0.292 inch with countersunk heads and shall be installed with a minimum edge distance of 3/8-inch. Gypsum board shall be attached to cold-formed steel with minimum No. 6 screws conforming to ASTM C954 or ASTM C1513 with a bugle-head style.

3.2.6 Connectors

Connectors shall be custom or pre-engineered pre-manufactured devices, approved by the *building official* and installed in accordance with the manufacturer's instructions. Connectors protected from weather shall be provided with a minimum of G90 zinc coating in accordance with ASTM A653. Connectors exposed to weather or in contact with preservative treated wood shall be provided with a minimum hot-dipped galvanized coating or G185 coating in accordance with ASTM A653, and fasteners conforming to ASTM A153.

3.2.7 Concrete

Concrete shall have a minimum specified compression strength, f'_c , of not less than 2,500 psi at 28 days. Materials used to produce concrete and testing thereof shall comply with the applicable standards listed in Chapters 19 and 20 of ACI 318 or ACI 332.

3.2.8 Reinforcing Steel

Steel reinforcement shall comply with the requirements of ASTM A615, A706 or A996. ASTM A996 bars produced from rail steel shall be Type R. The minimum yield strength of reinforcing shall be 40,000 psi (Grade 40). Reinforcement shall be secured in the proper location in the forms with tie wire or other support system to prevent displacement during concrete placement operations.

Reinforcing steel to be welded shall conform to ASTM A706.

3.2.9 Structural Steel

Structural steel sections shall comply with the requirements of ASTM A36, A572 or A992 for steel plates and sections. Structural steel HSS sections shall comply with ASTM A500, Grade B, $F_y = 46$ ksi. Identification of structural steel shall comply with the requirements of AISC 360.

Sheet steel for brick chimney adaptor cones shall conform to ASTM A1003, Structural Grade 33 Type H or Grade 50 Type H. Welding shall conform to AWS D1.3.

3.2.10 Bolts and Threaded Rods

Bolts shall conform to ASTM A307. Threaded rods shall conform to ASTM A36. Except where otherwise specifically required, cut washer between bolt head or nut and wood member shall be provided. Bolts, nuts, and washers exposed to weather or in contact with preservative treated wood shall be hot-dipped galvanized.

3.2.11 Post-Installed Anchors

Post-installed anchors used for *tie-down* anchors or anchor bolts shall be approved by the *building official* and installed in accordance with the manufacturer's instructions. *Adhesive anchors* shall be used for tie-down anchors. Anchor bolts may be adhesive anchors or concrete screws, provided the foundation into which the anchor is being installed is in conformance with the manufacturer's installation requirements.

3.2.12 Proprietary Shear Walls

Proprietary shear walls shall be prefabricated wood shear panels or prefabricated cold-formed steel shear panels complying with the requirements of ICC-ES AC 436, FEMA P-795 (FEMA, 2011), or shall have been tested in accordance with ASTM D7989, in a manner and with documentation acceptable to the building official. Proprietary shear walls shall be installed in accordance with the manufacturer's installation requirements and the provisions of this prestandard.

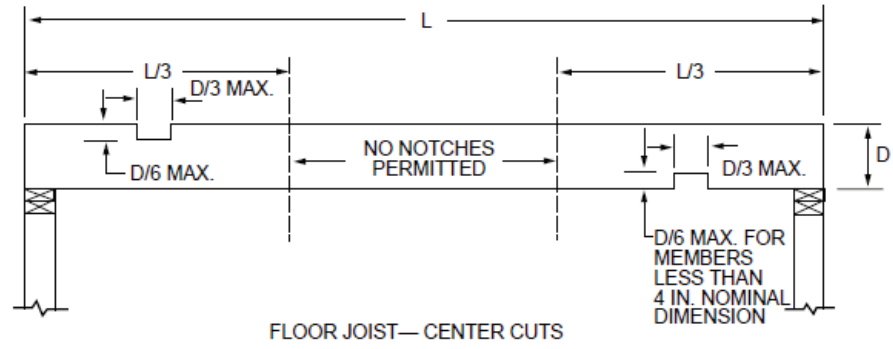
3.3 Installation

3.3.1 General

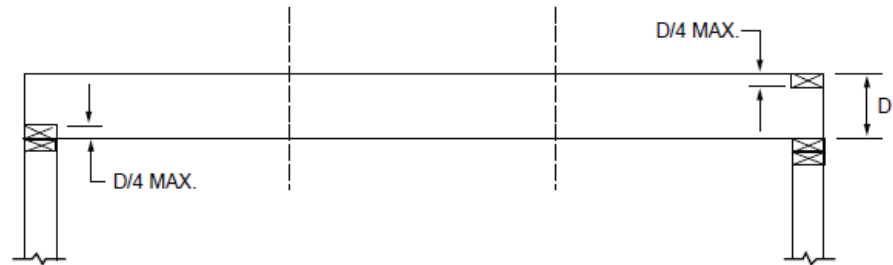
All new retrofit construction shall be in accordance with this section.

3.3.2 Notching and Boring

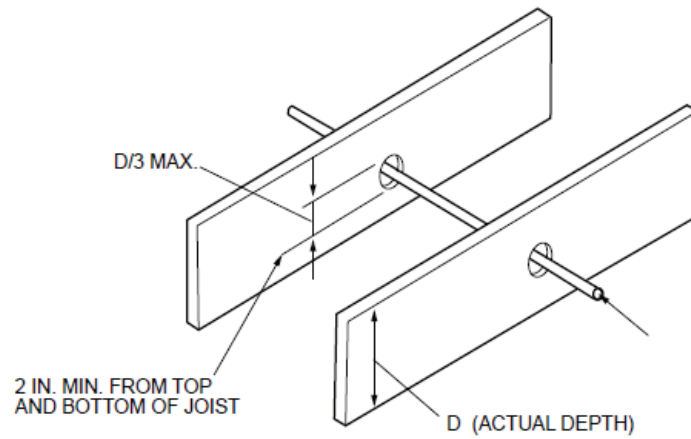
Solid sawn framing and sheathing shall not be notched or bored, except as specifically shown in the retrofit design, per IRC Figure R502.8 and R602.6(1), reprinted here as Figure 3.3-1 and Figure 3.3-2, or as approved. Engineered wood products shall not be notched or bored.



FLOOR JOIST— CENTER CUTS

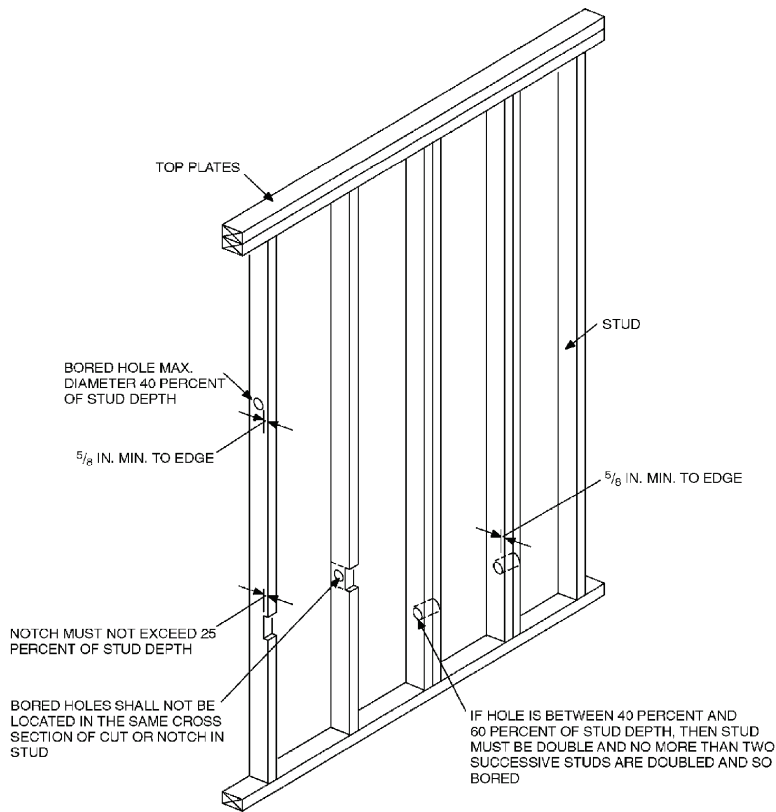


FLOOR JOIST— END CUTS



**FIGURE R502.8
CUTTING, NOTCHING AND DRILLING**

Figure 3.3-1 Notching and boring of solid-sawn framing, IRC Figure R502.8.



For SI: 1 inch = 25.4 mm.
 Note: Condition for exterior and bearing walls.

FIGURE R602.6(1)
 NOTCHING AND BORED HOLE LIMITATIONS FOR EXTERIOR WALLS AND BEARING WALLS

Figure 3.3-2 Notching and boring of solid-sawn framing, IRC Figure R602.6(1).

3.3.3 Anchorage to Existing Concrete

Anchors installed in existing concrete shall comply with all edge and end distances, as specified in this prestandard and the retrofit plans. Existing reinforcing steel shall not be drilled through. If reinforcing steel is hit during drilling, the hole shall be relocated a minimum of one inch clear of the initial hole, and the initial hole shall be filled with non-shrink grout.

3.3.4 Anchor Bolt Installation

New anchor bolts shall be provided at each perimeter wall *foundation sill plate*. Anchor bolts shall be spaced between 8 and 12 inches from each end of each section of foundation sill plate, and at the on-center spacing required by the retrofit provisions of this prestandard. Where existing sections of foundation sill plate are 24 inches or less in length, one anchor bolt shall be provided near center of the sill plate length. Foundation retrofit anchors shall be provided where the configuration does not permit the installation of new

anchor bolts. Spacing from end of foundation sill plate and on-center spacing shall be as required for anchor bolts.

Steel plate washers, not less than $0.227 \times 3 \times 3$ inches, shall be provided on each anchor bolt. The edge of the plate washer shall be placed within 1/2-inch of face of wood structural wall sheathing where wall is sheathed, and within 1/2-inch of inside face of exterior finish where wall is not sheathed.

3.3.5 Wood Structural Panel Sheathing

Wood structural panel sheathing shall be installed with 1/8-inch gaps at edges and ends of panels. Sheathing shall be laid out with its span direction (strength axis) perpendicular to supporting studs. Edge nailing, of the nail type and size specified in the retrofit design, shall be provided at each edge of each sheathing panel. A minimum distance of 3/8-inch shall be provided from center of nail to edge of sheathing panel. Provide new 2-2×, 3× or 4× studs where sheathing panels abut at a vertical joint. Provide 3× or 4× minimum blocking at all panel edges not otherwise falling on framing. No piece of new installed wood structural wall sheathing shall be less than 24 inch × 24 inch.

Sheathing nail heads shall be driven flush with the face of the sheathing. Where sheathing nails are overdriven to the extent that the nail head fractures the sheathing face, one additional nail shall be provided for each two overdriven nails. Added nails shall be spaced between existing.

3.3.6 Fasteners

Fasteners shall be installed in a manner so as to not cause splitting of the framing members. Where required to avoid splitting, nail holes shall be predrilled to 75 percent of the nail shank diameter. All holes for bolts shall be predrilled to 1/16-inch over bolt shank.

3.3.7 Connectors

Connectors shall be of the type and size specified in this prestandard, and shall be installed using the number and type of fasteners specified in the manufacturer's installation instructions. Connectors shall be distributed as specified by the applicable retrofit schedule or detail.

3.3.8 Structural Steel

The fabrication, corrosion protection, and erection of structural steel shall be in accordance with AISC 360. Welding of structural steel shall be in accordance with AWS D1.1.

3.3.9 Reinforcing Steel

Reinforcing steel fabrication, including bend radius and other detailing, shall be in accordance with the CRSI Manual of Practice. Lap splices shall not be less than 36 inches for #4 bars, 48 inches for #5 bars, and 60 inches for #6 bars. All straight bars shall be terminated with standard hooks unless otherwise noted. At foundation corners, each straight bar shall be extended all the way across the foundation to the minimum clear distance from the far edge and terminated with a 12-inch hook.

Welding of reinforcing steel shall be in accordance with AWS D1.4.

Steel reinforcement in concrete cast against the earth shall have a minimum cover of 3 inches (75 mm). Minimum cover for concrete cast in removable forms that will be exposed to the earth or weather shall be 1-1/2 inches (38 mm) for No. 5 bars or smaller, and 2 inches (50 mm) for No. 6 bars and larger.

Where lap splices occur, lap splices shall be provided in accordance with Table 3.3-1.

Table 3.3-1 Reinforcing Steel Minimum Lap Splice Length

	No. 4	No. 5
Horizontal bars with more than 12 inches concrete below	32 inches	42 inches
Other bars	24 inches	32 inches

12-inch long hooks shall be provided at all corners and intersections.

3.3.10 Crawlspace Ventilation and Access Openings

Where the existing area and distribution of crawlspace ventilation is modified by the retrofit work, it shall be demonstrated that the modified area and distribution meet the requirements of the adopted building or residential code. Where the existing crawlspace access openings are modified by the retrofit work, it shall be demonstrated that modified access openings meet the requirements of the adopted building or residential code.

3.3.11 Special Inspections

Special inspection by a third party inspector approved by the building official shall be provided for welding of structural steel.

Special inspection in accordance with the adopted building code and by a third party inspector approved by the building official shall be provided for seismic retrofit of hillside dwellings.

For *crawlspace dwellings, living-space-over-garage dwellings, chimneys* and *masonry fireplace surrounds*, special inspection by a third party inspector is not required for the following:

- Concrete or reinforcing steel for foundations provided a building department inspection is performed prior to placement of concrete. Design is based on an ultimate concrete strength of 2,500 psi or less.
- Installation of cast-in-place or *post-installed anchors* for anchor bolts.
- Installation of adhesive anchors for tie-down devices, provided that each anchor is torque-tested to 15 foot-pounds for 1/2-inch diameter anchors and 20 foot-pounds for 5/8-inch diameter anchors with no movement of anchor.
- Nailing of wood structural panel shear walls, provided a building department inspection is performed.

Chapter 4

Vulnerability-Based Assessment and Retrofit of Crawlspace Dwellings

4.1 General

This chapter contains provisions for vulnerability-based assessment and retrofit of wood light-frame *crawlspace dwellings* supported on a raised *cripple wall* and foundation systems (Figure 4.1-1, Configuration A) or supported directly on a foundation system (Figure 4.1-2, Configuration B). Where both occur in a single dwelling, dwellings shall be assessed for both Configuration A and Configuration B. Vulnerabilities addressed by this chapter are:

- At cripple walls and foundation systems (Configuration A)
 - Connection to the framing above (A)
 - Cripple wall sheathing (B)
 - *Foundation sill plate* anchorage to the foundation (C)
- At foundation *stem walls* or foundations without cripple walls (Configuration B)
 - Connection to the dwelling above (A)
 - Foundation sill plate anchorage to foundation (B)

The primary purpose of this chapter is the reduction of earthquake-induced damage to wood light-frame crawlspace dwellings.

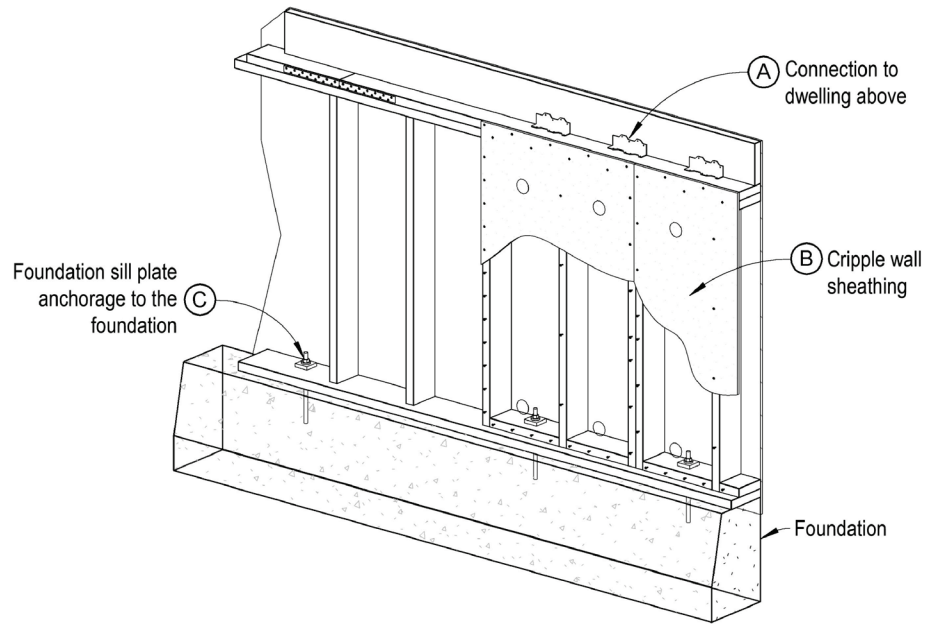


Figure 4.1-1 Example illustration of Configuration A.

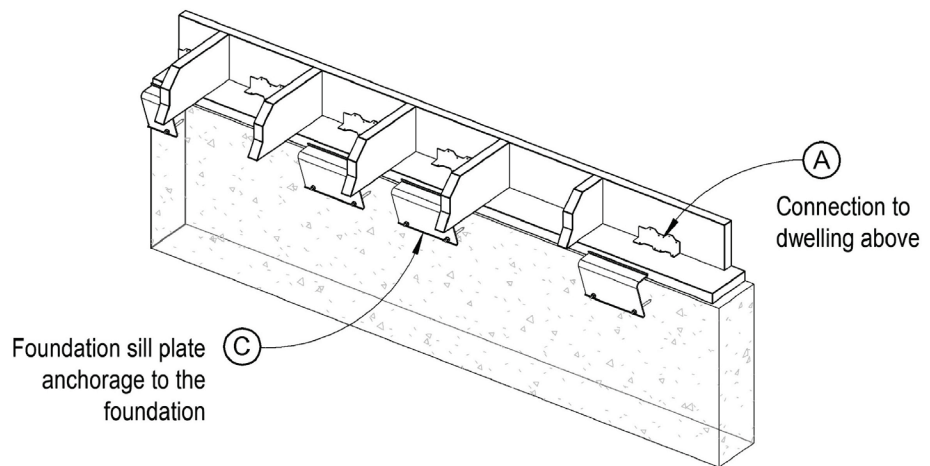


Figure 4.1-2 Example illustration of Configuration B.

4.1.1 Use of this Chapter

In addition to the scope limits of Section 1.8, the dwelling shall comply with all of the eligibility criteria of Table 4.1-1. Where the dwelling is not compliant with one or more of the eligibility statements, assessment and retrofit in accordance with this chapter shall not be permitted.

4.1.2 Vulnerability-Based Assessment and Retrofit Methods

Where a dwelling complies with Section 4.1.1, the dwelling need not be assessed and may be retrofitted in accordance with the prescriptive retrofit provisions of Section 4.4 or the simplified engineered retrofit provisions of Section 4.5 as applicable. If the dwelling does not comply with Section

4.1.1, assessment shall be in accordance with Section 4.3; alternately, assessment is not required if retrofit is to be provided. Where retrofit is required by Section 4.3, retrofit shall be in accordance with Section 4.1.3 or Section 4.1.4.

Table 4.1-1 Eligibility Criteria for Use of Chapter 4

Eligibility Criteria		Compliant	Non-Compliant
1	The dwelling is a detached <i>one- or two-family dwelling</i> or the dwelling is a unit in a <i>townhouse</i> and assessment and retrofit will occur for each attached <i>townhouse unit (the full townhouse structure)</i> .		
2	The dwelling is a wood light-frame dwelling that is two stories or less.		
3	The dwelling is a crawlspace dwelling as defined in Chapter 2 and the perimeter walls of the occupied stories (not including porches or other appurtenances) are supported on: <ul style="list-style-type: none"> a. Cripple walls foundation systems (Configuration A), or b. Foundation stem walls or foundations without cripple walls (Configuration B), or c. Post and pier systems to be retrofitted with cripple walls, or d. Cripple wall foundation systems or foundation without cripple walls in combination with a <i>slab-on-ground</i> foundation. 		
4	The dwelling has a continuous <i>perimeter foundation</i> (not including porches or other appurtenances), concrete stem walls or will be retrofitted to have a continuous perimeter foundation.		
5	Cripple walls, where they occur, do not exceed 7'-0" in clear height.		
6	The maximum slope as measured from the top of foundations along one edge of the home to the other end does not exceed 5 to 1 (horizontal to vertical) or 20%.		

4.1.3 Prescriptive Retrofit

For dwellings that meet the eligibility criteria of Table 4.1-1 and all of the additional eligibility criteria of Table 4.1-2, retrofit of the non-conforming conditions shall be permitted to use the prescriptive retrofit provisions of Section 4.4.

4.1.4 Simplified Engineered Retrofit

Where the prescriptive retrofit provisions of Section 4.4 are not used, a simplified engineered retrofit shall be provided in accordance with Section 4.5.

Table 4.1-2 Additional Eligibility Criteria for Use of Prescriptive Retrofit Provisions of Section 4.4

Eligibility Criteria		Compliant	Non-Compliant
1	The dwelling is assigned to <i>Seismic Design Category</i> (SDC) B through E in accordance with Section 1.6.		
2	The weight of roofing material shall not exceed 12 psf except where allowed by Section 4.4.10 for one-story crawlspace dwellings with clay tile roofing.		
3	Weight of exterior wall finish shall not exceed 10 psf, except veneer wainscots supported on concrete or masonry foundations that are permitted to extend up to four feet above the top of foundation.		
4	Weight of interior wall finish shall not exceed 8 psf, except <i>masonry fireplace surrounds</i> not more than 4 inches thick and not more than 100 square feet in area are permitted to exceed this weight.		
5	Weight of floor finish shall not exceed 5 psf, except that heavier floor finishes of up to 10 psf are acceptable where limited to 25% of the total floor area of each level.		
6	Floors in each story are at the same elevation, excluding slab-on-ground portions.		
7	The maximum square footage of the dwelling, excluding areas supported on slabs on grade, do not exceed 3,000 square feet for one-story dwellings and 4,000 square feet for two-story dwellings.		
8	No part of the foundations is constructed of unreinforced masonry or stone.		
9	Clear floor to ceiling heights at any occupied level do not exceed 9 feet.		
10	There is no indication that an engineered <i>seismic force-resisting system</i> is present in the dwelling (engineered plans, visible <i>tie-down</i> brackets).		

4.2 Definitions and Minimum Requirements

The definitions of Chapter 2 are applicable to all assessments and all retrofits designed in accordance with Chapter 4. The minimum requirements of Chapter 3 are applicable to all retrofits designed in accordance with Chapter 4. See Figure 4.4-18 for minimum requirements at existing single and double top plate splices, cutouts at braced wall panels, and allowable notching and reinforcing for cripple wall top plates and studs.

4.3 Vulnerability-Based Assessment

4.3.1 Scope

The assessment criteria of this section shall be used to determine whether existing foundations, anchorage, cripple walls, and connections are in compliance with the requirements of this chapter. Where they are in compliance with the requirements of this chapter, retrofit is not required. Where they are found to not be in compliance with the requirements of this chapter, retrofit in accordance with Section 4.4, Section 4.5, or a general engineered retrofit is required. The assessment provisions of Section 4.3 shall be permitted to be used provided existing cripple wall heights are 4

feet or less, and first floor framing is supported directly on cripple walls, a foundation sill, or any combination of the two, and where any existing retrofit work to be considered in the assessment obtained a building permit prior to the date of original publication of this prestandard.. Where Section 4.3.2 requires a detailed assessment, this detailed assessment shall be provided in accordance with Section 4.3.3.

In lieu of a detailed assessment, the dwelling may be retrofit in accordance with Section 4.4 or 4.5 as applicable.

4.3.2 Simplified Assessment

Crawlspace dwellings shall be assessed in accordance with Table 4.3-1. Each existing element listed in Table 4.3-1 and members to which these elements are directly attached, shall be assessed to identify incomplete or inadequate installation, damage, and deterioration that might significantly affect seismic performance. Where this assessment identifies incomplete or inadequate installation, damage or deterioration, the elements shall be deemed not adequate for use. For these conditions, the applicable assessment statement within Table 4.3-1 shall be determined to be false and the indicated compliance step taken. Alternately, a detailed assessment of existing elements in accordance with Chapter 8 may be provided.

The scope of this assessment shall be permitted to be based on the judgment of the evaluator. The findings and documentation of this investigation shall be subject to the approval of the *building official* where required.

Table 4.3-1 Simplified Structural Assessment for Crawlspace Dwellings

Item	Existing Configuration	Assessment Statement	Compliance Step if True	Compliance Step if False	Compliance Step if Unknown
1	A	The tallest cripple wall height does not exceed 4 feet.	Proceed to Item 2.	Provide engineered assessment or retrofit of sheathing, anchorage to foundation, and connection to dwelling above.	Not applicable.
2	A, B	Existing concrete foundation condition is adequate for use.	Retrofit of foundation is not required.	Retrofit of foundation is required.	Provide detailed assessment of foundation in accordance with Section 8.1.

Table 4.3-1 Simplified Structural Assessment for Crawlspace Dwellings (continued)

Item	Existing Configuration	Assessment Statement	Compliance Step if True	Compliance Step if False	Compliance Step if Unknown
3	A1	For the cripple wall with foundation system, the connectors to dwelling above are in condition adequate for use and are spaced on average, a maximum of 32 inches on center for a one-story dwelling or 16 inches on center for a two-story dwelling on average along each perimeter wall line.	Retrofit of connectors to dwelling above is not required.	Retrofit of connectors to dwelling above is required.	Provide detailed assessment or retrofit of connectors to dwelling above.
4	B1	For foundations without cripple walls, connectors to dwelling above are in adequate condition and are spaced on average a maximum, 32 inches on center for a one-story dwelling, or 16 inches on center for a two-story dwelling on average along each perimeter wall line.	Retrofit of connectors to dwelling above is not required.	Retrofit of connectors to dwelling above is required.	Provide detailed assessment or retrofit of connectors to dwelling above.
5	A2	The wood structural panel sheathing and nailing are in adequate condition for use and the length provided is at least 50% of the length of each perimeter wall for a one-story dwelling, or at least 70% of the length of each perimeter wall for a two-story dwelling. Wood structural panels shall be attached with 8d common nails spaced 4 inches on center along each edge and 12 inches on center at each intermediate support.	Retrofit of sheathing is not required.	Retrofit of sheathing, anchorage to foundation, and connectors to dwelling above is required.	Provide detailed assessment or sheathing retrofit.
6	A3, B2	Anchor bolts or proprietary anchors are in adequate condition for use and are spaced at 64 inches on center maximum for a one-story dwelling, or 32 inches on center maximum for a two-story dwelling on average along each perimeter wall line.	Retrofit of anchorage to foundation is not required.	Retrofit of anchorage to foundation is required.	Provide detailed assessment or anchorage retrofit.

Note: For configuration illustrations see Figure 4.1-1 and Figure 4.1-2.

4.3.3 Detailed Assessment

Detailed assessment for foundations, foundation sill plate anchorage to the foundation, cripple wall sheathing, and anchorage of perimeter blocking or rim joists to the foundation sill plate or cripple top plates below, shall be in accordance with Sections 8.1 through 8.4.

4.3.4 Engineered Assessment

As an alternate to the detailed assessment requirements of Section 4.3.3 and Sections 8.1 through 8.4, an evaluation by a *registered design professional* can be provided to demonstrate that existing components are in compliance with this prestandard. This evaluation shall utilize all engineering criteria listed in Section 4.5. For guidance, assumptions made in developing the simplified engineered vulnerability-based retrofit in Section 4.5 are listed in the commentary for Section 4.5.

4.4 Prescriptive Vulnerability-Based Retrofit

4.4.1 Scope

Prescriptive retrofit provisions of this section are permitted for use on dwellings and *dwelling units* complying with the eligibility criteria of Table 4.1-1 and Table 4.1-2.

Dwellings identified by Section 4.3 to require foundation retrofit shall comply with Section 4.4.4.

Dwellings identified by Section 4.3 to require foundation sill plate anchorage retrofit shall comply with Section 4.4.5.

Dwellings identified by Section 4.3 to require retrofit of the connection to dwelling above shall comply with Section 4.4.8.

Dwellings identified by Section 4.3 to require retrofit of the cripple wall sheathing shall comply with the requirements of Section 4.4.4 through Section 4.4.10.

Where a dwelling's actual conditions require modification of the vulnerability-based prescriptive retrofit solutions identified within this section, additional or modified details may be generated by a registered design professional and used to supplement the prescriptive procedures of this section. These supplemental details shall be stamped and signed by a registered design professional and *approved* by the building official.

All figures referenced in Section 4.4 describing the prescriptive retrofit provisions can be found at the end of Chapter 4.

4.4.2 Determination of Seismic Design Category

The prescriptive vulnerability-based retrofit procedures within Section 4.4 have been developed for dwellings located within Seismic Design Categories (SDCs) B to E. See Section 1.6 for S_{DS} values for use within this prescriptive procedure based upon the specific *Seismic Design Category*.

4.4.3 Determination of Weight Classification

The prescriptive vulnerability-based retrofit procedures of Section 4.4 have been developed for dwellings using three *weight classifications*: heavy, medium, and light construction. Further, eight weight combinations, based upon the type of exterior and interior wall finishes and roofing materials are assigned to three weight classifications as identified within Figure 4.4-1. Where interior or exterior finishes vary, a heavier type finish shall be assumed where 25% or more of that finish type exists within the dwelling.

4.4.4 Foundations

Where identified by Section 4.3 to require retrofit, foundations shall be replaced with continuous perimeter foundations conforming to Figure 4.4-19.

4.4.5 Foundation Sill Plate Anchorage to the Foundation

Where identified by Section 4.3 to require retrofit, foundation sill plate anchorage shall be retrofitted in accordance with this section. Foundation sill plate anchorage of one of the types listed in Figure 4.4-2 or Figure 4.4-3 shall be provided at each perimeter wall in accordance with Figure 4.4-12 and Figure 4.4-13. The number of anchors per line shall be in accordance with the Earthquake Retrofit Schedules in Figures 4.4-6 through Figure 4.4-11, but not more than 64 inches on center for one-story dwellings and 48 inches on center for two-story dwellings and can be evenly distributed along each wall line.

4.4.6 Cripple Wall Sheathing

Where identified by Section 4.3 to require retrofit, cripple wall sheathing shall be retrofitted to conform to this section. *Cripple wall clear heights* greater than 7 feet are not permitted and not covered by this chapter. Cripple wall lengths and nailing shall be proportioned in two equal length panels per wall line where possible as indicated in the Earthquake Retrofit Schedules provided in Figure 4.4-6 through Figure 4.4-11 as applicable. Two panels of slightly different lengths can be used where obstructions prohibit equal length walls. If a single panel is used on a wall line instead of two panels, the minimum single panel length shall be two times the two panel length in the schedule reduced by 10%. If more than two panels are used, the total length of the two panels should be increased 10% above the total panel length shown in the schedule. If panels of sufficient length with tie-downs cannot fit in the available wall length provided due to obstructions, the simplified engineering retrofit per Section 4.5 shall apply. In all cases, a fully sheathed wall line is deemed to comply with the bracing requirements within this prestandard.

Cripple walls sheathed with wood structural panels with or without tie-downs shall be provided at each perimeter wall line. Where tie-downs are used, the additional requirements of Section 4.4.7 shall apply. Wood structural panel bracing panels shall be provided in lengths not less than 4 feet. The length of braced panels without tie-downs shall be equal to or exceed twice the height of the cripple wall.

Wood structural bracing panels shall be provided as close to each end of each perimeter wall line as possible.

Where tie-downs are not used, wood structural panel installation shall conform to Figure 4.4-16. Where tie-downs are used, wood structural panel installation shall conform to Figure 4.4-17.

4.4.7 Additional Requirements for Cripple Walls with Tie-Downs

Where tie-downs are used in conjunction with the Earthquake Retrofit Schedules in Figure 4.4-6 through 4.4-11, the additional requirements of Section 4.4.7.1 shall apply.

4.4.7.1 Existing Foundation Requirements

Where tie-downs are used, the foundation requirements of Section 4.4.7.2 shall be met. Where these requirements are not met, a new foundation system shall be required in accordance with Section 4.4.4 or engineered retrofit design shall be provided in accordance with Section 4.5.

4.4.7.2 Existing Foundation Visual Verification and Testing Requirements

Where tie-downs are used in accordance with the Earthquake Retrofit Schedules provided in Figure 4.4-6 through Figure 4.4-11, additional visual verification and testing of the existing foundation system is required to be completed by the owner or general contractor and approved by the building official.

4.4.7.2.1 Visual Verification

The size of existing foundation systems at the location of new tie-down anchors shall be verified to be at least 15 inches deep (“D”) and 8 inches wide (“W”). The dimension “D” shall be measured from the bottom of footing to the underside of the existing mudsill. The dimension “W” shall be measured from the top outside face of footing to the inside top face of footing as indicated in Figure 4.4-17.

4.4.7.2.2 Existing Foundation Quality Requirements

Verification of the overall quality of the concrete along any wall line requiring tie-downs shall be made by use of a minimum of two sacrificial torque tests along each wall line where tie-downs are used. These tests shall consist of installing 1/2- or 5/8-inch diameter screw-type bolts into the existing concrete and verifying that a torque value per Table 4.4-1 can be achieved. Torque tests can be performed either by the owner, a general contractor, or a special inspection company or testing agency hired by the owner and as approved by the building official.

Table 4.4-1 Foundation Verification Requirements

Diameter	Screw Anchor Torque (ft-lbs.)	Adhesive Anchor Torque (ft-lbs.)
1/2"	35	15
5/8"	50	20

4.4.7.2.3 Existing Foundation Tension Test Requirements

Where “With Tie-downs” is specified within the Earthquake Retrofit Schedules in Figure 4.4-6 through Figure 4.4-11, each adhesive anchor shall be torque tested in accordance with Table 4.4-1. Torques in excess of those shown for adhesive anchors shall not be applied. Tests shall not be performed prior to adequate curing per manufacturer’s requirements. Anchors where torque tests fail shall be replaced and re-installed. Where torque tests continue to fail, the existing foundation system shall be replaced locally for a minimum of 30 inches on each side of the proposed tie-down anchor location.

4.4.7.2.4 Adhesive Anchor Installation Verification

Where “With Tie-downs” is specified within the Earthquake Retrofit Schedules in Figure 4.4-6 through Figure 4.4-11, installation shall conform to the manufacturer’s installation instructions. Items 1 through 10 below shall be performed and verified by the general contractor or owner:

1. Drill all holes to the specified diameter and depth
2. Blow all holes clean of dust with oil-free compressed air for a minimum of 4 seconds
3. Clean all holes with a nylon or steel brush for a minimum of 4 cycles (per manufacturer’s instructions)
4. Blow holes clean of dust with oil-free compressed air for a minimum of 4 seconds
5. Check adhesive cartridge expiration date and required minimum temperature for adhesive cure
6. Open cartridge, connect the required nozzle, and install cartridge in dispensing tool
7. Purge out the required amount of adhesive per the manufacturer’s instructions prior to filling any holes with adhesive
8. Fill the holes 1/2 to 2/3 full, starting at the bottom of the hole to prevent air pockets and withdraw the nozzle as the hole fills up

9. Insert a clean and oil-free threaded rod turning slowly until the threaded rod contacts the bottom of the hole
10. Do not disturb the threaded rod until adhesive has fully cured. See manufacturer's instructions for cure time required

4.4.7.3 Tie-Down Requirements

Tie-down requirements shall be as follows:

1. Tie-downs shall be as specified in Figure 4.4-4 and capable of developing 3,075 pounds based upon allowable stress design (ASD).
2. End studs(s) to which tie-downs are installed shall be 3× minimum or double 2× with nailing conforming to Figure 4.4-17.
3. All tie-downs shall use 5/8-inch diameter (A36) threaded rod adhesive-type anchors with minimum embedment per Figure 4.4-17.

4.4.8 Connection to Dwelling Above

Existing or new rim joists, blocking, and miscellaneous framing members shall be connected to the foundation sill or the top of cripple wall in accordance with Figures 4.4-13, Figure 4.4-14, and Figure 4.4-15, as required within the Earthquake Retrofit Schedules in Figure 4.4-6 through Figure 4.4-11, as applicable.

4.4.9 Additional Requirements for Non-Rectangular Dwellings with "T" or "L" Plan Configurations

Plan configurations other than rectangular such as "T" or "L" shapes that have offsets in the exterior wall lines, within the crawlspace plan area, greater than 33% of the largest plan dimension shall meet the following requirements in that direction:

- Foundation sill to foundation connections along offset walls shall have a maximum spacing of 32 inches on center.
- Floor joist to foundation sill and floor joist framing to the top of cripple wall connections along offset walls shall have a maximum spacing of 16 inches on center.
- Cripple walls, where they occur, shall be sheathed with new wood structural panels, as specified in Figure 4.4-16 or Figure 4.4-17. The sheathing shall have a minimum length of 90% of the offset wall length.

4.4.10 Special Provisions for One-Story Homes with Clay Tile Roofing

One story crawlspace dwellings with clay tile that weight up to 20 psf shall be permitted to be strengthened in accordance with the provisions for two-story heavy homes as noted in the applicable Earthquake Retrofit Schedules for an area twice the total area in square feet for any raised portion of the plan area.

4.5 Simplified Engineered Vulnerability-Based Retrofit

4.5.1 General

Engineered retrofit of foundations, foundation sill plate anchorage to the foundation, cripple wall sheathing, and anchorage of perimeter blocking or rim joists to the foundation sill plate or cripple wall top plates below shall be in accordance with the ASCE/SEI 7 Section 12.14, Simplified Alternative Structural Design Criteria for Simple Bearing Wall or Building Frame Systems, as amended below. Material design capacities for all components shall be as specified by the adopted building code.

1. The scope of seismic retrofit need only include the foundations, foundation sill plate anchorage to the foundation, cripple wall sheathing, and anchorage of perimeter blocking or rim joists to the foundation sill plate or cripple wall top plates below.
2. ASCE/SEI 7 Section 12.14 shall be modified as described in Table 4.5-1. ASCE/SEI 7 section may either be applicable as written (Y) with or without notes; not applicable (N); or applicable with clarifications noted (M).
3. Cripple wall wood structural panel sheathing and seismic load path shall be designed using a seismic response modification factor, R , of 4.0.
4. Finish and bracing materials other than wood structural panels (per definitions in Chapter 2) shall not be considered to provide seismic capacity in the crawlspace.
5. The in-plane *load path connections* for anchorage to foundations and anchorage to floor framing above shall be provided at all locations where retrofit cripple wall sheathing is provided. In-plane load path connections shall be designed using load combinations with an overstrength factor, Ω_0 , of 1.5 in lieu of 2.5 in ASCE/SEI 7 Section 12.14.3.2.

6. Where tie-downs are used in the existing foundation, the registered design professional shall be responsible for evaluating the existing foundation system.

Table 4.5-1 ASCE/SEI 7 Section 12.14 Application Matrix

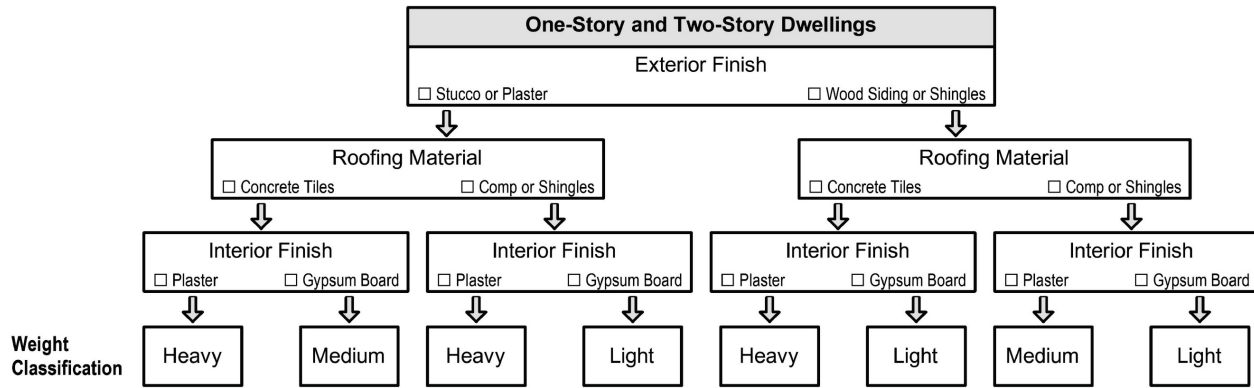
ASCE/SEI 7 Section	Applicability	Notes
12.14.1.1	N	All limitations listed within Items 1 through 12 shall be assumed to comply and ASCE/SEI 7 Section 12.14 is eligible for use
12.14.1.2	Y	
12.14.1.3	M	See Chapter 3 for additional definitions
12.14.1.4	M	Notations as applicable
12.14.2	M	See Section 4.5.1 Item 1
12.14.3	M	See Section 4.5.1 Item 1
12.14.3.1	Y	
12.14.3.2	M	E_{mh} shall be taken as $1.5Q_E$
12.14.4.1	N	
12.14.4.2	N	
12.14.5	M	See Section 4.5.2 Item 2
12.14.6	Y	
12.14.7	N	
12.14.8.1	M	$F = 1.0$ for two-story dwellings
12.14.8.2	Y	
12.14.8.3	Y	
12.14.8.3.1	M	See Section 4.5.2 Item 2
12.14.8.3.2	N	
12.14.8.3.2.1	N	
12.14.8.4	N	
12.14.8.5	N	

4.5.2 Additional Simplifying Assumptions

The following simplifications shall be permitted to be made in the engineered retrofit design:

1. Where applicable, the unit assembly weights listed in non-mandatory Appendix L of this prestandard are permitted to be used for determination of the seismic base shear.
2. In lieu of a horizontal force distribution in accordance with ASCE/SEI 7 Section 12.14.8, seismic forces may be distributed equally to each exterior wall line in each orthogonal direction, except as follows:

- a. Plan configurations other than rectangular such as “T” or “L” shapes that have offsets in the exterior wall lines, within the crawlspace plan area, greater than 33% of the largest plan dimension in each direction shall have seismic forces distributed to that exterior wall lines based upon rational analysis assuming relative diaphragm in-plane flexibility.
 - b. Where exterior walls of plan configurations other than rectangular such as “T” or “L” shapes have offset walls along the same orthogonal direction offset by less than 33%, the distribution of seismic forces may be assumed to be proportional to the length of each of the exterior wall segments.
3. When designing cripple walls for overturning, in lieu of a more detailed overturning analysis of the entire dwelling, each exterior cripple wall line shall be designed to resist its local overturning moment plus 15 percent of the total overturning moment of the superstructure above. The calculations of forces F_R and F_{2nd} (where applicable) can be based upon tributary mass to those levels per ASCE/SEI 7 Section 12.14.13.
 4. The allowable tension load at the end of cripple walls braced with wood structural panels can be assumed as follows:
 - a. Where two *post-installed anchor* bolts are installed at each end of cripple walls braced with wood structural panels as indicated in Figure 4.4-16, the allowable tension load may be assumed to have an allowable uplift capacity of 1.5 kips (ASD) provided there is a minimum length to height ratio of 2.0 for the sheathed portion of the cripple wall.
 - b. Where one post-installed anchor bolt and one tie-down anchor are installed at each end of cripple walls braced with wood structural panels as indicated Figure 4.4-17, the end of the wall may be assumed to have an allowable uplift capacity of 3.0 kips (ASD).
 5. Soil *site class* may be assumed to be type C if specific site class information is not available.



Weight Classification:

This flowchart is used to determine the general weight classification of your home's construction.

1. Check the box of the material that most closely matches your home's finishes.
2. Note the Weight Classification result for use in the Earthquake Retrofit Schedules.

Specific notes for exterior, interior and roof coverings

1. The "wood siding or shingles" exterior finish category also includes finishes of similar weight, including but not limited to fiber-cement and aluminum siding.
2. The "comp or shingles" roofing material category also includes roofing materials of similar weight, including but not limited to roll roofing, built-up felt roofing, single-ply membrane roofing, and metal roofing.
3. The "gypsum board" interior finish category also includes wall finish materials of similar weight, including but not limited to wood board or panel siding.
4. The exterior finish, roofing material and interior finish categories are intended to be identified based on the predominant materials used in construction.

Figure 4.4-1 Dwelling weight classification by interior and exterior finishes. Sheet S3.

ANCHOR BOLTS			
IMAGE	TYPE	EMBEDMENT DEPTH	
		1/2"Ø	5/8"Ø
	Screw-Type Anchor	4-1/2"	4-1/2"
	Adhesive-Type Anchor	4-1/4"	5"

Figure 4.4-3 Foundation sill anchors. Sheet S3.

TIE-DOWNS			
Supplemental Technical Notes, Sheet S2, Section T			
IMAGE	TYPE	SHEET REF	CAPACITY (ASD)
	Wood Stud to Foundation Tension Tie	SHEET D4	3000#

Figure 4.4-4 Tie-down requirements. Sheet S3.

CONNECTORS				
IMAGE	TYPE	SHEET REF	MIN CAPACITY (lbs) ASD	
	A	Foundation Sill to Foundation	1530	
	B		960	
	C		875	

Figure 4.4-2 Foundation sill anchors. Sheet S3.

	D	Floor to Cripple Wall or Floor to Foundation Sill	565
	E		740
	F		590
	G		445
	H		725

Figure 4.4-5 Floor to cripple wall or foundation sill connectors. Sheet S3.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.0$ Seismic) ONE-STORY																			
Weight Category	Total Area in Square Feet	Mark row that applies	Length Each of Two Braced Wall Sections Required Along Each Perimeter Wall Line								Number of Foundation Connectors or Anchors at Each Perimeter Wall Line Assume Distributed Along Length								
			Wood Structural Panels										Foundation Sill Anchors			Floor to Cripple Wall or Floor to Foundation Sill			
			Cripple Wall Height								Panel Edge Nailing								
			up to 1'	1'-1" to 2'	2'-1" to 4'-0"	4'-1" to 6'-0"	6'-1" to 7'-0"	Without Tie-downs	With Tie-downs	Without Tie-downs		With Tie-downs	Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"
1-Story Light Construction	up to 800	<input type="checkbox"/>	5.3'	5.3'	8.0'	5.3'	9.3'	5.3'	9.3'	6.7'	4"	4	7	7	7	5	11	10	14
	801 to 1000	<input type="checkbox"/>	6.7'	6.7'	8.0'	6.7'	10.7'	6.7'	10.7'	8.0'	4"	5	8	8	8	6	13	12	16
	1001 to 1200	<input type="checkbox"/>	6.7'	6.7'	9.3'	6.7'	10.7'	8.0'	12.0'	8.0'	4"	6	9	10	10	7	15	14	19
	1201 to 1500	<input type="checkbox"/>	8.0'	8.0'	10.7'	8.0'	13.3'	9.3'	13.3'	9.3'	4"	7	11	12	12	8	18	17	22
	1501 to 2000	<input type="checkbox"/>	9.3'	10.7'	13.3'	10.7'	14.7'	10.7'	16.0'	12.0'	4"	9	14	15	15	10	23	22	29
	2001 to 2500	<input type="checkbox"/>	12.0'	12.0'	14.7'	12.0'	17.3'	12.0'	18.7'	13.3'	4"	10	16	18	18	12	27	26	35
	2501 to 3000	<input type="checkbox"/>	14.7'	14.7'	16.0'	14.7'	18.7'	14.7'	20.0'	16.0'	4"	12	19	21	21	14	32	31	40
1-Story Medium Construction	up to 800	<input type="checkbox"/>	5.3'	6.7'	8.0'	5.3'	9.3'	6.7'	10.7'	6.7'	3"	5	8	8	8	6	13	12	16
	801 to 1000	<input type="checkbox"/>	5.3'	6.7'	9.3'	6.7'	10.7'	8.0'	12.0'	8.0'	3"	6	9	10	10	7	15	14	19
	1001 to 1200	<input type="checkbox"/>	6.7'	8.0'	9.3'	6.7'	12.0'	8.0'	12.0'	9.3'	3"	7	10	11	11	8	17	17	22
	1201 to 1500	<input type="checkbox"/>	8.0'	8.0'	10.7'	8.0'	13.3'	9.3'	14.7'	10.7'	3"	8	12	13	13	9	20	20	26
	1501 to 2000	<input type="checkbox"/>	9.3'	10.7'	13.3'	9.3'	14.7'	10.7'	16.0'	12.0'	3"	10	15	17	17	11	25	24	32
	2001 to 2500	<input type="checkbox"/>	10.7'	12.0'	14.7'	10.7'	17.3'	13.3'	18.7'	13.3'	3"	12	18	20	20	14	30	29	38
	2501 to 3000	<input type="checkbox"/>	12.0'	13.3'	16.0'	12.0'	18.7'	14.7'	20.0'	16.0'	3"	13	21	23	23	16	35	34	45
1-Story Heavy Construction	up to 800	<input type="checkbox"/>	5.3'	6.7'	8.0'	5.3'	10.7'	6.7'	10.7'	8.0'	2"	6	9	10	10	7	15	14	18
	801 to 1000	<input type="checkbox"/>	6.7'	8.0'	9.3'	6.7'	12.0'	8.0'	12.0'	9.3'	2"	7	10	11	11	8	17	17	22
	1001 to 1200	<input type="checkbox"/>	6.7'	8.0'	10.7'	8.0'	12.0'	9.3'	13.3'	10.7'	2"	8	12	13	13	9	20	19	25
	1201 to 1500	<input type="checkbox"/>	8.0'	9.3'	12.0'	9.3'	14.7'	10.7'	14.7'	12.0'	2"	9	14	15	15	11	24	23	30
	1501 to 2000	<input type="checkbox"/>	9.3'	10.7'	14.7'	10.7'	16.0'	12.0'	17.3'	13.3'	2"	11	18	19	19	13	30	29	38
	2001 to 2500	<input type="checkbox"/>	10.7'	13.3'	16.0'	12.0'	18.7'	14.7'	20.0'	16.0'	2"	13	21	23	23	16	36	34	45
	2501 to 3000	<input type="checkbox"/>	12.0'	14.7'	17.3'	13.3'	20.0'	16.0'	21.3'	17.3'	2"	16	25	27	27	18	41	40	53

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible and spaced as equally along each wall line as possible. Note that one additional anchor is required at the end of each braced wall panel per Sheet S4.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie-downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.)
- Connector Type "F" should be used as an alternative only if joists have blocking on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Foundation sill anchor types A, B, and C should not be used with cripple walls over 2 feet.

Figure 4.4-6 Earthquake retrofit schedule, $S_{DS} = 1.0$, one story. Sheet S3.1-1.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.2$ High Seismic) ONE-STORY																			
Weight Category	Total Area in Square Feet	Mark row that applies <input checked="" type="checkbox"/>	Length Each of Two Braced Wall Sections Required Along Each Perimeter Wall Line								Number of Foundation Connectors or Anchors at Each Perimeter Wall Line Assume Distributed Along Length								
			Wood Structural Panels										Foundation Sill Anchors				Floor to Cripple Wall or Floor to Foundation Sill		
			Cripple Wall Height								Panel Edge Nailing								
			up to 1'	1'-1" to 2'	2'-1" to 4'-0"		4'-1" to 6'-0"		6'-1" to 7'-0"										
			Without Tie-downs	Without Tie-downs	Without Tie-downs	With Tie-downs	Without Tie-downs	With Tie-downs	Without Tie-downs	With Tie-downs		Type "A"	Type "B"	Type "C"	1/2" ø Bolt	5/8" ø Bolt	Type "D"	Type "E" or "F"	Type "G"
1-Story Light Construction	up to 800		6.7'	6.7'	8.0'	6.7'	10.7'	6.7'	10.7'	8.0'	4"	5	8	8	8	6	13	12	16
	801 to 1000		6.7'	8.0'	9.3'	6.7'	12.0'	8.0'	12.0'	8.0'	4"	6	9	10	10	7	15	15	19
	1001 to 1200		8.0'	8.0'	10.7'	8.0'	13.3'	9.3'	13.3'	9.3'	4"	7	11	12	12	8	18	17	22
	1201 to 1500		9.3'	9.3'	12.0'	9.3'	14.7'	10.7'	16.0'	10.7'	4"	8	13	14	14	10	21	20	27
	1501 to 2000		12.0'	12.0'	14.7'	12.0'	17.3'	12.0'	18.7'	13.3'	4"	10	16	18	18	12	27	26	34
	2001 to 2500		14.7'	14.7'	17.3'	14.7'	20.0'	14.7'	21.3'	16.0'	4"	12	19	21	21	15	33	31	41
	2501 to 3000		17.3'	17.3'	18.7'	17.3'	21.3'	17.3'	22.7'	17.3'	4"	14	23	25	25	17	38	37	48
1-Story Medium Construction	up to 800		5.3'	6.7'	9.3'	6.7'	10.7'	8.0'	12.0'	8.0'	3"	6	9	10	10	7	15	15	19
	801 to 1000		6.7'	8.0'	10.7'	6.7'	12.0'	8.0'	13.3'	9.3'	3"	7	11	12	12	8	18	17	23
	1001 to 1200		8.0'	8.0'	10.7'	8.0'	13.3'	9.3'	14.7'	10.7'	3"	8	12	13	13	9	21	20	26
	1201 to 1500		9.3'	9.3'	12.0'	9.3'	14.7'	10.7'	16.0'	12.0'	3"	9	15	16	16	11	24	23	31
	1501 to 2000		10.7'	12.0'	14.7'	10.7'	17.3'	13.3'	18.7'	14.7'	3"	12	18	20	20	14	30	29	39
	2001 to 2500		13.3'	13.3'	17.3'	13.3'	20.0'	14.7'	21.3'	16.0'	3"	14	22	24	24	16	36	35	46
	2501 to 3000		14.7'	14.7'	18.7'	14.7'	21.3'	17.3'	22.7'	18.7'	3"	16	25	27	27	19	42	40	53
1-Story Heavy Construction	up to 800		6.7'	8.0'	9.3'	6.7'	12.0'	8.0'	12.0'	9.3'	2"	7	10	11	11	8	17	17	22
	801 to 1000		6.7'	8.0'	10.7'	8.0'	13.3'	9.3'	14.7'	10.7'	2"	8	12	14	13	9	21	20	26
	1001 to 1200		8.0'	9.3'	12.0'	9.3'	14.7'	10.7'	16.0'	12.0'	2"	9	14	16	15	11	24	23	30
	1201 to 1500		9.3'	10.7'	13.3'	10.7'	16.0'	12.0'	17.3'	13.3'	2"	11	17	18	18	13	28	27	36
	1501 to 2000		10.7'	13.3'	16.0'	12.0'	18.7'	14.7'	20.0'	16.0'	2"	13	21	23	23	16	36	34	45
	2001 to 2500		13.3'	14.7'	18.7'	13.3'	21.3'	16.0'	22.7'	17.3'	2"	16	25	28	28	19	43	41	54
	2501 to 3000		14.7'	16.0'	20.0'	16.0'	22.7'	18.7'	25.3'	20.0'	2"	19	29	32	32	22	50	48	63

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible and spaced as equally along each wall line as possible. Note that one additional anchor is required at the end of each braced wall panel per Sheet S4.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie-downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.)
- Connector Type "F" should be used as an alternative only if joists have blocking on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Foundation sill anchor types A, B, and C should not be used with cripple walls over 2 feet.

Figure 4.4-7 Earthquake retrofit schedule, $S_{DS} = 1.2$, one story. Sheet S3.1-2.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.5$ Very High Seismic) ONE-STORY																			
Weight Category	Total Area in Square Feet	Mark row that applies <input checked="" type="checkbox"/>	Length Each of Two Braced Wall Sections Required Along Each Perimeter Wall Line								Number of Foundation Connectors or Anchors at Each Perimeter Wall Line Assume Distributed Along Length								
			Wood Structural Panels								Foundation Sill Anchors					Floor to Cripple Wall or Floor to Foundation Sill			
			Cripple Wall Height																
			up to 1' Without Tie-downs	1'-1" to 2' Without Tie-downs	2'-1" to 4'-0" Without Tie-downs		4'-1" to 6'-0" Without Tie-downs		6'-1" to 7'-0" Without Tie-downs		Panel Edge Nailing	Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"
1-Story Light Construction	up to 800		8.0'	8.0'	10.7'	8.0'	12.0'	8.0'	13.3'	9.3'	4"	6	10	10	10	7	16	15	20
	801 to 1000		9.3'	9.3'	12.0'	9.3'	13.3'	9.3'	14.7'	10.7'	4"	7	11	12	12	9	19	18	24
	1001 to 1200		10.7'	10.7'	13.3'	10.7'	16.0'	10.7'	16.0'	12.0'	4"	8	13	14	14	10	22	21	28
	1201 to 1500		12.0'	12.0'	14.7'	12.0'	17.3'	12.0'	18.7'	13.3'	4"	10	16	17	17	12	26	25	33
	1501 to 2000		14.7'	14.7'	17.3'	14.7'	21.3'	16.0'	22.7'	16.0'	4"	13	20	22	22	15	34	32	43
	2001 to 2500		18.7'	18.7'	20.0'	18.7'	24.0'	18.7'	25.3'	18.7'	4"	15	24	27	27	18	41	39	52
	2501 to 3000		21.3'	21.3'	22.7'	21.3'	26.7'	21.3'	28.0'	21.3'	4"	18	28	31	31	21	48	46	60
1-Story Medium Construction	up to 800		6.7'	8.0'	10.7'	6.7'	13.3'	9.3'	13.3'	9.3'	3"	7	11	12	12	9	19	18	24
	801 to 1000		8.0'	9.3'	12.0'	8.0'	14.7'	10.7'	16.0'	10.7'	3"	9	13	15	15	10	22	21	28
	1001 to 1200		9.3'	10.7'	13.3'	9.3'	16.0'	12.0'	17.3'	12.0'	3"	10	15	17	17	11	26	25	32
	1201 to 1500		10.7'	12.0'	14.7'	10.7'	17.3'	13.3'	18.7'	14.7'	3"	12	18	20	20	14	30	29	38
	1501 to 2000		13.3'	13.3'	17.3'	13.3'	21.3'	16.0'	22.7'	17.3'	3"	14	23	25	25	17	38	36	48
	2001 to 2500		16.0'	16.0'	20.0'	16.0'	22.7'	17.3'	25.3'	20.0'	3"	17	27	29	29	20	45	43	57
	2501 to 3000		18.7'	18.7'	21.3'	18.7'	25.3'	20.0'	26.7'	21.3'	3"	20	31	34	34	23	53	50	67
1-Story Heavy Construction	up to 800		8.0'	9.3'	12.0'	8.0'	13.3	10.7'	14.7'	10.7'	2"	8	13	14	14	10	22	21	27
	801 to 1000		8.0'	10.7'	13.3'	9.3'	16.0'	12.0'	17.3'	12.0'	2"	10	15	17	17	11	26	25	33
	1001 to 1200		9.3'	12.0'	14.7'	10.7'	17.3'	13.3'	18.7'	13.3'	2"	11	18	19	19	13	30	28	37
	1201 to 1500		10.7'	13.3	16.0'	12.0'	18.7'	14.7'	20.0'	16.0'	2"	13	21	23	23	16	35	34	45
	1501 to 2000		13.3	16.0'	18.7'	14.7'	22.7'	17.3'	24.0'	18.7'	2"	17	26	29	29	20	44	43	56
	2001 to 2500		14.7'	17.3'	21.3'	16.0'	25.3'	20.0'	26.7'	21.3'	2"	20	32	35	34	24	53	51	67
	2501 to 3000		17.3'	20.0'	24.0'	18.7'	28.0'	22.7'	29.3'	24.0'	2"	23	37	40	40	27	62	59	79

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible and spaced as equally along each wall line as possible. Note that one additional anchor is required at the end of each braced wall panel per Sheet S4.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie-downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.)
- Connector Type "F" should be used as an alternative only if joists have blocking on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Foundation sill anchor types A, B, and C should not be used with cripple walls over 2 feet.

Figure 4.4-8 Earthquake retrofit schedule, $S_{DS} = 1.5$, one story. Sheet S3.1-3.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.0$ Seismic) TWO-STORY																				
Weight Category	Total Area in Square Feet	<input checked="" type="checkbox"/> Mark row that applies	Length Each of Two Braced Wall Sections Required Along Each Perimeter Wall Line								Number of Foundation Connectors or Anchors at Each Perimeter Wall Line Assume Distributed Along Length									
			Wood Structural Panels										Foundation Sill Anchors				Floor to Cripple Wall or Floor to Foundation Sill			
			Cripple Wall Height								Panel Edge Nailing									
			up to 1'		1'-1" to 2'		2'-1" to 4'-0"		4'-1" to 6'-0"			6'-1" to 7'-0"		Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"
Without Tie-downs	With Tie-downs	Without Tie-downs	With Tie-downs	Without Tie-downs	With Tie-downs	Without Tie-downs	With Tie-downs	Without Tie-downs	With Tie-downs											
2-Story Light Construction	up to 1600		8.0'	8.0'	10.7'	8.0'	12.0'	9.3'	13.3'	9.3'	4"	7	10	11	11	8	17	17	22	
	1601 to 2000		9.3'	9.3'	12.0'	9.3'	13.3'	10.7'	14.7'	10.7'	4"	8	12	13	13	9	20	19	26	
	2001 to 2400		10.7'	10.7'	13.3'	10.7'	14.7'	10.7'	16.0'	12.0'	4"	9	14	15	15	10	23	22	29	
	2401 to 3000		12.0'	12.0'	14.7'	12.0'	17.3'	13.3'	18.7'	13.3'	4"	10	16	18	18	12	27	26	34	
	3001 to 4000		14.7'	14.7'	17.3'	16.0'	20.0'	16.0'	21.3'	16.0'	4"	13	20	22	22	15	34	32	43	
2-Story Medium Construction	up to 1600		8.0'	9.3'	10.7'	8.0'	13.3'	9.3'	13.3'	10.7'	3"	7	11	12	12	9	19	18	24	
	1601 to 2000		9.3'	10.7'	12.0'	9.3'	14.7'	10.7'	14.7'	12.0'	3"	9	13	15	15	10	22	22	28	
	2001 to 2400		9.3'	10.7'	13.3'	10.7'	16.0'	12.0'	16.0'	13.3'	3"	10	15	17	17	11	26	25	32	
	2401 to 3000		10.7'	12.0'	14.7'	12.0'	17.3'	13.3'	18.7'	14.7'	3"	12	18	20	20	14	30	29	39	
	3001 to 4000		13.3'	14.7'	17.3'	13.3'	20.0'	16.0'	21.3'	17.3'	3"	14	23	25	25	17	38	36	48	
2-Story Heavy Construction	up to 1600		9.3'	9.3'	12.0'	9.3'	13.3'	10.7'	14.7'	12.0'	2"	9	14	16	16	11	24	23	30	
	1601 to 2000		9.3'	10.7'	13.3'	10.7'	14.7'	12.0'	16.0'	13.3'	2"	11	17	18	18	13	28	27	35	
	2001 to 2400		10.7'	12.0'	14.7'	10.7'	16.0'	13.3'	17.3'	14.7'	2"	12	19	21	21	14	32	31	41	
	2401 to 3000		12.0'	13.3'	16.0'	13.3'	18.7'	14.7'	18.7'	16.0'	2"	14	23	25	25	17	38	37	48	
	3001 to 4000		13.3'	16.0'	18.7'	14.7'	21.3'	17.3'	22.7'	18.7'	2"	18	28	31	31	21	48	46	60	

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible and spaced as equally along each wall line as possible. Note that one additional anchor is required at the end of each braced wall panel per Sheet S4.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie-downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.)
- Connector Type "F" should be used as an alternative only if joists have blocking on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Foundation sill anchor types A, B, and C should not be used with cripple walls over 2 feet.

Figure 4.4-9 Earthquake retrofit schedule, $S_{DS} = 1.0$, two story. Sheet S3.1-4.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.2$ High Seismic) TWO-STORY																							
Weight Category	Total Area in Square Feet	Mark row that applies <input checked="" type="checkbox"/>	Length Each of Two Braced Wall Sections Required Along Each Perimeter Wall Line								Number of Foundation Connectors or Anchors at Each Perimeter Wall Line Assume Distributed Along Length												
			Wood Structural Panels										Foundation Sill Anchors				Floor to Cripple Wall or Floor to Foundation Sill						
			Cripple Wall Height								Panel Edge Nailing	Type "A"		Type "B"		Type "C"		Type "D"		Type "E" or "F"		Type "G"	
			up to 1'		1'-1" to 2'		2'-1" to 4'-0"		4'-1" to 6'-0"			6'-1" to 7'-0"		Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"		
2-Story Light Construction	up to 1600		9.3'	9.3'	12.0'	9.3'	14.7'	10.7'	16.0'	12.0'	4"	8	12	13	13	9	21	20	26				
	1601 to 2000		10.7'	10.7'	13.3'	10.7'	16.0'	12.0'	17.3'	13.3'	4"	9	14	16	16	11	24	23	31				
	2001 to 2400		12.0'	12.0'	14.7'	13.3'	17.3'	13.3'	18.7'	14.7'	4"	10	16	18	18	12	28	26	35				
	2401 to 3000		14.7'	14.7'	16.0'	14.7'	20.0'	14.7'	20.0'	16.0'	4"	12	19	21	21	14	33	31	41				
	3001 to 4000		17.3'	18.7'	18.7'	18.7'	22.7'	18.7'	24.0'	18.7'	4"	15	24	26	26	18	40	39	51				
2-Story Medium Construction	up to 1600		9.3'	10.7'	12.0'	9.3'	14.7'	10.7'	16.0'	12.0'	3"	9	14	15	15	10	23	22	29				
	1601 to 2000		10.7'	12.0'	13.3'	10.7'	16.0'	12.0'	17.3'	13.3'	3"	10	16	18	17	12	27	26	34				
	2001 to 2400		10.7'	12.0'	14.7'	12.0'	17.3'	13.3'	18.7'	14.7'	3"	12	18	20	20	14	31	29	39				
	2401 to 3000		13.3'	14.7'	17.3'	13.3'	20.0'	16.0'	21.3'	16.0'	3"	14	22	24	24	16	36	35	46				
	3001 to 4000		16.0'	16.0'	20.0'	16.0'	22.7'	18.7'	24.0'	20.0'	3"	17	27	30	29	20	46	44	58				
2-Story Heavy Construction	up to 1600		9.3'	10.7'	13.3'	10.7'	16.0'	12.0'	16.0'	13.3'	2"	11	17	19	18	13	28	27	36				
	1601 to 2000		10.7'	12.0'	14.7'	12.0'	17.3'	13.3'	18.7'	14.7'	2"	13	20	22	22	15	34	32	42				
	2001 to 2400		12.0'	13.3'	16.0'	13.3'	18.7'	14.7'	20.0'	16.0'	2"	15	23	25	25	17	38	37	49				
	2401 to 3000		13.3'	14.7'	18.7'	14.7'	21.3'	17.3'	21.3'	18.7'	2"	17	27	30	29	20	46	44	58				
	3001 to 4000		16.0'	17.3'	21.3'	17.3'	24.0'	20.0'	25.3'	21.3'	2"	21	34	37	37	25	57	55	72				

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible and spaced as equally along each wall line as possible. Note that one additional anchor is required at the end of each braced wall panel per Sheet S4.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie-downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.)
- Connector Type "F" should be used as an alternative only if joists have blocking on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Foundation sill anchor types A, B, and C should not be used with cripple walls over 2 feet.

Figure 4.4-10 Earthquake retrofit schedule, $S_{DS} = 1.2$, two story. Sheet S3.1-5.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS}= 1.5$ Very High Seismic) TWO-STORY																					
Weight Category	Total Area in Square Feet	<input checked="" type="checkbox"/> Mark row that applies	Length Each of Two Braced Wall Sections Required Along Each Perimeter Wall Line								Number of Foundation Connectors or Anchors at Each Perimeter Wall Line Assume Distributed Along Length										
			Wood Structural Panels										Foundation Sill Anchors					Floor to Cripple Wall or Floor to Foundation Sill			
			Cripple Wall Height								Panel Edge Nailing	Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"		
			up to 1'	1'-1" to 2'	2'-1" to 4'-0"		4'-1" to 6'-0"		6'-1" to 7'-0"												
Without Tie-downs	Without Tie-downs	Without Tie-downs	With Tie-downs	Without Tie-downs	With Tie-downs	Without Tie-downs	With Tie-downs	Without Tie-downs	With Tie-downs												
2-Story Light Construction	up to 1600		12.0'	12.0'	14.7'	12.0'	17.3'	12.0'	18.7'	13.3'	4"	10	15	17	17	11	26	25	32		
	1601 to 2000		13.3'	13.3'	16.0'	13.3'	18.7'	14.7'	20.0'	16.0'	4"	11	18	20	19	13	30	29	38		
	2001 to 2400		14.7'	16.0'	17.3'	16.0'	21.3'	16.0'	22.7'	17.3'	4"	13	20	22	22	15	34	33	43		
	2401 to 3000		18.7'	18.7'	20.0'	18.7'	22.7'	18.7'	24.0'	18.7'	4"	15	24	26	26	18	41	39	51		
	3001 to 4000		22.7'	22.7'	22.7'	22.7'	26.7'	24.0'	28.0'	24.0'	4"	19	30	33	33	22	50	48	64		
2-Story Medium Construction	up to 1600		10.7'	12.0'	14.7'	10.7'	17.3'	13.3'	18.7'	14.7'	3"	11	17	18	18	13	28	27	36		
	1601 to 2000		12.0'	13.3'	16.0'	12.0'	18.7'	14.7'	20.0'	16.0'	3"	13	20	22	22	15	33	32	42		
	2001 to 2400		13.3'	14.7'	18.7'	13.3'	21.3'	16.0'	22.7'	17.3'	3"	14	23	25	25	17	38	37	48		
	2401 to 3000		16.0'	17.3'	20.0'	16.0'	22.7'	18.7'	24.0'	20.0'	3"	17	27	29	29	20	45	43	58		
	3001 to 4000		20.0'	20.0'	22.7'	20.0'	26.7'	21.3'	28.0'	22.7'	3"	21	34	37	37	25	57	54	72		
2-Story Heavy Construction	up to 1600		12.0'	13.3'	16.0'	12.0'	18.7'	14.7'	20.0'	16.0'	2"	13	21	23	23	16	35	34	45		
	1601 to 2000		13.3'	14.7'	17.3'	14.7'	20.0'	16.0'	21.3'	17.3'	2"	16	25	27	27	19	42	40	53		
	2001 to 2400		14.7'	16.0'	20.0'	16.0'	22.7'	18.7'	24.0'	18.7'	2"	18	28	31	31	21	48	46	61		
	2401 to 3000		16.0'	18.7'	21.3'	17.3'	24.0'	20.0'	25.3'	21.3'	2"	21	34	37	37	25	57	55	72		
	3001 to 4000		18.7'	21.3'	25.3'	20.0'	28.0'	24.0'	29.3'	25.3'	2"	27	42	46	46	31	71	68	90		

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible and spaced as equally along each wall line as possible. Note that one additional anchor is required at the end of each braced wall panel per Sheet S4.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie-downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.)
- Connector Type "F" should be used as an alternative only if joists have blocking on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Foundation sill anchor types A, B, and C should not be used with cripple walls over 2 feet.

Figure 4.4-11 Earthquake retrofit schedule, $S_{DS} = 1.5$, two story. Sheet S3.1-6.

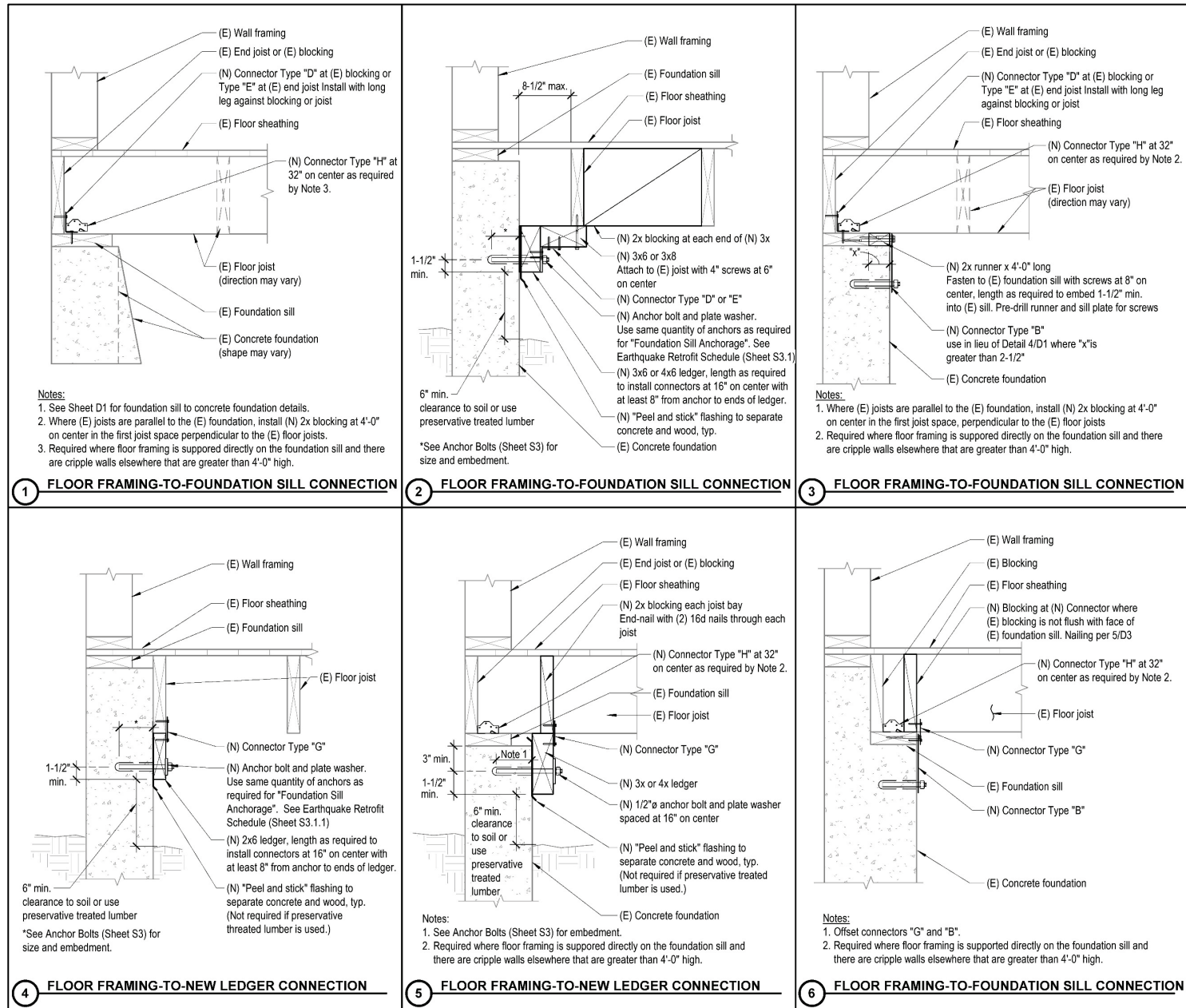


Figure 4.4-13 Floor framing to foundation sill connection details. Sheet D2.

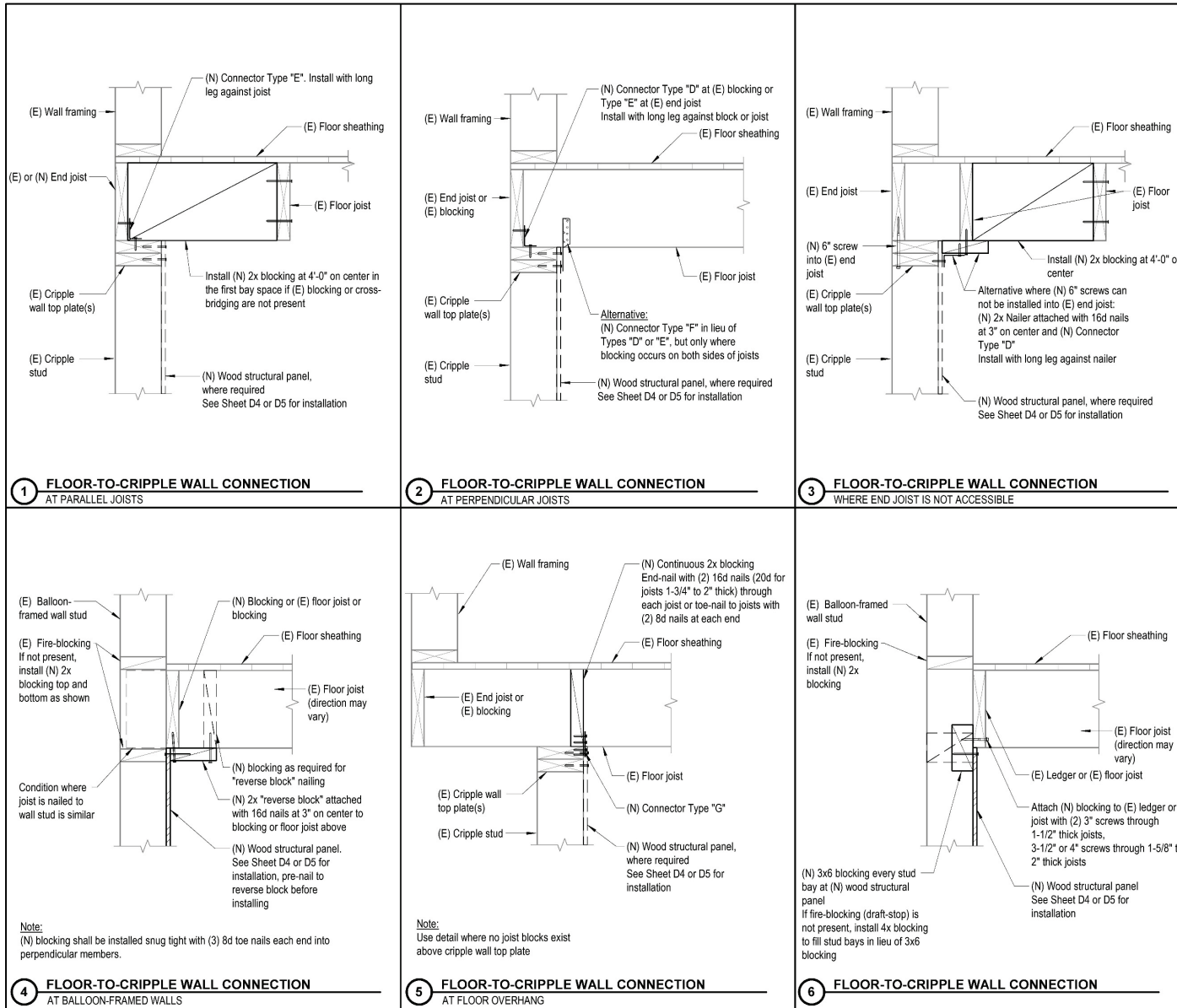


Figure 4.4-14 Floor framing to cripple wall connection details. Sheet D3.

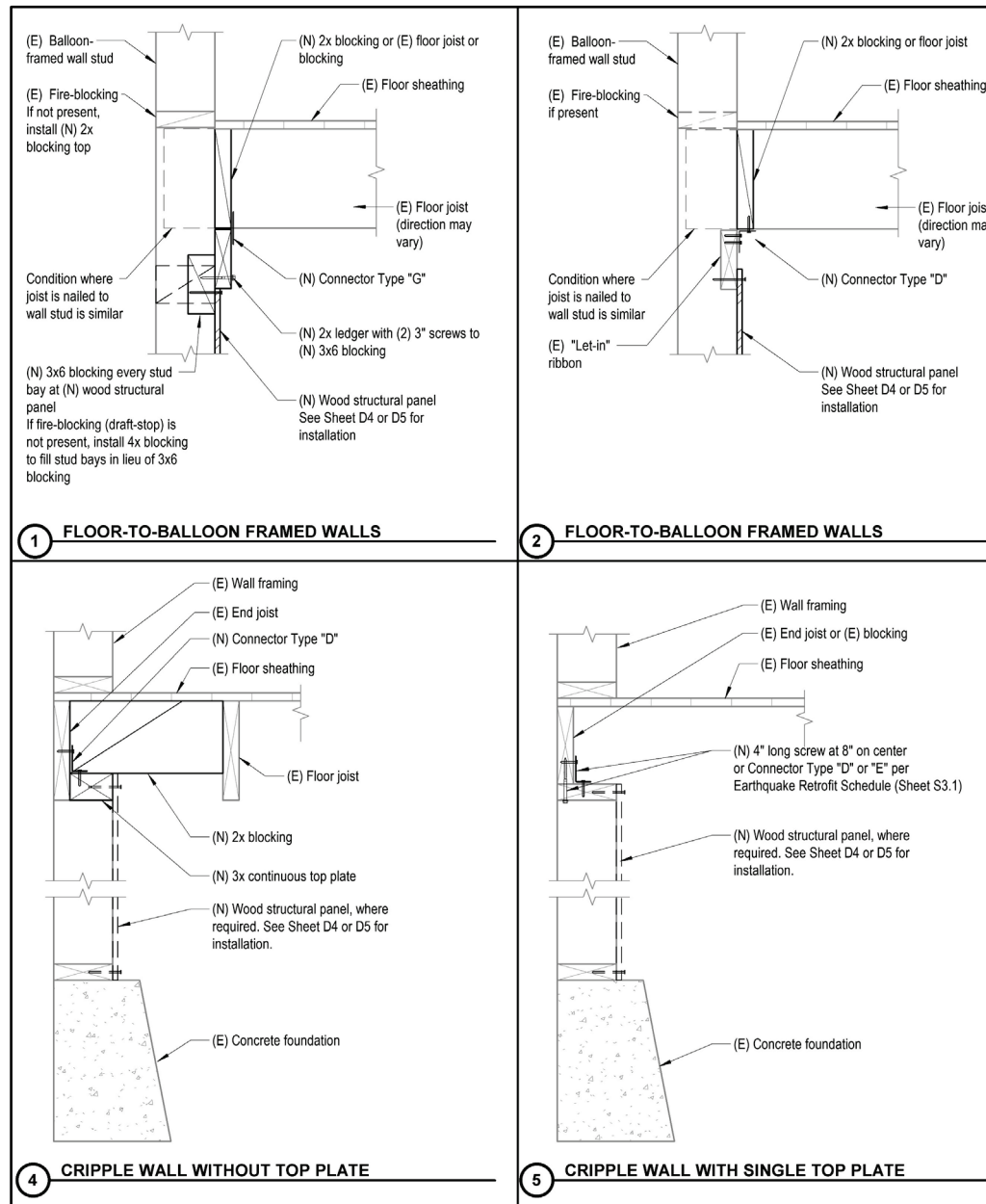


Figure 4.4-15 Floor framing to cripple wall connection details. Sheet D3.1.

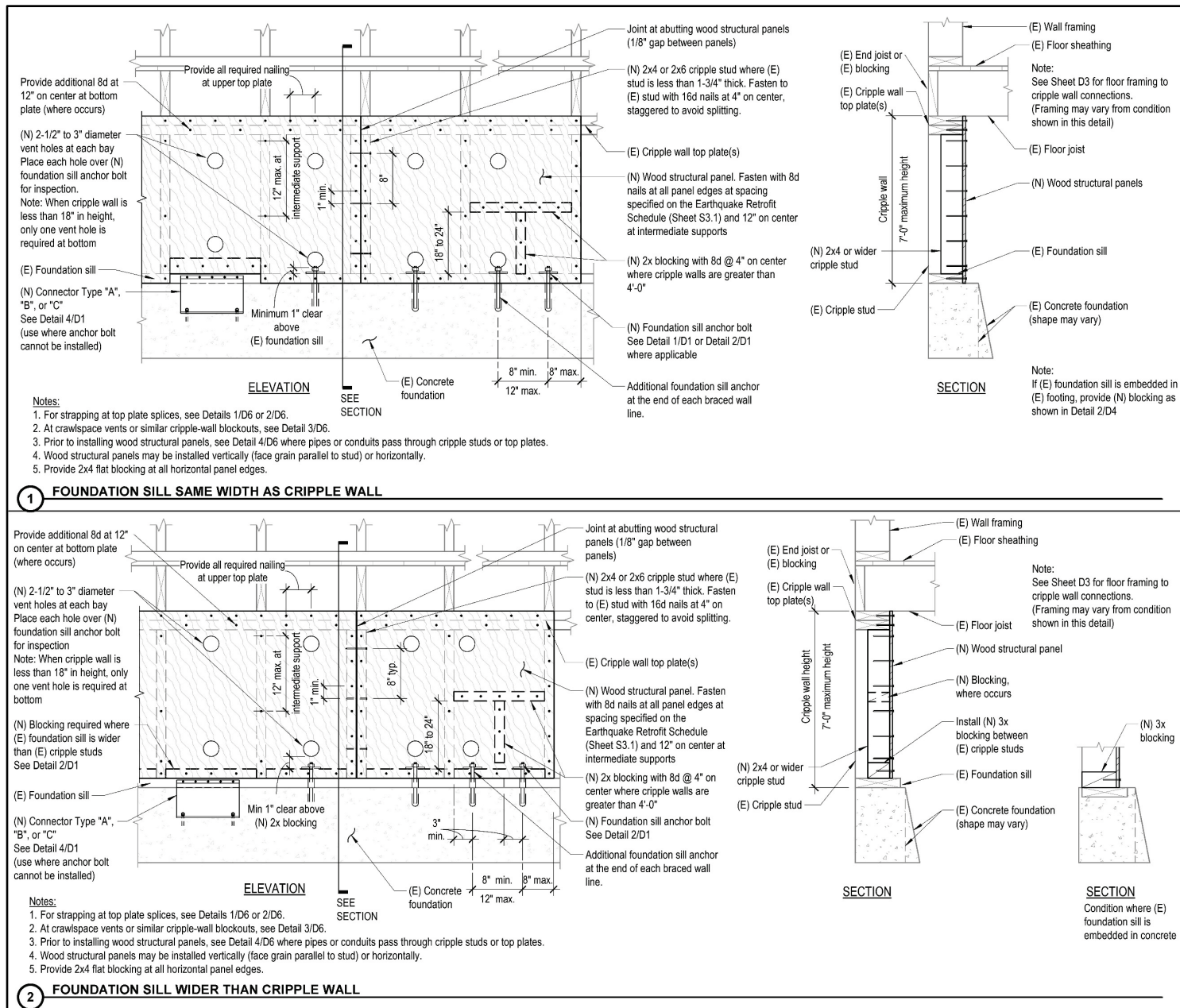


Figure 4.4-16 Wood structural panel installation without tie-downs. Sheet D4.

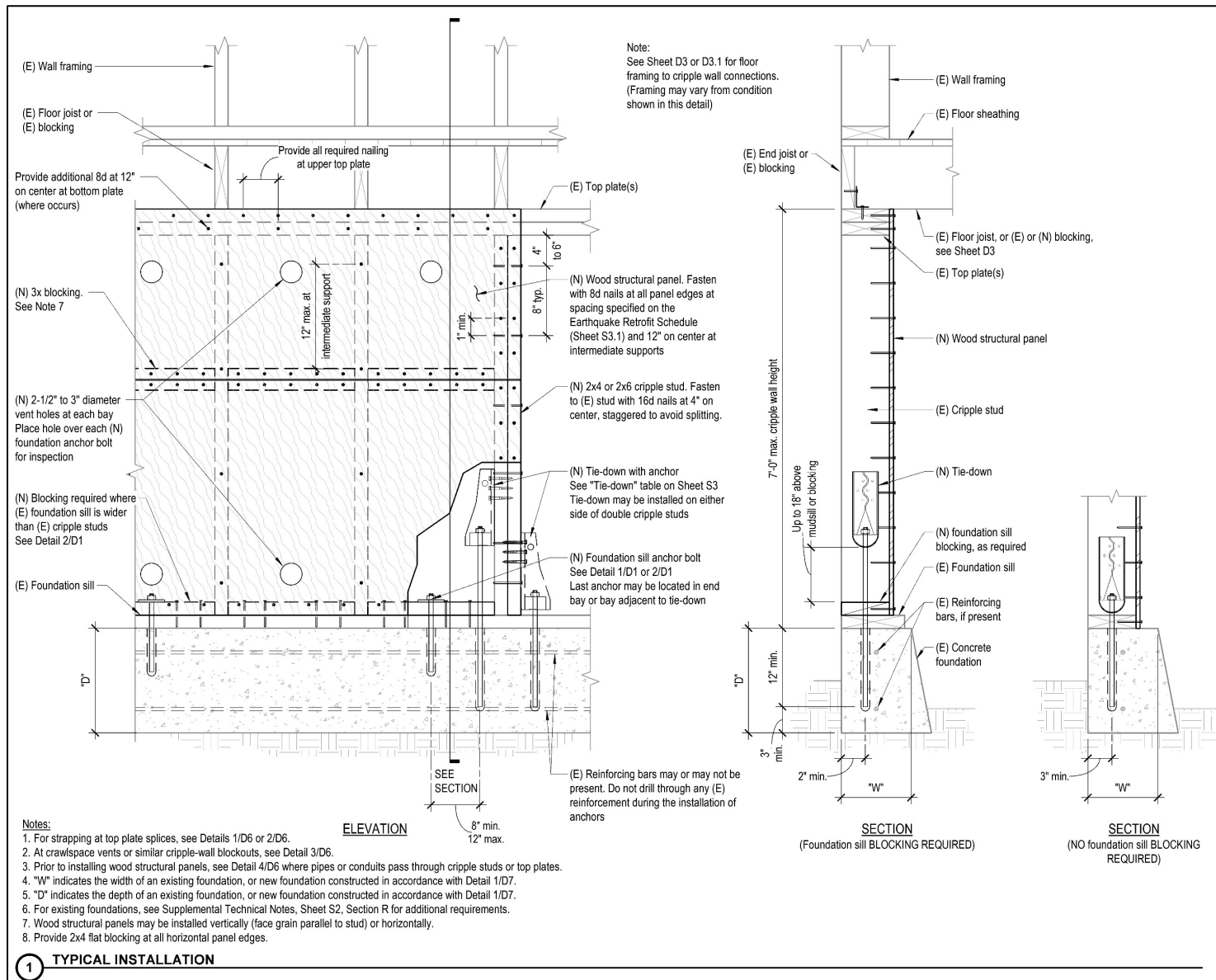


Figure 4.4-17 Wood structural panel installation with tie-downs. Sheet D5.

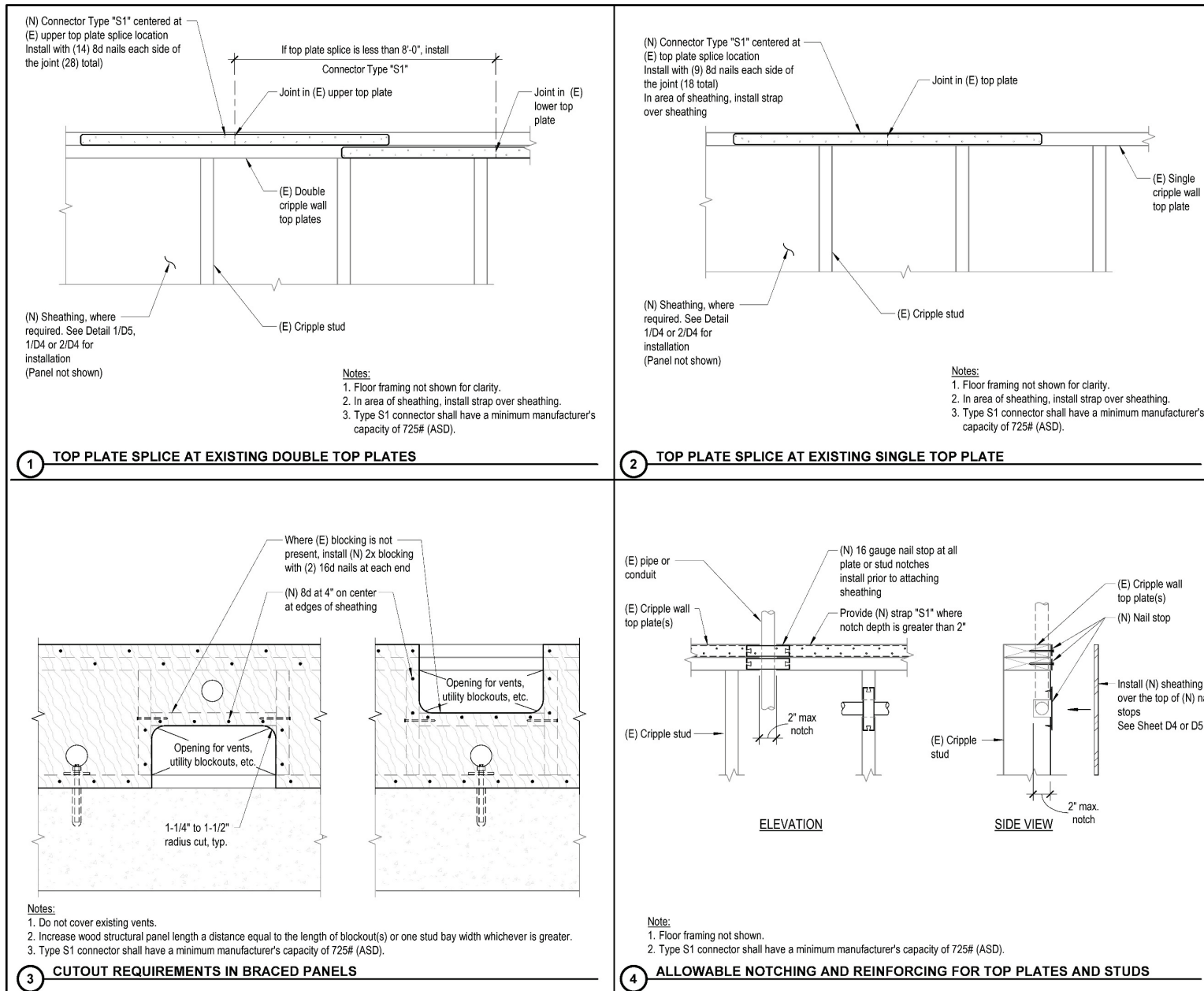


Figure 4.4-18 Vent openings and top plate details. Sheet D6.

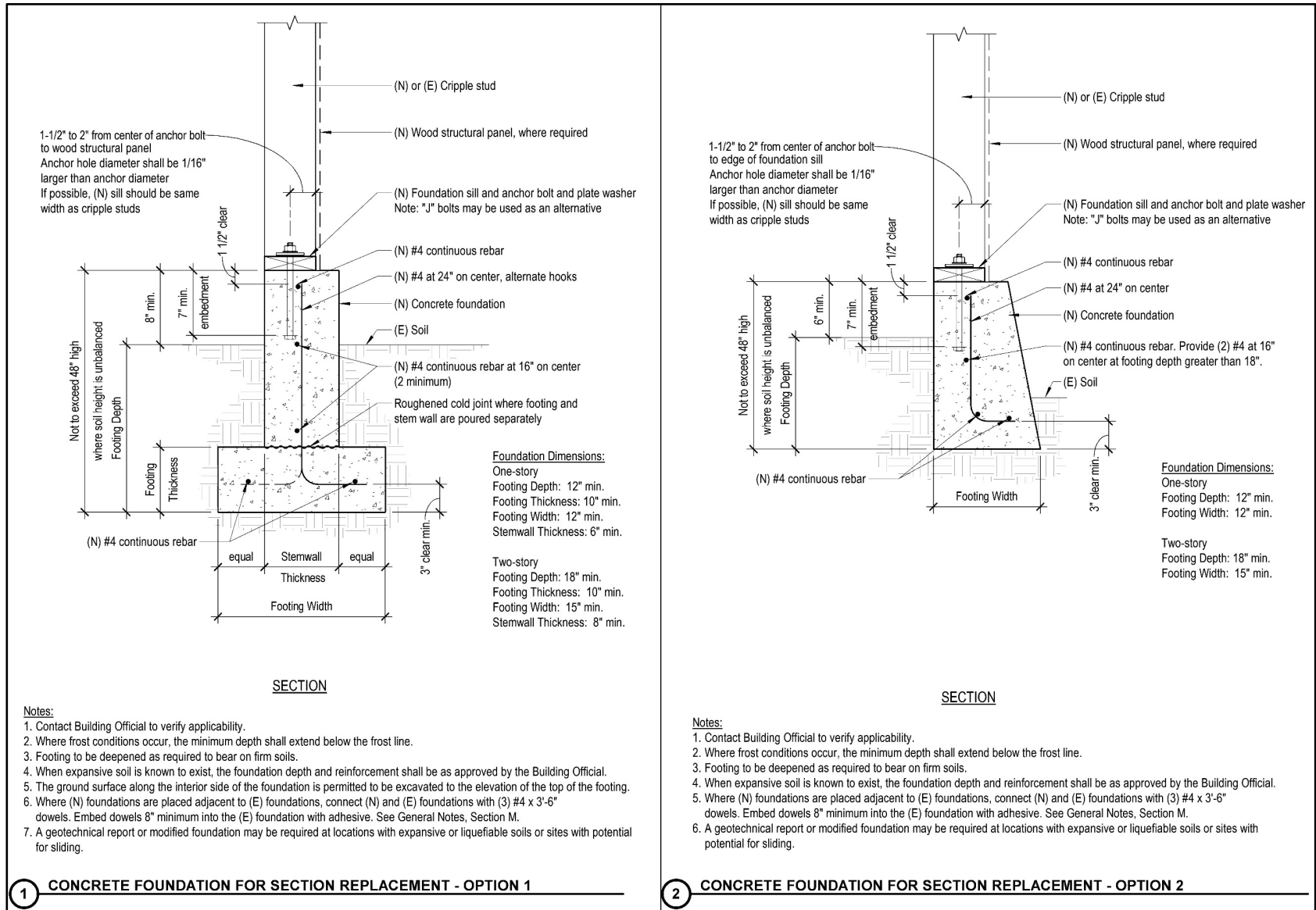


Figure 4.4-19 Foundation replacement details. Sheet D7.

Chapter 5

Vulnerability-Based Assessment and Retrofit of Living-Space-Over-Garage Dwellings

5.1 General

This chapter contains provisions for vulnerability-based assessment and retrofit of ground story *bracing walls* in wood light-frame *living-space-over-garage dwellings*. These provisions are also permitted to be used in other conditions in which enclosed living space occurs over unoccupied ground floor areas having inadequate ground story wall bracing.

The primary purpose of this chapter is the reduction of earthquake-induced damage to wood light-frame living-space-over-garage dwellings.

5.1.1 Use of this Chapter

In addition to the scope limits of Section 1.8, the dwelling shall comply with all of the eligibility criteria of Table 5.1-1. Where dwelling is not compliant with one or more of the eligibility statements, assessment and retrofit in accordance with this chapter shall not be permitted.

5.1.2 Vulnerability-Based Assessment and Retrofit Methods

Where a dwelling complies with Section 5.1.1, the dwelling need not be assessed and may be retrofitted in accordance with the prescriptive retrofit provisions of Section 5.4 or the simplified engineered retrofit provisions of Section 5.5 as applicable. If the dwelling does not comply with Section 5.1.1, assessment shall be in accordance with Section 5.3; alternately, assessment is not required if retrofit is to be provided. Where retrofit is required by Section 5.3, retrofit shall be in accordance with Section 5.1.3 or Section 5.1.4.

5.1.3 Prescriptive Retrofit

Dwellings compliant with the eligibility criteria of Table 5.1-1 and all of the additional eligibility criteria of Table 5.1-2 shall be permitted to use the prescriptive retrofit provisions of Section 5.4.

Table 5.1-1 Eligibility Criteria for Use of Chapter 5

Eligibility Criteria		Compliant	Non-Compliant
1	The dwelling is a detached <i>one- or two-family dwelling</i> or the dwelling is a unit in a <i>townhouse</i> and assessment and retrofit will occur for each attached townhouse unit (the full <i>townhouse structure</i>).		
2	The dwelling is of wood <i>light-frame construction</i> and has a maximum of one story above the garage story.		
3	The dwelling is a <i>living-space-over-garage</i> dwelling, as defined in Chapter 2.		
4	The dwelling perimeter (not including porches or other appurtenances) is supported on continuous concrete foundations, concrete <i>stem walls</i> or thickened slab edge footings.		
5	The lower (garage) level floor is constructed of a conventionally reinforced concrete slab on ground (or at least the portion of the floor that bounds the garage).		

Table 5.1-2 Additional Eligibility Criteria for Use of Prescriptive Retrofit Provisions (Section 5.4)

Scoping Statement	Compliant	Non-Compliant
1	The dwelling is located within <i>Seismic Design Category</i> (SDC) B through E as noted in Section 1.6.	
2	The weight of roofing material shall not exceed 12 psf (measured on slope).	
3	The weight of exterior wall finish shall not exceed 10 psf, except veneer wainscots supported on concrete or masonry foundations that are permitted to extend up to four feet above the top of foundation.	
4	Weight of interior wall finish shall not exceed 8 psf, except that masonry fire place surrounds not more than 4 inches thick and not more than 100 square feet in area are permitted to exceed this weight.	
5	Weight of floor finish shall not exceed 5 psf, except that heavier floor finishes of up to 10 psf are acceptable where limited to 25% of the total floor area of each level.	
6	Floors in each story are at the same level, excluding slab on ground portions.	
7	The building area (determined in Section 5.4.4) shall not exceed 2,000 square feet.	
8	No part of the foundations is constructed of unreinforced masonry or stone.	
9	Clear floor to ceiling heights at any occupied level do not exceed 9 feet.	
10	The aspect ratio of the full depth of the dwelling at the lowest level to width of the garage (plan length to plan width) shall not be greater than 2 ½ to 1. See commentary Section C5.4.4.	

5.1.4 Simplified Engineered Retrofit

Where the prescriptive retrofit provisions of Section 5.4 are not used, a simplified engineered retrofit shall be provided in accordance with Section 5.5, or a general engineered retrofit shall be provided in accordance with Section 1.7.2.

5.2 Definitions and Minimum Requirements

The definitions of Chapter 2 are applicable to all assessments and all retrofits designed in accordance with Chapter 5. The minimum requirements of Chapter 3 are applicable to all retrofits designed in accordance with Chapter 5. See Figure 5.4-30 for minimum requirements at existing single and double top plate splices, cutouts at braced wall panels, and allowable notching and reinforcing for cripple wall top plates and studs.

5.3 Vulnerability-Based Assessment

5.3.1 Scope

The assessment criteria of this section shall be used to determine whether existing ground story *bracing walls*, foundations, anchorage, and connections are in compliance with the requirements of this chapter. Where they are in compliance with the requirements of this chapter, retrofit is not required. Where they are found to not be in compliance with the requirements of this chapter, retrofit in accordance with Section 5.4, Section 5.5 or a general engineered retrofit is required. The simplified assessment provisions of Section 5.3.2 shall be permitted to be used where applicable. Where Section 5.3.2 requires a detailed assessment, this shall be provided in accordance with Section 5.3.3.

In lieu of a detailed assessment, the dwelling may be retrofitted in accordance with Section 5.4 or 5.5 as applicable.

5.3.2 Simplified Assessment

Ground story bracing walls in living-space-over-garage dwellings shall be assessed in accordance with Table 5.3-1.

Where existing ground floor bracing is deemed to conform to the assessment statement, this bracing as well as the elements they are directly attached to, shall also be assessed to identify incomplete or inadequate installation, damage, and deterioration that might significantly affect seismic performance. This condition assessment can be limited to those elements that are visible or easily accessed. Where this assessment identifies incomplete or inadequate installation, damage or deterioration, the elements shall be deemed not adequate for use. For these conditions, the applicable assessment statement within Table 5.3-1 shall be determined to be false and the indicated compliance step taken. Alternately, a detailed assessment of existing elements in accordance with Chapter 8 may be provided.

The scope of this assessment shall be permitted to be based on the judgment of the evaluator. The findings and documentation of this investigation shall be subject to the approval of the *building official* where required.

Table 5.3-1 Simplified Structural Assessment for Living-Space-Over-Garage Dwellings

Assessment Statement	Compliance Step if True	Compliance Step if False	Compliance Step if Unknown
Bracing walls throughout the ground story comply with one or more of the following: <ul style="list-style-type: none"> • Conventional construction bracing requirements from 1994 or 1997 Uniform Building Code • Engineered seismic design provisions of the 1997 Uniform Building Code • Seismic bracing provisions of 2000 International Residential Code or later • Engineered seismic design provisions of 2000 International Building Code or later 	Retrofit of ground story bracing walls is not required	Retrofit of ground story bracing walls is required	Provide detailed assessment in accordance with Section 5.3.3

5.3.3 Detailed Assessment

Detailed assessment for type, extent, and condition of ground story *bracing walls* shall be assessed in accordance with Section 8.5.

5.3.4 Engineered Assessment

As an alternate to the detailed assessment requirements of Section 5.3.3 and Section 8.5, an evaluation by a *registered design professional* can be provided to demonstrate that existing components are in compliance with this prestandard. This evaluation shall utilize all engineering criteria listed in Section 5.5. For guidance, assumptions made in developing the simplified engineered vulnerability-based retrofit in Section 5.5 are listed in the commentary for Section 5.5.

5.4 Prescriptive Vulnerability-Based Retrofit

5.4.1 Scope

Living-space-over-garage dwellings and dwelling units complying with all eligibility criteria of Table 5.1-1 and Table 5.1-2 are permitted to use the prescriptive retrofit provisions of this section. Other dwellings shall have an engineered retrofit designed in accordance with Section 5.5.

Where the retrofit of the ground story wall bracing is required by Section 5.3, living-space-over-garage dwellings shall be retrofit in accordance with all requirements of Section 5.4.

Where a dwelling's actual conditions require modification of the vulnerability-based retrofit solutions identified within this section, additional or modified details may be generated by a registered design professional and used to supplement the prescriptive procedures of this section. These supplemental details shall be stamped and signed by a registered design professional and *approved* by the building official.

All figures referenced in Section 5.4 describing the prescriptive retrofit provisions can be found at the end of Chapter 5.

5.4.2 Determination of Earthquake Retrofit Schedule

The prescriptive vulnerability-based retrofit procedures of Section 5.4 have been developed for short-period response acceleration parameter S_{DS} values of 1.0, 1.2, and 1.5. The S_{DS} value required for retrofit design shall be determined in accordance with Section 1.6. Based on the determined S_{DS} value, the applicable figure presenting the relevant Earthquake Retrofit Schedule shall be selected from Figure 5.4-1.

5.4.3 Determination of Weight Classification

The prescriptive vulnerability-based retrofit procedures of Section 5.4 have been developed for dwellings using three *weight classifications*: heavy, medium, and light construction. Further, eight weight combinations, based upon the type of exterior and interior wall finishes and roofing materials, are assigned to three weight classifications as identified within Figure 5.4-2. Where interior or exterior finishes vary, a heavier type finish shall be assumed where 25% or more of that finish type exists within the dwelling.

5.4.4 Determination of Building Area

The building area that is used to define the vulnerability-based retrofit is equal to the width of the garage times the full depth of the house at the ground level floor (in square feet) for all living-space-over-garage dwellings. See Section C5.4.4 for clarification of area calculations.

5.4.5 Determination of Building Retrofit Type

The building retrofit type is based on the existing configuration of the living-space-over-garage dwelling. Where the existing dwelling does not have a *ground story residential unit*, the retrofit shall include *retrofit elements* at the dwelling front, back, and side walls, as shown in the Earthquake Retrofit Schedules of Figures 5.4-7 through 5.4-24 as applicable. Retrofit elements at the front and back walls are permitted to be of any of the retrofit element types in Section 5.4.6 through Section 5.4.8. Retrofit elements at the side

walls are to be wood structural panel shear walls in accordance with Section 5.4.6.

Where the existing dwelling has a ground story residential unit, the retrofit shall include retrofit elements at the garage front and side walls, and the wall separating the garage use from the residential use. Retrofit elements at the front wall are permitted to be of any of the retrofit element types in Section 5.4.6 through Section 5.4.8 and shall include retrofit elements as shown in the Earthquake Retrofit Schedules of Figures 5.4-7 through 5.4-24 as applicable. Retrofit elements at the side walls and wall separating the garage use from the residential-use are to be *wood structural panel* shear walls in accordance with Section 5.4.6.

5.4.6 Wood Structural Panel Shear Wall Retrofit

Where retrofits are identified by Section 5.4.5 to require wood structural panel shear walls, retrofit shall conform to this section.

5.4.6.1 Wood Structural Panel Shear Wall Sheathing

Wood structural panel shear walls, with or without *tie-downs* shall meet the minimum total length requirements of the Earthquake Retrofit Schedules in Figures 5.4-7 through 5.4-24 as applicable (exclusive of the Alternate Earthquake Retrofit Schedules of Figures 5.4-9, 5.4-12, 5.4-15, 5.4-18, 5.4-21, and 5.4-24).

Wood structural panel installation shall be in accordance with Figure 5.4-28 and additional requirements per Section 3.3.5.

5.4.6.2 Foundation for Wood Structural Shear Panel

Where new foundations are triggered by Section 5.4.6, a new foundation shall be provided, extending across the full width of the area being retrofit to existing perpendicular foundations. The new foundation and connection of the new foundation to the perpendicular foundation shall be in accordance with Figure 5.4-26.

5.4.6.3 Tie-Downs to Existing Foundations

Where tie-downs to existing foundations are identified by Section 5.4.6 to be required, tie-downs shall be one of the types listed in Figure 5.4-5 and shall be installed in accordance with Figure 5.4-29. In addition, the foundation requirements of Section 5.4.6.4 shall be met. Where these requirements are not met, a new foundation system shall be provided in accordance with Section 4.4.4 or an engineered retrofit design shall be provided in accordance with Section 5.5.

Where tie-downs to new foundations are identified by Section 5.4.5 to be required, tie-downs shall be one of the types listed in Figure 5.4-5 and shall be installed in accordance with Figure 5.4-26.

5.4.6.4 Existing Foundation Visual Verification and Testing Requirements

Where tie-downs to existing foundations are used in accordance with the Earthquake Retrofit Schedules in Figures 5.4-7 through 5.4-24 as applicable (exclusive of the Alternate Earthquake Retrofit Schedules of Figures 5.4-9, 5.4-12, 5.4-15, 5.4-18, 5.4-21, and 5.4-24), additional visual verification and testing of the existing foundation system is required to be completed by the owner or general contractor and approved by the building official.

5.4.6.4.1 Visual Verification

The size of existing foundation systems at the location of new tie-down anchors shall be verified to be at least 15 inches deep (“D”) and 8 inches wide (“W”). The dimension “D” shall be measured from the bottom of footing to the underside of the existing mudsill. The dimension “W” shall be measured from the top outside face of footing to the inside top face of footing.

5.4.6.4.2 Existing Foundation Quality Requirements

Verification of the overall quality of the concrete along any wall line requiring tie-downs shall be made by use of a minimum of two sacrificial torque tests along each wall line where tie-downs are used. These tests shall consist of installing 1/2- or 5/8-inch diameter screw-type bolts into the existing concrete and verifying that a value per Table 5.4-1 can be achieved. Torque tests can be performed either by the owner, a general contractor, or a special inspection company or testing agency hired by the owner and as approved by the building official.

Table 5.4-1 Foundation Verification Requirements

Diameter	Screw Anchor Torque (ft-lbs.)	Adhesive Anchor Torque (ft-lbs.)
1/2"	35	15
5/8"	50	20

5.4.6.4.3 Existing Foundation Tension Test Requirements

Where tie-downs to an existing foundations are identified in Section 5.4.6, each adhesive anchor shall be torque tested in accordance with Table 5.4-1. Torques in excess of those shown for adhesive anchors shall not be applied.

Tests shall not be performed prior to adequate curing per manufacturer's requirements. Anchors where torque tests fail shall be replaced and re-installed. Where torque tests continue to fail, the existing foundation system shall be replaced locally for a minimum of 30 inches on each side of the proposed tie-down anchor location.

5.4.6.4.4 Adhesive Anchor Installation Verification

Where "With Tie-downs" is specified within the Earthquake Retrofit Schedules in Figures 5.4-7 through 5.4-24, installation shall conform to the manufacturer's installation instructions. Items 1 through 10 below shall be verified by performed and verified by the general contractor or owner.

1. Drill all holes to the specified diameter and depth.
2. Blow all holes clean of dust with oil-free compressed air for a minimum of 4 seconds.
3. Clean all holes with a nylon or steel brush for a minimum of 4 cycles (per manufacturer's instructions).
4. Blow holes clean of dust with oil-free compressed air for a minimum of 4 seconds.
5. Check adhesive cartridge expiration date and required minimum temperature for adhesive cure.
6. Open cartridge, connect the required nozzle, and install cartridge in dispensing tool.
7. Purge out the required amount of adhesive per the manufacturer's instructions prior to filling any holes with adhesive.
8. Fill the holes 1/2 to 2/3 full, starting at the bottom of the hole to prevent air pockets and withdraw the nozzle as the hole fills up.
9. Insert a clean and oil-free threaded rod turning slowly until the threaded rod contacts the bottom of the hole.
10. Do not disturb the threaded rod until adhesive has fully cured. See manufacturer's instructions for cure time required.

5.4.6.5 Foundation Sill Plate Anchorage to the Foundation

Foundation sill plate anchorage shall be retrofit in accordance with this section. Foundation sill plate anchorage of one of the types listed in Figure 5.4-3 or Figure 5.4-4 shall be provided in accordance with Figure 5.4-25. The number of anchors per wall section shall be in accordance with the

Earthquake Retrofit Schedules in Figures 5.4-7 through 5.4-24 and shall be evenly distributed along each wall line.

5.4.6.6 Connection to Dwelling Above

Existing or new rim joists, blocking, and miscellaneous framing members can be connected to the dwelling above in accordance with Figure 5.4-27, and with the number and type of connectors specified in the Earthquake Retrofit Schedules in Figures 5.4-7, 5.4-8, 5.4-13, 5.4-14, 5.4-19, or 5.4-20.

5.4.7 Steel Retrofit Column

Retrofits that select to use steel columns shall be in accordance with this section.

5.4.7.1 Steel Column

Steel column sections shall comply with ASTM A572 Grade 50 or A992. Identification of structural steel shall comply with AISC 360. One steel retrofit column shall be selected in accordance with Figure 5.4-9, 5.4-12, 5.4-15, 5.4-18, 5.4-21, or 5.4-24 for each wall line to be braced per this section. Installation and detailing of the steel column shall be in accordance with Figure 5.4-31.

5.4.7.2 Foundation for Steel Column

A new retrofit foundation shall be provided, extending across the full width of the area being retrofit to existing perpendicular foundations. The new foundation shall be in accordance with Figure 5.4-31. Connection of the new foundation to the perpendicular foundation shall be in accordance with Figure 5.4-26. The new foundation shall be cast-in-place around the steel column.

5.4.7.3 Collector for Steel Column

A new collector shall be provided, extending the full width of the area of retrofit. The new collector shall be in accordance with Figure 5.4-31.

5.4.8 Proprietary Shear Wall Retrofit

Retrofits that select to use *proprietary shear walls* shall be in accordance with this section.

5.4.8.1 Proprietary Shear Wall

Proprietary shear walls shall be prefabricated wood shear panels or prefabricated cold-formed steel shear panels complying with the requirements of ICC-ES AC 436 or FEMA P-795, or shall have been tested

in accordance with ASTM D7989 in a manner and with documentation acceptable to the building official. Proprietary shear walls shall be installed in accordance with the manufacturer's installation instructions and Section 5.4.8. Proprietary shear walls shall be selected in accordance with the Earthquake Retrofit Schedules in Figure 5.4-9, 5.4-12, 5.4-15, 5.4-18, 5.4-21, or 5.4-24 for each wall line to be braced per this section. Placement and detailing of the proprietary shear wall shall be as permitted by Figure 5.4-32.

5.4.8.2 Foundation for Proprietary Shear Wall

A new retrofit foundation shall be provided, extending across the full width of the area being retrofit to existing perpendicular foundations. The new foundation and connection of the new foundation to the perpendicular foundation shall be in accordance with Figure 5.4-32.

5.4.8.3 Collector for Proprietary Shear Wall

A new collector shall be provided, extending the full width of the area of retrofit. The new collector shall be in accordance with Figure 5.4-32.

5.5 Simplified Engineered Vulnerability-Based Retrofit

5.5.1 General

Engineered retrofit of *living-space-over-garage* ground story *bracing walls* shall be in accordance with the ASCE/SEI 7 Section 12.14, Simplified Alternative Structural Design Criteria for Simple Bearing Wall or Building Frame Systems, as amended below. Material design capacities for all components shall be as specified by the adopted building code.

1. The scope of seismic evaluation and retrofit, where required, shall include ground story vertical elements, such as steel columns, proprietary shear walls, or wood structural panel shear walls, the foundation, anchorage to the foundation, collectors at the top of the vertical element, and anchorage to floor framing above.
2. Seismic weight for purposes of calculating base shear shall include the dead load summed over all stories and occurring in an area defined by the garage width times the length of the dwelling perpendicular to the garage.
3. ASCE/SEI 7 Section 12.14 shall be modified as shown in Table 5.5-1. ASCE/SEI 7 section may either be applicable as written (Y) with or without notes; not applicable (N); or applicable with clarifications noted (M).

Table 5.5-1 ASCE/SEI 7 Section 12.14 Application Matrix

ASCE/SEI 7 Section	Applicability	Notes
12.14.1.1	N	All limitation listed within Items 1 through 12 shall be assumed to comply and ASCE/SEI 7 Section 12.14 is eligible for use
12.14.1.2	Y	
12.14.1.3	M	See Chapter 3 for additional definitions
12.14.1.4	M	Notations as applicable
12.14.2	M	See Section 5.5.1 Item 1
12.14.3	M	See Section 5.5.1 Item 2
12.14.3.1	Y	
12.14.3.2	M	E_{mh} shall be taken as $1.5Q_E$
12.14.4.1	N	
12.14.4.2	N	
12.14.5	M	See Section 5.5.2 Item 1
12.14.6	Y	
12.14.7	N	
12.14.8.1	M	$F = 1.0$ for two-story dwellings
12.14.8.2	Y	
12.14.8.3	Y	
12.14.8.3.1	M	See Section 5.5.2 Items 1 and 2
12.14.8.3.2	N	
12.14.8.3.2.1	N	
12.14.8.4	N	
12.14.8.5	N	

4. Wood structural panel shear walls, steel columns, proprietary shear walls, and their seismic load path shall be designed using a seismic response modification factor, R , of 5.0.
5. Finish and bracing materials other than wood structural panels (per definitions in Chapter 2) shall not be considered to provide seismic capacity.
6. The in-plane *load path connections* for anchorage to foundations and anchorage to floor framing above shall be provided at all locations where wood structural panel for retrofit shear walls are provided. In-plane load path connections shall be designed using load combinations with an overstrength factor, Ω_0 , of 1.5 in lieu of 2.5 specified in ASCE/SEI 7 Section 12.14.3.2.2.

7. Where tie-downs are used in existing foundations, the registered design professional shall be responsible for evaluating the existing foundation system.
8. Where tie-downs are using in new foundations, anchorage of shear walls for overturning shall be in accordance with the concrete design provisions of the adopted building code.

5.5.2 Additional Simplifying Assumptions

The following simplifications shall be permitted to be made in the engineered retrofit design:

1. Where the existing dwelling does not have a ground story residential unit, the retrofit shall include retrofit elements at the dwelling front, back and side walls, and each wall shall resist 50% of the total base shear.
2. Where the existing dwelling has a ground story residential unit, the retrofit shall include retrofit elements at the garage front and side walls, and the wall separating the garage use from the residential use. The front wall shall be designed to resist 25% of the total base shear; the back wall of the garage and each side wall shall be designed to resist 50% of the base shear.
3. Retrofit elements at the front/back walls shall be offset a maximum of 4 feet from the exterior wall line.
4. When designing vertical lateral load-resisting elements for overturning (wood structural panel shear walls, steel columns, or proprietary shear walls), in lieu of a more detailed overturning analysis of the entire dwelling, each exterior wall line shall be designed to resist its local overturning moment plus 15 percent of the total overturning moment of the superstructure. The calculations of forces F_R and F_{2nd} (where applicable) can be based upon tributary mass to those levels per ASCE/SEI 7 Section 12.14-13.
5. The allowable tension load at the end of a wood structural panel shear wall can be assumed as follows:
 - a. Where two *post-installed anchor* bolts are installed at each end of wood structural panel shear wall as indicated Figure 5.4-28, the wall may assume to have an allowable uplift capacity of 1.5 kips (ASD), provided there is a minimum length to height ratio of 2.0 for the sheathed portion of the *cripple wall*.
 - b. Where one post-installed anchor bolt and one tie-down anchor are installed at each end of a section of wood structural panel shear wall

as indicated in Figure 5.4-29, the end of wall may be assumed to have an allowable uplift capacity of 3.0 kips (ASD).

6. Soil *site class* may be assumed to be type C if specific site class information is not available.

5.5.3 Design of Steel Column Retrofit

Steel retrofit columns shall be designed in accordance with the seismic forces of Section 5.5 and the material design provisions of the adopted building code. For purpose of seismic design per AISC 341, steel columns shall be treated as special steel cantilevered columns.

Exceptions

1. Steel column and load path design shall use the seismic response modification factor, R , specified in Section 5.5.1.
2. Steel columns shall be designed to have a full moment connection to the grade beam foundations. Columns shall be designed to have a pinned connection at the top of the column.
3. Steel retrofit columns shall be selected such that the demand to capacity ratio for column flexural strength does not exceed 1.2.
4. The grade beam minimum dimensions shall not be less than two-foot wide by two-foot deep. Grade beam shall be doweled into existing foundation at each end, and shall be designed per ASCE/SEI 7 and the foundation and concrete requirements of the applicable building code.
5. The steel column is exempt from meeting the drift and deformation requirements of ASCE/SEI 7 Section 12.12.

5.5.4 Design of Proprietary Shear Wall Retrofit

Proprietary walls shall be designed in accordance with the provisions of Section 5.4.8.1, the seismic forces of Section 5.5, and the material design provisions of the adopted building code.

1. Proprietary wall and load path design shall use the seismic response modification factor, R , specified in Section 5.5.1.
2. Proprietary walls shall be selected such that the demand to capacity ratio for wall shear strength does not exceed 1.0.
3. The proprietary wall is required to meet the drift and deformation requirements of ASCE/SEI 7 Section 12.12, and any additional requirements specified by the manufacturer or as a condition of acceptance by the building official.

4. The grade beam dimensions shall not be less than two foot wide by two foot deep. Grade beam shall be doveled into existing foundation at each end, and shall be designed per ASCE/SEI 7 and the foundation and concrete requirements of the adopted building code.

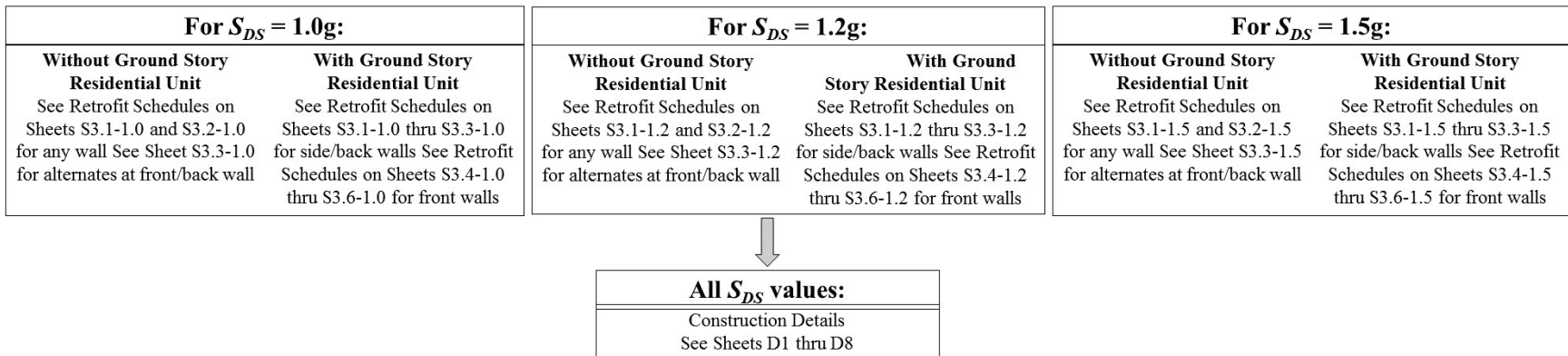
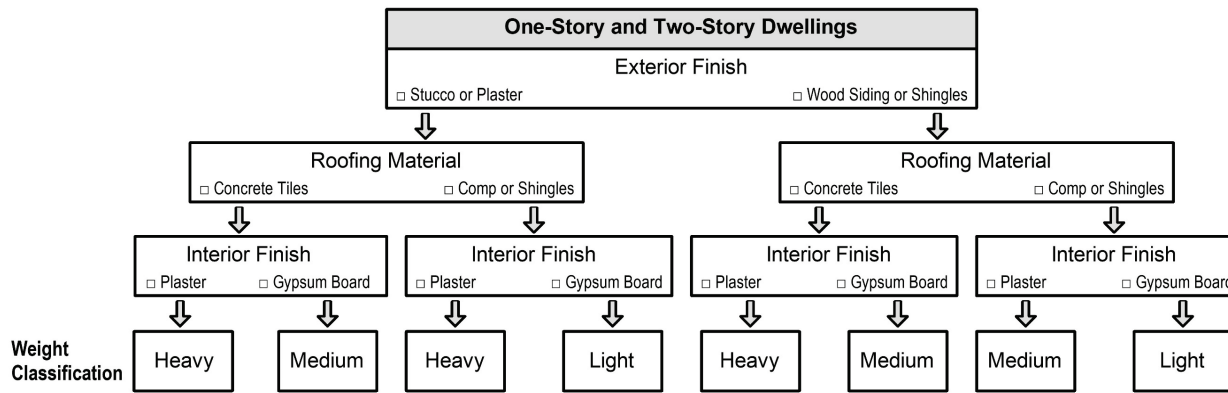


Figure 5.4-1 Flowchart for selecting Earthquake Retrofit Schedule.



Weight Classification:

This flowchart is used to determine the general weight classification of your home's construction.

1. Check the box of the material that most closely matches your home's finishes.
2. Note the Weight Classification result for use in the Earthquake Retrofit Schedules.

Specific notes for exterior, interior and roof coverings

1. The "wood siding or shingles" exterior finish category also includes finishes of similar weight, including but not limited to fiber-cement and aluminum siding.
2. The "comp or shingles" roofing material category also includes roofing materials of similar weight, including but not limited to roll roofing, built-up felt roofing, single-ply membrane roofing, and metal roofing.
3. The "gypsum board" interior finish category also includes wall finish materials of similar weight, including but not limited to wood board or panel siding.
4. The exterior finish, roofing material and interior finish categories are intended to be identified based on the predominant materials used in construction.

Figure 5.4-2 Dwelling weight classification by interior and exterior finishes. Sheet S3.

ANCHOR BOLTS			
IMAGE	TYPE	EMBEDMENT DEPTH	
		1/2"Ø	5/8"Ø
	Screw-Type Anchor	3-1/2"	3-1/2"
		4-1/2"	n/a
		3-3/8"	3-3/8"
	Adhesive-Type Anchor	4-1/4"	5"
		2-3/4"	3-1/8"
		2-3/4"	3-1/8"

Figure 5.4-4 Foundation sill anchors. Sheet S3.

TIE-DOWNS				
Supplemental Technical Notes, Sheet S2, Section I				
MARK (kips)	IMAGE	TYPE	SHEET REF	CAPACITY (lbs)
TD1		Wood Stud to Foundation Tension Tie	SHEET D2,D5	3075
TD2				4565
TD3				5645
TD4				7870
TD5				11,175

Figure 5.4-5 Tie-downs. Sheet S3.

CONNECTORS				
IMAGE	TYPE	SHEET REF	MIN CAPACITY (lbs) ASD	
	A	Foundation Sill to Foundation	1530	
	B		SHEETS D1 & D4	960
	C			875

Figure 5.4-3 Foundation sill anchorage connectors. Sheet S3.

CONNECTORS				
	D	Wall to Upper Floor	SHEET D3	565
	E			740
	F			590
	G			445
	H			220
	S1	Miscellaneous Strap	SHEET D6	tbd

Figure 5.4-6 Floor to wall connectors. Sheet S3.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.0$) for Single Section of Wall																					
① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input checked="" type="checkbox"/>	④ MINIMUM REQUIRED LENGTH OF A SINGLE SECTION OF WALL OF WOOD STRUCTURAL PANEL SHEAR WALLS (at each wall line)											⑤ FOUNDATION SILL ANCHORAGE					⑥ FLOOR FRAMING TO WALL CONNECTION		
			No Tie-down			w/ Tie-downs in Existing or New Foundations								Min. No. of Foundation Connectors or Anchors at Each Wall Panel					Min. No. of Connectors at Each Wall Panel		
						8d at 6" O.C.			8d at 4" O.C.			8d at 2" O.C.		Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"
			8d Nail Spacing	Wall Length	Wall Length	Tie- down	New Fdn Req'd ?	Wall Length	Tie- down	New Fdn Req'd ?	Wall Length	Tie- down	New Fdn Req'd ?	Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"
Light Construction	800		6	16'-6"	12'-6"	TD1	No	8'-6"	TD2	Yes	5'-0"	TD5	Yes	4	6	7	6	4	9	9	11
	1000		6	19'-6"	15'-6"	TD1	No	10'-6"	TD2	Yes	6'-6"	TD5	Yes	4	7	9	7	5	11	11	14
	1200		6	22'-0"	18'-6"	TD1	No	13'-0"	TD2	Yes	7'-6"	TD4	Yes	5	8	11	9	6	13	13	17
	1500		6	25'-6"	23'-6"	TD1	No	16'-0"	TD2	Yes	9'-6"	TD4	Yes	6	10	13	11	8	17	16	21
	2000		4	31'-0"	31'-0"	None	No	21'-6"	TD2	Yes	12'-6"	TD4	Yes	8	13	17	14	10	22	21	28
Medium Construction	800		6	20'-6"	16'-0"	TD1	No	11'-0"	TD2	Yes	6'-6"	TD5	Yes	5	7	9	8	5	12	11	15
	1000		6	23'-6"	20'-0"	TD1	No	14'-0"	TD2	Yes	8'-0"	TD5	Yes	6	9	11	9	7	14	14	18
	1200		6	26'-6"	24'-0"	TD1	No	16'-6"	TD2	Yes	10'-0"	TD4	Yes	7	10	14	11	8	17	17	22
	1500		6	31'-0"	30'-6"	TD1	No	20'-6"	TD2	Yes	12'-6"	TD4	Yes	8	13	17	14	10	21	21	27
	2000		4	37'-6"	40'-6"	None	No	27'-6"	TD2	Yes	16'-6"	TD4	Yes	11	17	22	18	13	28	27	36
Heavy Construction	800		6	21'-6"	21'-0"	TD1	No	14'-6"	TD2	Yes	8'-6"	TD4	Yes	6	9	12	10	7	15	14	19
	1000		4	24'-6"	26'-6"	None	No	18'-0"	TD2	Yes	10'-6"	TD4	Yes	7	11	15	12	8	19	18	24
	1200		4	27'-6"	31'-6"	None	No	21'-6"	TD1	No	13'-0"	TD4	Yes	9	13	18	15	10	22	21	28
	1500		4	29'-6"	39'-6"	None	No	27'-0"	TD1	No	16'-0"	TD4	Yes	11	17	22	18	12	28	27	35
	2000		2	30'-0"	53'-0"	None	No	36'-0"	None	No	21'-6"	TD3	Yes	14	22	29	24	16	37	35	47

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible. Additional anchors and connectors may be necessary to meet the requirements of specific details and General Notes.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.) Where "None" occurs, no tie-down is required.
- Foundations: Where new foundations are required at front and back walls, see sheet D2 for details. At side walls, select retrofit options that do not require foundations whenever possible. Otherwise, provide foundations that extend the full depth of the garage in Figures 4 and 5 on Sheet S0 and for Figure 3 conditions (*living-space-over-garage dwellings without ground floor residential unit*), consult a design professional for remedial direction.
- Connector Type "F" should be used as an alternative only if joists are blocked on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Wall lengths are total length of a single wall section required on each side of the building. See sheet S3.2-1.0 for 2 section of wall options.
- See sheet S3.3-1.0 for Alternate Earthquake Retrofit Options where sufficient length of wall does not occur or where wood structural panel shear wall retrofit installations are otherwise prohibited.
- See sheets S3.4-1.0 thru S3.6-1.0 for Earthquake Retrofit Schedules for the front wall only at dwellings with a ground story residential unit. See also sheet S0, Figure 2.

Figure 5.4-7 Earthquake Retrofit Schedule at $S_{DS} = 1.0$ with single section of wood structural panel shear wall. Sheet S3.1-1.0.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.0$) Two Sections of Wall																
① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input checked="" type="checkbox"/>	④ MINIMUM TOTAL REQUIRED LENGTH OF EACH SECTION OF WOOD STRUCTURAL PANEL SHEAR WALL For a Two Section of Wall Option						⑤ FOUNDATION SILL ANCHORAGE					⑥ FLOOR FRAMING TO WALL CONNECTION		
			Length per Section for a Two Section Option						Min. No. of Foundation Connectors or Anchors at Each Section of Wall					Min. No. of Connectors at Each Section of Wall		
			8d at 6" O.C.			8d at 2" O.C.			Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"
			Wall Length	Tie- down	New Fdn Req'd ?	Wall Length	Tie- down	New Fdn Req'd ?								
Light Construction	800		6'-6"	TD1	No	3'-0"	TD4	Yes	2	3	4	3	2	5	5	6
	1000		8'-0"	TD1	No	3'-6"	TD4	Yes	2	4	5	4	3	6	6	7
	1200		9'-6"	TD1	No	4'-0"	TD4	Yes	3	4	6	5	3	7	7	9
	1500		12'-0"	TD1	No	5'-0"	TD4	Yes	3	5	7	6	4	9	8	11
	2000		15'-6"	None	No	6'-6"	TD4	Yes	4	7	9	7	5	11	11	14
Medium Construction	800		8'-0"	TD1	No	3'-6"	TD5	Yes	3	4	5	4	3	6	6	8
	1000		10'-0"	TD1	No	4'-0"	TD5	Yes	3	5	6	5	4	7	7	9
	1200		12'-0"	TD1	No	5'-0"	TD5	Yes	4	5	7	6	4	9	9	11
	1500		15'-0"	TD1	No	6'-0"	TD4	Yes	4	7	9	7	5	11	11	14
	2000		20'-0"	None	No	8'-6"	TD4	Yes	6	9	11	9	7	14	14	18
Heavy Construction	800		10'-6"	TD1	No	4'-6"	TD4	Yes	3	5	6	5	4	8	7	10
	1000		13'-0"	None	No	5'-6"	TD4	Yes	4	6	8	6	4	10	9	12
	1200		16'-0"	None	No	6'-6"	TD4	Yes	5	7	9	8	5	11	11	14
	1500		20'-0"	None	No	8'-0"	TD4	Yes	6	9	11	9	6	14	14	18
	2000		26'-6"	None	No	11'-0"	TD3	Yes	7	11	15	12	8	19	18	24

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible. Additional anchors and connectors may be necessary to meet the requirements of specific details and General Notes.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.) Where "None" occurs, no tie-down is required.
- Foundations: Where new foundations are required at front and back walls, see sheet D2 for details. At side walls, select retrofit options that do not require foundations whenever possible. Otherwise, provide foundations that extend the full depth of the garage in Figures 4 and 5 on Sheet S0 and for Figure 3 conditions (*living-space-over-garage dwellings without ground floor residential unit*), consult a design professional for remedial direction.
- Connector Type "F" should be used as an alternative only if joists are blocked on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Wall lengths are total length of a single wall section required on each side of the building. See sheet S3.2-1.0 for 2 section of wall options.
- See sheet S3.3-1.0 for Alternate Earthquake Retrofit Options where sufficient length of wall does not occur or where wood structural panel shear wall retrofit installations are otherwise prohibited.
- See sheets S3.4-1.0 thru S3.6-1.0 for Earthquake Retrofit Schedules for the front wall only at dwellings with a ground story residential unit. See also sheet S0, Figure 2.

Figure 5.4-8 Earthquake Retrofit Schedule at $S_{DS} = 1.0$ with two sections of wood structural panel shear wall. Sheet S3.2-1.0.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.0$)						
① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input checked="" type="checkbox"/>	④ STEEL COLUMN RETROFIT (2) (3)		⑤ PROPRIETARY SHEAR WALL RETROFIT (4) (5)	⑥ DIAPHRAGM NAILING (3) (5)
			Steel Column	Column Connection Type (per detail 2 on sheet D7) at Upper Floor	Minimum Required at Allowable Shear Capacity (Pounds)	Edge Nail Spacing
Light Construction	800		W8x21	C1	3250	6
	1000		W8x21	C1	4060	6
	1200		W8x28	C1	4870	6
	1500		W8x28	C1	6090	6
	2000		W10x30	C2	8120	6
Medium Construction	800		W8x21	C1	4200	6
	1000		W8x28	C1	5250	6
	1200		W8x28	C1	6300	6
	1500		W10x30	C2	7880	6
	2000		W12x35	C3	10,500	6
Heavy Construction	800		W8x28	C1	5400	6
	1000		W8x28	C1	6860	4
	1200		W10x30	C2	8230	4
	1500		W12x35	C3	10,300	4
	2000		W10x45	C3	13,700	4

Notes:

1. Steel column and Proprietary Shear Wall Options are provided for front of garage or back of garage or house only.
2. See detail 4 on sheet D7 for footing detail at steel column retrofit.
3. See details 1 & 2 on sheet D7 for steel column connections at upper floor.
4. See details 4 & 5 on sheet D8 for footing details at proprietary shear wall.
5. See details 1 & 2 on sheet D8 for upper floor connection at proprietary shear wall.

Figure 5.4-9 Alternate Earthquake Retrofit Schedule at $S_{DS} = 1.0$ with steel column or propriety shear wall). Sheet S3.3-1.0.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.0$) for Single Section of Wall at Front of Garage - Only																					
① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input type="checkbox"/>	④ MINIMUM REQUIRED LENGTH OF A SINGLE SECTION OF WALL OF WOOD STRUCTURAL PANEL SHEAR WALLS (at each wall line)										⑤ FOUNDATION SILL ANCHORAGE					⑥ FLOOR FRAMING TO WALL CONNECTION			
			No Tie-down		w/ Tie-downs in Existing or New Foundations										Min. No. of Foundation Connectors or Anchors at Each Wall Panel					Min. No. of Connectors at Each Wall Panel	
					8d at 6" O.C.			8d at 4" O.C.			8d at 2" O.C.										
			8d Nail Spacing	Wall Length	Wall Length	Tie- down	New Fdn Req'd ?	Wall Length	Tie- down	New Fdn Req'd ?	Wall Length	Tie- down	New Fdn Req'd ?	Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"
Light Construction	800		6	10'-0"	6'-0"	TD2	Yes	4'-6"	TD3	Yes	3'-0"	TD4	Yes	2	3	4	3	2	5	5	6
	1000		6	11'-6"	8'-0"	TD1	No	5'-6"	TD3	Yes	3'-6"	TD5	Yes	2	4	5	4	3	6	6	7
	1200		6	13'-6"	9'-6"	TD1	No	6'-6"	TD2	Yes	4'-0"	TD5	Yes	3	4	6	5	3	7	7	9
	1500		6	15'-6"	11'-6"	TD1	No	8'-0"	TD2	Yes	5'-0"	TD5	Yes	3	5	7	6	4	9	8	11
	2000		6	19'-6"	15'-6"	TD1	No	10'-6"	TD2	Yes	6'-6"	TD5	Yes	4	7	9	7	5	11	11	14
Medium Construction	800		6	12'-6"	8'-0"	TD1	No	5'-6"	TD3	Yes	3'-6"	TD5	Yes	3	4	5	4	3	6	6	8
	1000		6	14'-6"	10'-0"	TD1	No	7'-0"	TD3	Yes	4'-0"	TD5	Yes	3	5	6	5	4	7	7	9
	1200		6	16'-6"	12'-0"	TD1	No	8'-6"	TD2	Yes	5'-0"	TD5	Yes	4	5	7	6	4	9	9	11
	1500		6	19'-6"	15'-0"	TD1	No	10'-6"	TD2	Yes	6'-0"	TD5	Yes	4	7	9	7	5	11	11	14
	2000		6	24'-0"	20'-0"	TD1	No	14'-0"	TD2	Yes	8'-0"	TD5	Yes	6	9	11	9	7	14	14	18
Heavy Construction	800		6	13'-6"	10'-6"	TD1	No	7'-0"	TD2	Yes	4'-6"	TD5	Yes	3	5	6	5	4	8	7	10
	1000		6	15'-6"	13'-0"	TD1	No	9'-0"	TD2	Yes	5'-6"	TD5	Yes	4	6	8	6	4	10	9	12
	1200		6	17'-6"	16'-0"	TD1	No	11'-0"	TD2	Yes	6'-6"	TD4	Yes	5	7	9	8	5	11	11	14
	1500		4	19'-6"	20'-0"	None	No	13'-6"	TD2	Yes	8'-0"	TD4	Yes	6	9	11	9	6	14	14	18
	2000		4	20'-0"	26'-6"	None	No	18'-0"	TD1	No	10'-6"	TD4	Yes	7	11	15	12	8	19	18	24

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible. Additional anchors and connectors may be necessary to meet the requirements of specific details and General Notes.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.) Where "none" occurs, no tie-down is required.
- Foundations: Where new foundations are required, see sheet D2 for details.
- Connector Type "F" should be used as an alternative only if joists are blocked on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Wall lengths are total length of a single wall section required on each side of the building. See sheet S3.5-1.0 for 2 section of wall options.
- See sheet S3.6-1.0 for Alternate Earthquake Retrofit Options where sufficient length of wall does not occur or where wood structural panel shear wall retrofit installations are otherwise prohibited.

Figure 5.4-10 Earthquake Retrofit Schedule at $S_{DS} = 1.0$ at front of garage in dwelling with a ground story residential unit with single section of wood structural panel shear wall. Sheet S3.4-1.0.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.0$) Two Sections of Wall at Front of Garage - Only

① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies	④ MINIMUM TOTAL REQUIRED LENGTH OF EACH SECTION OF WOOD STRUCTURAL PANEL SHEAR WALLS For a Two Section of Wall Option					⑤ FOUNDATION SILL ANCHORAGE					⑥ FLOOR FRAMING TO WALL CONNECTION			
			Length per Section for a Two Section Option					Min. No. of Foundation Connectors or Anchors at Each Section of Wall					Min. No. of Connectors at Each Section of Wall			
			8d at 6" O.C.			8d at 2" O.C.			Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"
			Wall Length	Tie-down	New Fdn Req'd ?	Wall Length	Tie-down	New Fdn Req'd ?								
Light Construction	800		3'-6"	TD1	No	2'-8"	TD2	Yes	1	2	2	2	1	3	3	3
	1000		4'-0"	TD1	No	2'-8"	TD3	Yes	1	2	3	2	2	3	3	4
	1200		4'-6"	TD1	No	2'-8"	TD4	Yes	2	2	3	3	2	4	4	5
	1500		6'-0"	TD1	No	3'-0"	TD4	Yes	2	3	4	3	2	5	4	6
	2000		8'-0"	TD1	No	3'-6"	TD4	Yes	2	4	5	4	3	6	6	7
Medium Construction	800		4'-0"	TD2	Yes	2'-8"	TD4	Yes	2	2	3	2	2	3	3	4
	1000		5'-0"	TD1	No	2'-8"	TD4	Yes	2	3	3	3	2	4	4	5
	1200		6'-0"	TD1	No	3'-0"	TD4	Yes	2	3	4	3	2	5	5	6
	1500		7'-6"	TD1	No	3'-6"	TD5	Yes	2	4	5	4	3	6	6	7
	2000		10'-0"	TD1	No	4'-0"	TD5	Yes	3	5	6	5	4	7	7	9
Heavy Construction	800		5'-6"	TD1	No	2'-8"	TD4	Yes	2	3	3	3	2	4	4	5
	1000		6'-6"	TD1	No	3'-0"	TD4	Yes	2	3	4	3	2	5	5	6
	1200		8'-0"	TD1	No	3'-6"	TD4	Yes	3	4	5	4	3	6	6	7
	1500		10'-0"	None	No	4'-0"	TD4	Yes	3	5	6	5	3	7	7	9
	2000		13'-0"	None	No	5'-6"	TD4	Yes	4	6	8	6	4	10	9	12

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible. Additional anchors and connectors may be necessary to meet the requirements of specific details and General Notes.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.) Where "none" occurs, no tie-down is required.
- Foundations: Where new foundations are required, see sheet D2 for details.
- Connector Type "F" should be used as an alternative only if joists are blocked on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Wall lengths are total length of a single wall section required on each side of the building. See sheet S3.5-1.0 for 2 section of wall options.
- See sheet S3.6-1.0 for Alternate Earthquake Retrofit Options where sufficient length of wall does not occur or where wood structural panel shear wall retrofit installations are otherwise prohibited.

Figure 5.4-11 Earthquake Retrofit Schedule at $S_{DS} = 1.0$ at front of garage in dwelling with a ground story residential unit with two sections of wood structural panel shear wall. Sheet S3.5-1.0.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.0$) at front of Garage						
① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input checked="" type="checkbox"/>	STEEL COLUMN RETROFIT (2) (3)		PROPRIETARY SHEAR WALL RETROFIT (4) (5)	DIAPHRAGM NAILING (3) (5)
			Steel Column	Column Connection Type (per detail 2 on sheet D7) at Upper Floor	Minimum Required at Allowable Shear Capacity (lbs)	Edge Nail Spacing
Light Construction	800		W8x21	C1	1620	6
	1000		W8x21	C1	2030	6
	1200		W8x21	C1	2440	6
	1500		W8x21	C1	3050	6
	2000		W8x21	C1	4060	6
Medium Construction	800		W8x21	C1	2100	6
	1000		W8x21	C1	2630	6
	1200		W8x21	C1	3150	6
	1500		W8x21	C1	3940	6
	2000		W8x28	C1	5250	6
Heavy Construction	800		W8x21	C1	2740	6
	1000		W8x21	C1	3430	6
	1200		W8x21	C1	4120	6
	1500		W8x28	C1	5150	6
	2000		W8x28	C1	6860	6

Notes:

1. Steel column and Proprietary Shear Wall Options are provided for front of garage or back of garage or house only.
2. See detail 4 on sheet D7 for footing detail at steel column retrofit.
3. See details 1 & 2 on sheet D7 for steel column connections at upper floor.
4. See details 4 & 5 on sheet D8 for footing details at proprietary shear wall.
5. See details 1 & 2 on sheet D8 for upper floor connection at proprietary shear wall.

Figure 5.4-12 Alternate Earthquake Retrofit Schedule at $S_{DS} = 1.0$ at front of garage in dwelling with a ground story residential unit with steel column or proprietary shear wall. Sheet S3.6-1.0.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.2$) for Single Section of Wall																						
① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input checked="" type="checkbox"/>	④ MINIMUM REQUIRED LENGTH OF A SINGLE SECTION OF WALL OF WOOD STRUCTURAL PANEL SHEAR WALLS (at each wall line)											⑤ FOUNDATION SILL ANCHORAGE					⑥ FLOOR FRAMING TO WALL CONNECTION			
			No Tie-down			w/ Tie-downs in Existing or New Foundations									Min. No. of Foundation Connectors or Anchors at Each Wall Panel					Min. No. of Connectors at Each Wall Panel		
						8d at 6" O.C.			8d at 4" O.C.			8d at 2" O.C.										
			8d Nail Spacing	Wall Length	Wall Length	Tie- down	New Fdn Req'd ?	Wall Length	Tie- down	New Fdn Req'd ?	Wall Length	Tie- down	New Fdn Req'd ?	Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"	
Light Construction	800		6	19'-0"	15'-0"	TD1	No	10'-6"	TD2	Yes	6'-0"	TD5	Yes	4	7	9	7	5	11	10	14	
	1000		6	22'-6"	18'-6"	TD1	No	13'-0"	TD2	Yes	7'-6"	TD4	Yes	5	8	11	9	6	13	13	17	
	1200		6	25'-6"	22'-6"	TD1	No	15'-6"	TD2	Yes	9'-0"	TD4	Yes	6	10	13	10	7	16	15	20	
	1500		6	29'-6"	28'-0"	TD1	No	19'-0"	TD2	Yes	11'-6"	TD4	Yes	8	12	16	13	9	20	19	25	
	2000		4	36'-0"	37'-6"	None	No	25'-6"	TD2	Yes	15'-0"	TD4	Yes	10	16	21	17	12	26	25	33	
Medium Construction	800		6	23'-6"	19'-6"	TD1	No	13'-6"	TD2	Yes	8'-0"	TD5	Yes	5	8	11	9	6	14	13	17	
	1000		6	27'-6"	24'-0"	TD1	No	16'-6"	TD2	Yes	10'-0"	TD4	Yes	7	10	14	11	8	17	17	22	
	1200		6	31'-0"	29'-0"	TD1	No	20'-0"	TD2	Yes	12'-0"	TD4	Yes	8	12	16	13	9	21	20	26	
	1500		4	35'-6"	36'-6"	None	No	25'-0"	TD2	Yes	15'-0"	TD4	Yes	10	15	20	17	11	26	25	32	
	2000		4	43'-0"	48'-6"	None	No	33'-0"	TD2	Yes	19'-6"	TD4	Yes	13	20	27	22	15	34	33	43	
Heavy Construction	800		4	24'-6"	25'-6"	None	No	17'-6"	TD2	Yes	10'-6"	TD4	Yes	7	11	14	12	8	18	17	23	
	1000		4	28'-0"	31'-6"	None	No	21'-6"	TD2	Yes	13'-0"	TD4	Yes	9	13	18	15	10	22	21	28	
	1200		4	31'-6"	38'-0"	None	No	26'-0"	TD1	No	15'-6"	TD4	Yes	10	16	21	17	12	27	26	34	
	1500		4	34'-0"	47'-6"	None	No	32'-6"	TD1	No	19'-6"	TD4	Yes	13	20	26	22	15	33	32	42	
	2000		2	34'-6"	"NG"	None	No	43'-6"	None	No	25'-6"	TD3	Yes	17	26	35	29	20	44	42	56	

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible. Additional anchors and connectors may be necessary to meet the requirements of specific details and General Notes.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.) Where "None" occurs, no tie-down is required.
- Foundations: Where new foundations are required at front and back walls, see sheet D2 for details. At side walls, select retrofit options that do not require foundations whenever possible. Otherwise, provide foundations that extend the full depth of the garage in Figures 4 and 5 on Sheet S0 and for Figure 3 conditions (*living-space-over-garage dwellings without ground floor residential unit*), consult a design professional for remedial direction.
- Connector Type "F" should be used as an alternative only if joists are blocked on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Wall lengths are total length of a single wall section required on each side of the building. See sheet S3.2-1.0 for 2 section of wall options.
- See sheet S3.3-1.0 for Alternate Earthquake Retrofit Options where sufficient length of wall does not occur or where wood structural panel shear wall retrofit installations are otherwise prohibited.
- See sheets S3.4-1.0 thru S3.6-1.0 for Earthquake Retrofit Schedules for the front wall only at dwellings with a ground story residential unit. See also sheet S0, Figure 2.

Figure 5.4-13 Earthquake Retrofit Schedule at $S_{DS} = 1.2$ with single section of wood structural panel shear wall. Sheet S3.1-1.2.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.2$) Two Sections of Wall																
① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input checked="" type="checkbox"/>	④ MINIMUM TOTAL REQUIRED LENGTH OF EACH SECTION OF WOOD STRUCTURAL PANEL SHEAR WALL For a Two Section of Wall Option						⑤ FOUNDATION SILL ANCHORAGE					⑥ FLOOR FRAMING TO WALL CONNECTION		
			Length per Section for a Two Section Option						Min. No. of Foundation Connectors or Anchors at Each Section of Wall					Min. No. of Connectors at Each Section of Wall		
			8d at 6" O.C.			8d at 2" O.C.			Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"
			Wall Length	Tie- down	New Fdn Req'd ?	Wall Length	Tie- down	New Fdn Req'd ?								
Light Construction	800		7'-6"	TD1	No	3'-6"	TD4	Yes	2	4	5	4	3	6	5	7
	1000		9'-6"	TD1	No	4'-0"	TD4	Yes	3	4	6	5	3	7	7	9
	1200		11'-6"	TD1	No	4'-6"	TD5	Yes	3	5	7	5	4	8	8	10
	1500		14'-0"	TD1	No	6'-0"	TD4	Yes	4	6	8	7	5	10	10	13
	2000		19'-0"	None	No	7'-6"	TD4	Yes	5	8	11	9	6	13	13	17
Medium Construction	800		9'-6"	TD1	No	4'-0"	TD5	Yes	3	4	6	5	3	7	7	9
	1000		12'-0"	TD1	No	5'-0"	TD5	Yes	4	5	7	6	4	9	9	11
	1200		14'-6"	TD1	No	6'-0"	TD4	Yes	4	6	8	7	5	11	10	13
	1500		18'-0"	None	No	7'-6"	TD4	Yes	5	8	10	9	6	13	13	16
	2000		24'-6"	None	No	10'-0"	TD4	Yes	7	10	14	11	8	17	17	22
Heavy Construction	800		12'-6"	None	No	5'-0"	TD4	Yes	4	6	7	6	4	9	9	12
	1000		16'-0"	None	No	6'-6"	TD4	Yes	5	7	9	8	5	11	11	14
	1200		19'-0"	None	No	8'-0"	TD4	Yes	5	8	11	9	6	14	13	17
	1500		24'-0"	None	No	9'-6"	TD4	Yes	7	10	13	11	8	17	16	21
	2000		"NG"	None	No	13'-0"	TD3	Yes	9	13	18	15	10	22	21	28

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible. Additional anchors and connectors may be necessary to meet the requirements of specific details and General Notes.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.) Where "None" occurs, no tie-down is required.
- Foundations: Where new foundations are required at front and back walls, see sheet D2 for details. At side walls, select retrofit options that do not require foundations whenever possible. Otherwise, provide foundations that extend the full depth of the garage in Figures 4 and 5 on Sheet S0 and for Figure 3 conditions (*living-space-over-garage dwellings without ground floor residential unit*), consult a design professional for remedial direction.
- Connector Type "F" should be used as an alternative only if joists are blocked on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Wall lengths are total length of a single wall section required on each side of the building. See sheet S3.2-1.0 for 2 section of wall options.
- See sheet S3.3-1.0 for Alternate Earthquake Retrofit Options where sufficient length of wall does not occur or where wood structural panel shear wall retrofit installations are otherwise prohibited.
- See sheets S3.4-1.0 thru S3.6-1.0 for Earthquake Retrofit Schedules for the front wall only at dwellings with a ground story residential unit. See also sheet S0, Figure 2.

Figure 5.4-14 Earthquake Retrofit Schedule at $S_{DS} = 1.2$ with two sections of WSP shear wall. Sheet S3.2-1.2.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.2$)						
① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input checked="" type="checkbox"/>	④ STEEL COLUMN RETROFIT (2) (3)		⑤ PROPRIETARY SHEAR WALL RETROFIT (4) (5)	⑥ DIAPHRAGM NAILING (3) (5)
			Steel Column	Column Connection Type (per detail 2 on sheet D7) at Upper Floor	Minimum Required at Allowable Shear Capacity (lbs)	Edge Nail Spacing
Light Construction	800		W8x21	C1	3900	6
	1000		W8x28	C1	4870	6
	1200		W8x28	C1	5850	6
	1500		W10x26	C2	7310	6
	2000		W12x35	C2	9740	6
Medium Construction	800		W8x28	C1	5040	6
	1000		W8x28	C1	6300	6
	1200		W10x30	C2	7560	4
	1500		W12x35	C2	9450	4
	2000		W10x45	C3	12,600	4
Heavy Construction	800		W8x28	C1	6590	4
	1000		W10x30	C2	8230	4
	1200		W12x35	C2	9880	3
	1500		W12x35	C3	12,400	3
	2000		"NG"	"NG"	16,500	3

Notes:

1. Steel column and Proprietary Shear Wall Options are provided for front of garage or back of garage or house only.
2. See detail 4 on sheet D7 for footing detail at steel column retrofit.
3. See details 1 & 2 on sheet D7 for steel column connections at upper floor.
4. See details 4 & 5 on sheet D8 for footing details at proprietary shear wall.
5. See details 1 & 2 on sheet D8 for upper floor connection at proprietary shear wall.

Figure 5.4-15 Alternate Earthquake Retrofit Schedule at $S_{DS} = 1.2$ with steel column or propriety shear wall). Sheet S3.3-1.2.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.2$) for Single Section of Wall at Front of Garage - Only																						
① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input checked="" type="checkbox"/>	④ MINIMUM REQUIRED LENGTH OF A SINGLE SECTION OF WALL OF WOOD STRUCTURAL PANEL SHEAR WALLS (at each wall line)											⑤ FOUNDATION SILL ANCHORAGE					⑥ FLOOR FRAMING TO WALL CONNECTION			
			No Tie-down			w/ Tie-downs in Existing or New Foundations								Min. No. of Foundation Connectors or Anchors at Each Wall Panel					Min. No. of Connectors at Each Wall Panel			
						8d at 6" O.C.			8d at 4" O.C.			8d at 2" O.C.			Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"
			8d Nail Spacing	Wall Length	Wall Length	Tie-down	New Fdn Req'd ?	Wall Length	Tie-down	New Fdn Req'd ?	Wall Length	Tie-down	New Fdn Req'd ?	Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"	
Light Construction	800		6	11'-6"	7'-6"	TD1	No	5'-0"	TD3	Yes	3'-6"	TD5	Yes	2	4	5	4	3	6	5	7	
	1000		6	13'-6"	9'-6"	TD1	No	6'-6"	TD2	Yes	4'-0"	TD5	Yes	3	4	6	5	3	7	7	9	
	1200		6	15'-6"	11'-0"	TD1	No	7'-6"	TD2	Yes	4'-6"	TD5	Yes	3	5	7	5	4	8	8	10	
	1500		6	18'-0"	14'-0"	TD1	No	9'-6"	TD2	Yes	5'-6"	TD5	Yes	4	6	8	7	5	10	10	13	
	2000		6	22'-6"	18'-6"	TD1	No	13'-0"	TD2	Yes	7'-6"	TD4	Yes	5	8	11	9	6	13	13	17	
Medium Construction	800		6	14'-6"	9'-6"	TD1	No	6'-6"	TD3	Yes	4'-0"	TD5	Yes	3	4	6	5	3	7	7	9	
	1000		6	17'-0"	12'-0"	TD1	No	8'-6"	TD2	Yes	5'-0"	TD5	Yes	4	5	7	6	4	9	9	11	
	1200		6	19'-0"	14'-6"	TD1	No	10'-0"	TD2	Yes	6'-0"	TD5	Yes	4	6	8	7	5	11	10	13	
	1500		6	22'-6"	18'-0"	TD1	No	12'-6"	TD2	Yes	7'-6"	TD5	Yes	5	8	10	9	6	13	13	16	
	2000		6	27'-6"	24'-0"	TD1	No	16'-6"	TD2	Yes	10'-0"	TD5	Yes	7	10	14	11	8	17	17	22	
Heavy Construction	800		6	15'-6"	12'-6"	TD1	No	8'-6"	TD2	Yes	5'-0"	TD5	Yes	4	6	7	6	4	9	9	12	
	1000		6	18'-0"	16'-0"	TD1	No	11'-0"	TD2	Yes	6'-6"	TD5	Yes	5	7	9	8	5	11	11	14	
	1200		6	20'-6"	19'-0"	TD1	No	13'-0"	TD2	Yes	7'-6"	TD4	Yes	5	8	11	9	6	14	13	17	
	1500		4	22'-0"	23'-6"	None	No	16'-0"	TD2	Yes	9'-6"	TD4	Yes	7	10	13	11	8	17	16	21	
	2000		4	23'-0"	31'-6"	None	No	21'-6"	TD1	No	13'-0"	TD4	Yes	9	13	18	15	10	22	21	28	

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible. Additional anchors and connectors may be necessary to meet the requirements of specific details and General Notes.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.) Where "none" occurs, no tie-down is required.
- Foundations: Where new foundations are required, see sheet D2 for details.
- Connector Type "F" should be used as an alternative only if joists are blocked on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Wall lengths are total length of a single wall section required on each side of the building. See sheet S3.5-1.0 for 2 section of wall options.
- See sheet S3.6-1.0 for Alternate Earthquake Retrofit Options where sufficient length of wall does not occur or where wood structural panel shear wall retrofit installations are otherwise prohibited.

Figure 5.4-16 Earthquake Retrofit Schedule at $S_{DS} = 1.2$ at front of garage in dwelling with a ground story residential unit with single section of wood structural panel shear wall. Sheet S3.4-1.2.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.2$) Two Sections of Wall at Front of Garage - Only

① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies	④ MINIMUM TOTAL REQUIRED LENGTH OF EACH SECTION OF WOOD STRUCTURAL PANEL SHEAR WALLS For a Two Section of Wall Option					⑤ FOUNDATION SILL ANCHORAGE					⑥ FLOOR FRAMING TO WALL CONNECTION				
			Length per Section for a Two Section Option							Min. No. of Foundation Connectors or Anchors at Each Section of Wall					Min. No. of Connectors at Each Section of Wall		
			8d at 6" O.C.			8d at 2" O.C.				Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"
			Wall Length	Tie-down	New Fdn Req'd ?	Wall Length	Tie-down	New Fdn Req'd ?									
Light Construction	800		4'-0"	TD1	No	2'-6"	TD3	Yes	1	2	3	2	2	3	3	4	
	1000		4'-6"	TD1	No	2'-6"	TD4	Yes	2	2	3	3	2	4	4	5	
	1200		5'-6"	TD1	No	3'-0"	TD4	Yes	2	3	4	3	2	4	4	5	
	1500		7'-0"	TD1	No	3'-0"	TD4	Yes	2	3	4	4	3	5	5	7	
	2000		9'-6"	TD1	No	4'-0"	TD5	Yes	3	4	6	5	3	7	7	9	
Medium Construction	800		5'-0"	TD2	Yes	2'-6"	TD4	Yes	2	2	3	3	2	4	4	5	
	1000		6'-0"	TD1	No	3'-0"	TD4	Yes	2	3	4	3	2	5	5	6	
	1200		7'-6"	TD1	No	3'-6"	TD5	Yes	2	3	4	4	3	6	5	7	
	1500		9'-0"	TD1	No	4'-0"	TD5	Yes	3	4	5	5	3	7	7	8	
	2000		12'-0"	TD1	No	5'-0"	TD5	Yes	4	5	7	6	4	9	9	11	
Heavy Construction	800		6'-6"	TD1	No	3'-0"	TD4	Yes	2	3	4	3	2	5	5	6	
	1000		8'-0"	TD1	No	3'-6"	TD4	Yes	3	4	5	4	3	6	6	7	
	1200		9'-6"	TD1	No	4'-0"	TD5	Yes	3	4	6	5	3	7	7	9	
	1500		12'-0"	None	No	5'-0"	TD4	Yes	4	5	7	6	4	9	8	11	
	2000		16'-0"	None	No	6'-6"	TD4	Yes	5	7	9	8	5	11	11	14	

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible. Additional anchors and connectors may be necessary to meet the requirements of specific details and General Notes.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.) Where "none" occurs, no tie-down is required.
- Foundations: Where new foundations are required, see sheet D2 for details.
- Connector Type "F" should be used as an alternative only if joists are blocked on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Wall lengths are total length of a single wall section required on each side of the building. See sheet S3.5-1.0 for 2 section of wall options.
- See sheet S3.6-1.0 for Alternate Earthquake Retrofit Options where sufficient length of wall does not occur or where wood structural panel shear wall retrofit installations are otherwise prohibited.

Figure 5.4-17 Earthquake Retrofit Schedule at $S_{DS} = 1.2$ at front of garage in dwelling with a ground story residential unit with two sections of wood structural panel shear wall. Sheet S3.5-1.2.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.2$) at front of Garage

① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input checked="" type="checkbox"/>	STEEL COLUMN RETROFIT (2) (3)		PROPRIETARY SHEAR WALL RETROFIT (4) (5)	DIAPHRAGM NAILING (3) (5)
			Steel Column	Column Connection Type (per detail 2 on sheet D7) at Upper Floor	Minimum Required at Allowable Shear Capacity (lbs)	Edge Nail Spacing (inches on center)
Light Construction	800		W8x21	C1	1950	6
	1000		W8x21	C1	2440	6
	1200		W8x21	C1	2920	6
	1500		W8x21	C1	3650	6
	2000		W8x28	C1	4870	6
Medium Construction	800		W8x21	C1	2520	6
	1000		W8x21	C1	3150	6
	1200		W8x21	C1	3780	6
	1500		W8x28	C1	4730	6
	2000		W8x28	C1	6300	6
Heavy Construction	800		W8x21	C1	3290	6
	1000		W8x21	C1	4120	6
	1200		W8x28	C1	4940	6
	1500		W8x28	C1	6170	6
	2000		W10x30	C2	8230	6

Notes:

1. Steel column and Proprietary Shear Wall Options are provided for front of garage or back of garage or house only.
2. See detail 4 on sheet D7 for footing detail at steel column retrofit.
3. See details 1 & 2 on sheet D7 for steel column connections at upper floor.
4. See details 4 & 5 on sheet D8 for footing details at proprietary shear wall.
5. See details 1 & 2 on sheet D8 for upper floor connection at proprietary shear wall.

Figure 5.4-18 Alternate Earthquake Retrofit Schedule at $S_{DS} = 1.2$ at front of garage in dwelling with a ground story residential unit with steel column or proprietary shear wall. Sheet S3.6-1.2.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.5$) for Single Section of Wall																					
① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input checked="" type="checkbox"/>	④ MINIMUM REQUIRED LENGTH OF A SINGLE SECTION OF WALL OF WOOD STRUCTURAL PANEL SHEAR WALLS (at each wall line)										⑤ FOUNDATION SILL ANCHORAGE					⑥ FLOOR FRAMING TO WALL CONNECTION			
			No Tie-down			w/ Tie-downs in Existing or New Foundations							Min. No. of Foundation Connectors or Anchors at Each Wall Panel					Min. No. of Connectors at Each Wall Panel			
						8d at 6" O.C.			8d at 4" O.C.		8d at 2" O.C.										
			8d Nail Spacing	Wall Length	Wall Length	Tie- down	New Fdn Req'd ?	Wall Length	Tie- down	New Fdn Req'd ?	Wall Length	Tie- down	New Fdn Req'd ?	Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"
Light Construction	800		6	23'-0"	18'-6"	TD1	No	13'-0"	TD2	Yes	7'-6"	TD4	Yes	5	8	11	9	6	13	13	17
	1000		6	27'-0"	23'-6"	TD1	No	16'-0"	TD2	Yes	9'-6"	TD4	Yes	6	10	13	11	8	17	16	21
	1200		6	30'-6"	28'-0"	TD1	No	19'-0"	TD2	Yes	11'-6"	TD4	Yes	8	12	16	13	9	20	19	25
	1500		4	35'-0"	35'-0"	None	No	24'-0"	TD2	Yes	14'-6"	TD4	Yes	9	15	19	16	11	25	24	31
	2000		4	43'-0"	47'-0"	None	No	32'-0"	TD2	Yes	19'-0"	TD4	Yes	12	20	26	21	15	33	31	42
Medium Construction	800		6	28'-6"	24'-0"	TD1	No	16'-6"	TD2	Yes	10'-0"	TD5	Yes	7	10	14	11	8	17	17	22
	1000		6	33'-0"	30'-6"	TD1	No	20'-6"	TD2	Yes	12'-6"	TD4	Yes	8	13	17	14	10	21	21	27
	1200		6	37'-0"	36'-6"	TD1	No	25'-0"	TD2	Yes	15'-0"	TD4	Yes	10	15	20	17	11	26	25	32
	1500		4	42'-6"	45'-6"	None	No	31'-0"	TD2	Yes	18'-6"	TD4	Yes	12	19	25	21	14	32	31	40
	2000		4	51'-6"	"NG"	None	No	41'-6"	TD1	No	24'-6"	TD4	Yes	16	25	33	27	19	42	41	54
Heavy Construction	800		4	29'-6"	31'-6"	None	No	21'-6"	TD2	Yes	13'-0"	TD4	Yes	9	13	18	15	10	22	21	28
	1000		4	33'-6"	39'-6"	None	No	27'-0"	TD1	No	16'-0"	TD4	Yes	11	17	22	18	12	28	27	35
	1200		4	37'-6"	47'-6"	None	No	32'-6"	TD1	No	19'-6"	TD4	Yes	13	20	26	22	15	33	32	42
	1500		2	40'-6"	"NG"	None	No	40'-6"	None	No	24'-0"	TD4	Yes	16	25	32	27	18	41	40	53
	2000		2	41'-0"	"NG"	None	No	54'-0"	None	No	32'-0"	TD2	Yes	21	33	43	36	24	55	53	70

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible. Additional anchors and connectors may be necessary to meet the requirements of specific details and General Notes.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.) Where "None" occurs, no tie-down is required.
- Foundations: Where new foundations are required at front and back walls, see sheet D2 for details. At side walls, select retrofit options that do not require foundations whenever possible. Otherwise, provide foundations that extend the full depth of the garage in Figures 4 and 5 on Sheet S0 and for Figure 3 conditions (*living-space-over-garage dwellings without ground floor residential unit*), consult a design professional for remedial direction.
- Connector Type "F" should be used as an alternative only if joists are blocked on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Wall lengths are total length of a single wall section required on each side of the building. See sheet S3.2-1.0 for 2 section of wall options.
- See sheet S3.3-1.0 for Alternate Earthquake Retrofit Options where sufficient length of wall does not occur or where wood structural panel shear wall retrofit installations are otherwise prohibited.
- See sheets S3.4-1.0 thru S3.6-1.0 for Earthquake Retrofit Schedules for the front wall only at dwellings with a ground story residential unit. See also sheet S0, Figure 2.

Figure 5.4-19 Earthquake Retrofit Schedule at $S_{DS} = 1.5$ with single section of wood structural panel shear wall. Sheet S3.1-1.5.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.5$) Two Sections of Wall																		
① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input checked="" type="checkbox"/>	④ MINIMUM TOTAL REQUIRED LENGTH OF EACH SECTION OF WOOD STRUCTURAL PANEL SHEAR WALL For a Two Section of Wall Option					⑤ FOUNDATION SILL ANCHORAGE					⑥ FLOOR FRAMING TO WALL CONNECTION					
			Length per Section for a Two Section Option							Min. No. of Foundation Connectors or Anchors at Each Section of Wall					Min. No. of Connectors at Each Section of Wall			
			8d at 6" O.C.			8d at 2" O.C.				Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"	
			Wall Length	Tie- down	New Fdn Req'd ?	Wall Length	Tie- down	New Fdn Req'd ?	Type "D"									Type "E" or "F"
Light Construction	800		9'-6"	TD1	No	4'-0"	TD5	Yes	3	4	6	5	3	7	7	9		
	1000		12'-0"	TD1	No	5'-0"	TD5	Yes	3	5	7	6	4	9	8	11		
	1200		14'-0"	TD1	No	6'-0"	TD4	Yes	4	6	8	7	5	10	10	13		
	1500		17'-6"	TD1	No	7'-0"	TD4	Yes	5	8	10	8	6	13	12	16		
	2000		23'-6"	None	No	9'-6"	TD4	Yes	6	10	13	11	8	17	16	21		
Medium Construction	800		12'-0"	TD1	No	5'-0"	TD5	Yes	4	5	7	6	4	9	9	11		
	1000		15'-0"	TD1	No	6'-0"	TD5	Yes	4	7	9	7	5	11	11	14		
	1200		18'-0"	TD1	No	7'-6"	TD4	Yes	5	8	10	9	6	13	13	16		
	1500		23'-0"	None	No	9'-6"	TD4	Yes	6	10	13	11	7	16	16	20		
	2000		"NG"	None	No	12'-6"	TD4	Yes	8	13	17	14	10	21	21	27		
Heavy Construction	800		16'-0"	None	No	6'-6"	TD4	Yes	5	7	9	8	5	11	11	14		
	1000		20'-0"	None	No	8'-0"	TD4	Yes	6	9	11	9	6	14	14	18		
	1200		24'-0"	None	No	9'-6"	TD4	Yes	7	10	13	11	8	17	16	21		
	1500		"NG"	None	No	12'-0"	TD4	Yes	8	13	16	14	9	21	20	27		
	2000		"NG"	None	No	16'-0"	TD2	Yes	11	17	22	18	12	28	27	35		

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible. Additional anchors and connectors may be necessary to meet the requirements of specific details and General Notes.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.) Where "None" occurs, no tie-down is required.
- Foundations: Where new foundations are required at front and back walls, see sheet D2 for details. At side walls, select retrofit options that do not require foundations whenever possible. Otherwise, provide foundations that extend the full depth of the garage in Figures 4 and 5 on Sheet S0 and for Figure 3 conditions (*living-space-over-garage dwellings without ground floor residential unit*), consult a design professional for remedial direction.
- Connector Type "F" should be used as an alternative only if joists are blocked on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Wall lengths are total length of a single wall section required on each side of the building. See sheet S3.2-1.0 for 2 section of wall options.
- See sheet S3.3-1.0 for Alternate Earthquake Retrofit Options where sufficient length of wall does not occur or where wood structural panel shear wall retrofit installations are otherwise prohibited.
- See sheets S3.4-1.0 thru S3.6-1.0 for Earthquake Retrofit Schedules for the front wall only at dwellings with a ground story residential unit. See also sheet S0, Figure 2.

Figure 5.4-20 Earthquake Retrofit Schedule at $S_{DS} = 1.5$ with two sections of wood structural panel shear wall. Sheet S3.2-1.5.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.5$)						
① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input checked="" type="checkbox"/>	④ STEEL COLUMN RETROFIT (2) (3)		⑤ PROPRIETARY SHEAR WALL RETROFIT (4) (5)	⑥ DIAPHRAGM NAILING (3) (5)
			Steel Column	Column Connection Type (per detail 2 on sheet D7) at Upper Floor	Minimum Required at Allowable Shear Capacity (lbs)	Edge Nail Spacing
Light Construction	800		W8x28	C1	4870	6
	1000		W8x28	C1	6090	6
	1200		W10x26	C2	7310	4
	1500		W12x35	C2	9140	4
	2000		W12x35	C3	12,200	4
Medium Construction	800		W8x28	C1	6300	4
	1000		W10x30	C2	7880	4
	1200		W12x35	C2	9450	4
	1500		W12x35	C3	11,800	3
	2000		"NG"	"NG"	15,800	3
Heavy Construction	800		W10x30	C2	8230	3
	1000		W12x35	C3	10,300	3
	1200		W12x35	C3	12,300	3
	1500		"NG"	"NG"	15,400	3
	2000		"NG"	"NG"	20,600	3

Notes:

1. Steel column and Proprietary Shear Wall Options are provided for front of garage or back of garage or house only.
2. See detail 4 on sheet D7 for footing detail at steel column retrofit.
3. See details 1 & 2 on sheet D7 for steel column connections at upper floor.
4. See details 4 & 5 on sheet D8 for footing details at proprietary shear wall.
5. See details 1 & 2 on sheet D8 for upper floor connection at proprietary shear wall.

Figure 5.4-21 Alternate Earthquake Retrofit Schedule at $S_{DS} = 1.5$ with steel column or propriety shear wall). Sheet S3.3-1.5.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.5$) for Single Section of Wall at Front of Garage - Only																							
① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input type="checkbox"/>	④ MINIMUM REQUIRED LENGTH OF A SINGLE SECTION OF WALL OF WOOD STRUCTURAL PANEL SHEAR WALLS (at each wall line)										⑤ FOUNDATION SILL ANCHORAGE					⑥ FLOOR FRAMING TO WALL CONNECTION					
			No Tie-down			w/ Tie-downs in Existing or New Foundations							Min. No. of Foundation Connectors or Anchors at Each Wall Panel					Min. No. of Connectors at Each Wall Panel					
						8d at 6" O.C.			8d at 4" O.C.			8d at 2" O.C.				Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"
			8d Nail Spacing	Wall Length	Wall Length	Tie-down	New Fdn Req'd ?	Wall Length	Tie-down	New Fdn Req'd ?	Wall Length	Tie-down	New Fdn Req'd ?	Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"		
Light Construction	800		6	14'-0"	9'-6"	TD1	No	6'-6"	TD3	Yes	4'-0"	TD5	Yes	3	4	6	5	3	7	7	9		
	1000		6	16'-6"	11'-6"	TD1	No	8'-0"	TD2	Yes	5'-0"	TD5	Yes	3	5	7	6	4	9	8	11		
	1200		6	18'-6"	14'-0"	TD1	No	9'-6"	TD2	Yes	5'-6"	TD5	Yes	4	6	8	7	5	10	10	13		
	1500		6	22'-0"	17'-6"	TD1	No	12'-0"	TD2	Yes	7'-0"	TD4	Yes	5	8	10	8	6	13	12	16		
	2000		6	27'-0"	23'-6"	TD1	No	16'-0"	TD2	Yes	9'-6"	TD4	Yes	6	10	13	11	8	17	16	21		
Medium Construction	800		6	17'-6"	12'-0"	TD1	No	8'-6"	TD3	Yes	5'-0"	TD5	Yes	4	5	7	6	4	9	9	11		
	1000		6	20'-6"	15'-0"	TD1	No	10'-6"	TD2	Yes	6'-0"	TD5	Yes	4	7	9	7	5	11	11	14		
	1200		6	23'-0"	18'-0"	TD1	No	12'-6"	TD2	Yes	7'-6"	TD5	Yes	5	8	10	9	6	13	13	16		
	1500		6	27'-0"	22'-6"	TD1	No	15'-6"	TD2	Yes	9'-0"	TD4	Yes	6	10	13	11	7	16	16	20		
	2000		6	33'-0"	30'-6"	TD1	No	20'-6"	TD2	Yes	12'-6"	TD4	Yes	8	13	17	14	10	21	21	27		
Heavy Construction	800		6	18'-6"	16'-0"	TD1	No	11'-0"	TD2	Yes	6'-6"	TD5	Yes	5	7	9	8	5	11	11	14		
	1000		6	21'-6"	20'-0"	TD1	No	13'-6"	TD2	Yes	8'-0"	TD4	Yes	6	9	11	9	6	14	14	18		
	1200		6	24'-6"	23'-6"	TD1	No	16'-0"	TD2	Yes	9'-6"	TD4	Yes	7	10	13	11	8	17	16	21		
	1500		4	26'-6"	29'-6"	None	No	20'-6"	TD2	Yes	12'-0"	TD4	Yes	8	13	16	14	9	21	20	27		
	2000		4	27'-6"	39'-6"	None	No	27'-0"	TD1	No	16'-0"	TD4	Yes	11	17	22	18	12	28	27	35		

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible. Additional anchors and connectors may be necessary to meet the requirements of specific details and General Notes.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.) Where "none" occurs, no tie-down is required.
- Foundations: Where new foundations are required, see sheet D2 for details.
- Connector Type "F" should be used as an alternative only if joists are blocked on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Wall lengths are total length of a single wall section required on each side of the building. See sheet S3.5-1.0 for 2 section of wall options.
- See sheet S3.6-1.0 for Alternate Earthquake Retrofit Options where sufficient length of wall does not occur or where wood structural panel shear wall retrofit installations are otherwise prohibited.

Figure 5.4-22 Earthquake Retrofit Schedule at $S_{DS} = 1.5$ at front of garage in dwelling with a ground story residential unit with single section of wood structural panel shear wall. Sheet S3.4-1.5.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.5$) Two Sections of Wall at Front of Garage - Only

① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input checked="" type="checkbox"/>	④ MINIMUM TOTAL REQUIRED LENGTH OF EACH SECTION OF WOOD STRUCTURAL PANEL SHEAR WALLS For a Two Section of Wall Option						⑤ FOUNDATION SILL ANCHORAGE					⑥ FLOOR FRAMING TO WALL CONNECTION		
			Length per Section for a Two Section Option						Min. No. of Foundation Connectors or Anchors at Each Section of Wall					Min. No. of Connectors at Each Section of Wall		
			8d at 6" O.C.			8d at 2" O.C.			Type "A"	Type "B"	Type "C"	1/2"Ø Bolt	5/8"Ø Bolt	Type "D"	Type "E" or "F"	Type "G"
			Wall Length	Tie-down	New Fdn Req'd ?	Wall Length	Tie-down	New Fdn Req'd ?								
Light Construction	800		4'-6"	TD1	No	2'-6"	TD4	Yes	2	2	3	3	2	4	4	5
	1000		6'-0"	TD1	No	3'-0"	TD4	Yes	2	3	4	3	2	5	4	6
	1200		7'-0"	TD1	No	3'-0"	TD4	Yes	2	3	4	4	3	5	5	7
	1500		9'-0"	TD1	No	4'-0"	TD4	Yes	3	4	5	4	3	7	6	8
	2000		12'-0"	TD1	No	5'-0"	TD5	Yes	3	5	7	6	4	9	8	11
Medium Construction	800		6'-0"	TD1	No	3'-0"	TD4	Yes	2	3	4	3	2	5	5	6
	1000		7'-6"	TD1	No	3'-6"	TD5	Yes	2	4	5	4	3	6	6	7
	1200		9'-0"	TD1	No	4'-0"	TD5	Yes	3	4	5	5	3	7	7	8
	1500		11'-6"	TD1	No	4'-6"	TD5	Yes	3	5	7	6	4	8	8	10
	2000		15'-0"	TD1	No	6'-0"	TD5	Yes	4	7	9	7	5	11	11	14
Heavy Construction	800		8'-0"	TD1	No	3'-6"	TD4	Yes	3	4	5	4	3	6	6	7
	1000		10'-0"	TD1	No	4'-0"	TD4	Yes	3	5	6	5	3	7	7	9
	1200		12'-0"	TD1	No	5'-0"	TD4	Yes	4	5	7	6	4	9	8	11
	1500		15'-0"	None	No	6'-0"	TD4	Yes	4	7	8	7	5	11	10	14
	2000		20'-0"	None	No	8'-0"	TD4	Yes	6	9	11	9	6	14	14	18

Notes:

- Anchor bolts and Connectors shown in the Earthquake Retrofit Schedule are the minimum required per wall line, placed within the length of strengthening where possible. Additional anchors and connectors may be necessary to meet the requirements of specific details and General Notes.
- Tie-downs: If your foundation meets the criteria, you may choose the tie-down option to decrease the required length of strengthening. This may be required where the length of the wall without tie downs specified in this schedule is longer than can be accommodated by existing conditions. However, there is a level of uncertainty when dealing with existing foundations, therefore, where possible, longer lengths of strengthening, without tie-downs, are preferred. (See Supplemental Technical Notes, Sheet S2 to verify the existing foundation is suitable and meets criteria.) Where "none" occurs, no tie-down is required.
- Foundations: Where new foundations are required, see sheet D2 for details.
- Connector Type "F" should be used as an alternative only if joists are blocked on both sides and where accessibility makes the use of Types "D" or "E" impractical.
- Any of the connectors listed within a particular group and as shown on sheet S3 may be used for strengthening the particular condition.
- This plan set was developed using the lowest listed manufacturer's capacity within a particular group. Cells marked "NG" on the applicable Earthquake Retrofit Schedule may be found to have an acceptable spacing where an alternate connector is used. Any such substitution can only be made by a Registered Design Professional.
- Wall lengths are total length of a single wall section required on each side of the building. See sheet S3.5-1.0 for 2 section of wall options.
- See sheet S3.6-1.0 for Alternate Earthquake Retrofit Options where sufficient length of wall does not occur or where wood structural panel shear wall retrofit installations are otherwise prohibited.

Figure 5.4-23 Earthquake Retrofit Schedule at $S_{DS} = 1.5$ at front of garage in dwelling with a ground story residential unit with two sections of wood structural panel shear wall. Sheet S3.5-1.5.

EARTHQUAKE RETROFIT SCHEDULE ($S_{DS} = 1.5$) at front of Garage

① WEIGHT CLASSIFICATION	② Floor Area in Square Feet	③ Mark row that applies <input checked="" type="checkbox"/>	STEEL COLUMN RETROFIT (2) (3)		PROPRIETARY SHEAR WALL RETROFIT (4) (5)	DIAPHRAGM NAILING (3) (5)
			Steel Column	Column Connection Type (per detail 2 on sheet D7) at Upper Floor	Minimum Required at Allowable Shear Capacity (lbs)	Edge Nail Spacing
Light Construction	800		W8x21	C1	2440	6
	1000		W8x21	C1	3050	6
	1200		W8x21	C1	3650	6
	1500		W8x21	C1	4570	6
	2000		W8x28	C1	6090	6
Medium Construction	800		W8x21	C1	3150	6
	1000		W8x21	C1	3940	6
	1200		W8x28	C1	4730	6
	1500		W8x28	C1	5910	6
	2000		W10x30	C2	7880	6
Heavy Construction	800		W8x21	C1	4120	6
	1000		W8x28	C1	5150	6
	1200		W8x28	C1	6170	6
	1500		W10x30	C2	7720	6
	2000		W12x35	C3	10,300	6

Notes:

1. Steel column and Proprietary Shear Wall Options are provided for front of garage or back of garage or house only.
2. See detail 4 on sheet D7 for footing detail at steel column retrofit.
3. See details 1 & 2 on sheet D7 for steel column connections at upper floor.
4. See details 4 & 5 on sheet D8 for footing details at proprietary shear wall.
5. See details 1 & 2 on sheet D8 for upper floor connection at proprietary shear wall.

Figure 5.4-24 Alternate Earthquake Retrofit Schedule at $S_{DS} = 1.5$ at front of garage in dwelling with a ground story residential unit with steel column or proprietary shear wall. Sheet S3.6-1.5.

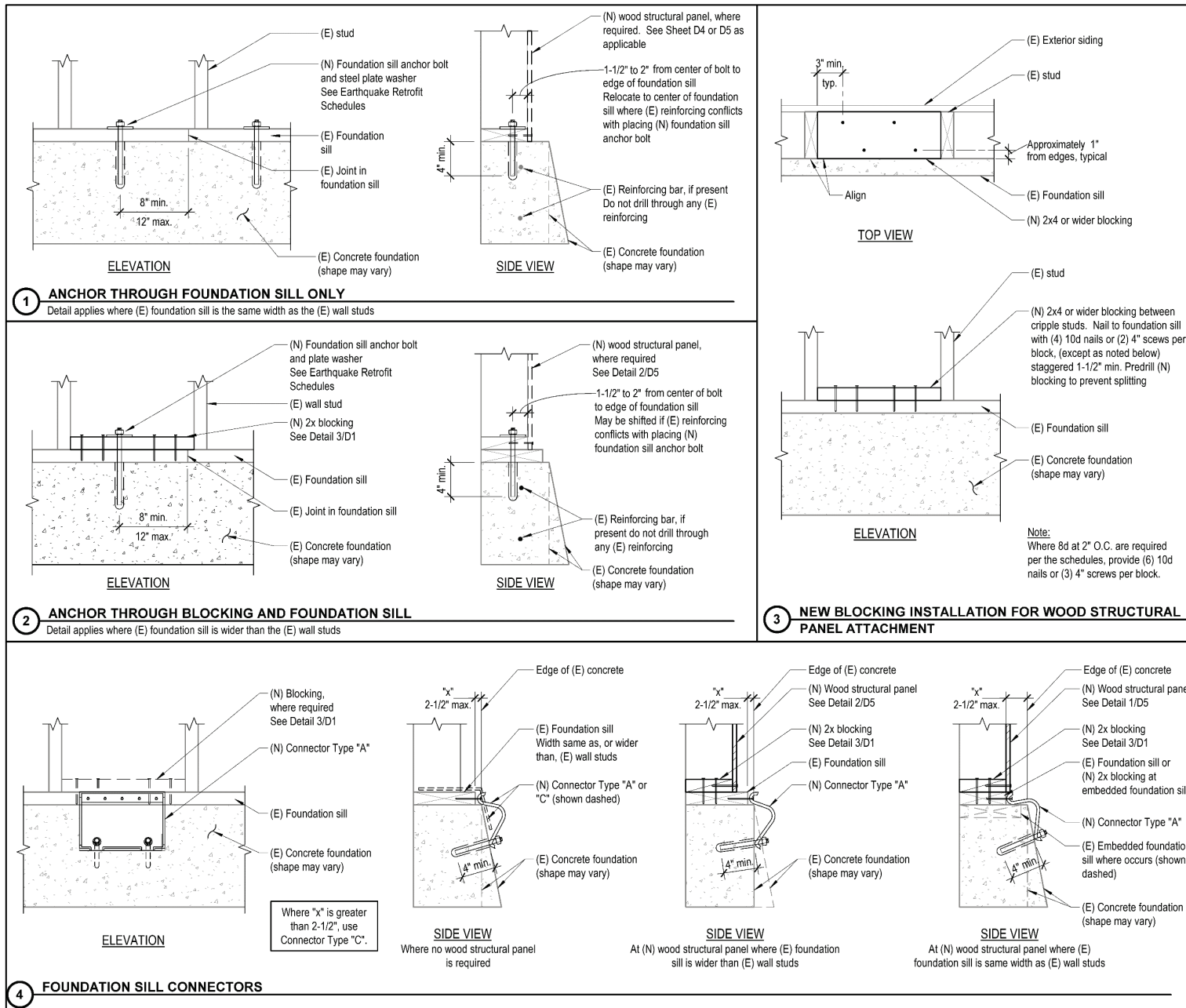


Figure 5.4-25 Foundation sill to concrete foundation connection details. Sheet D1.

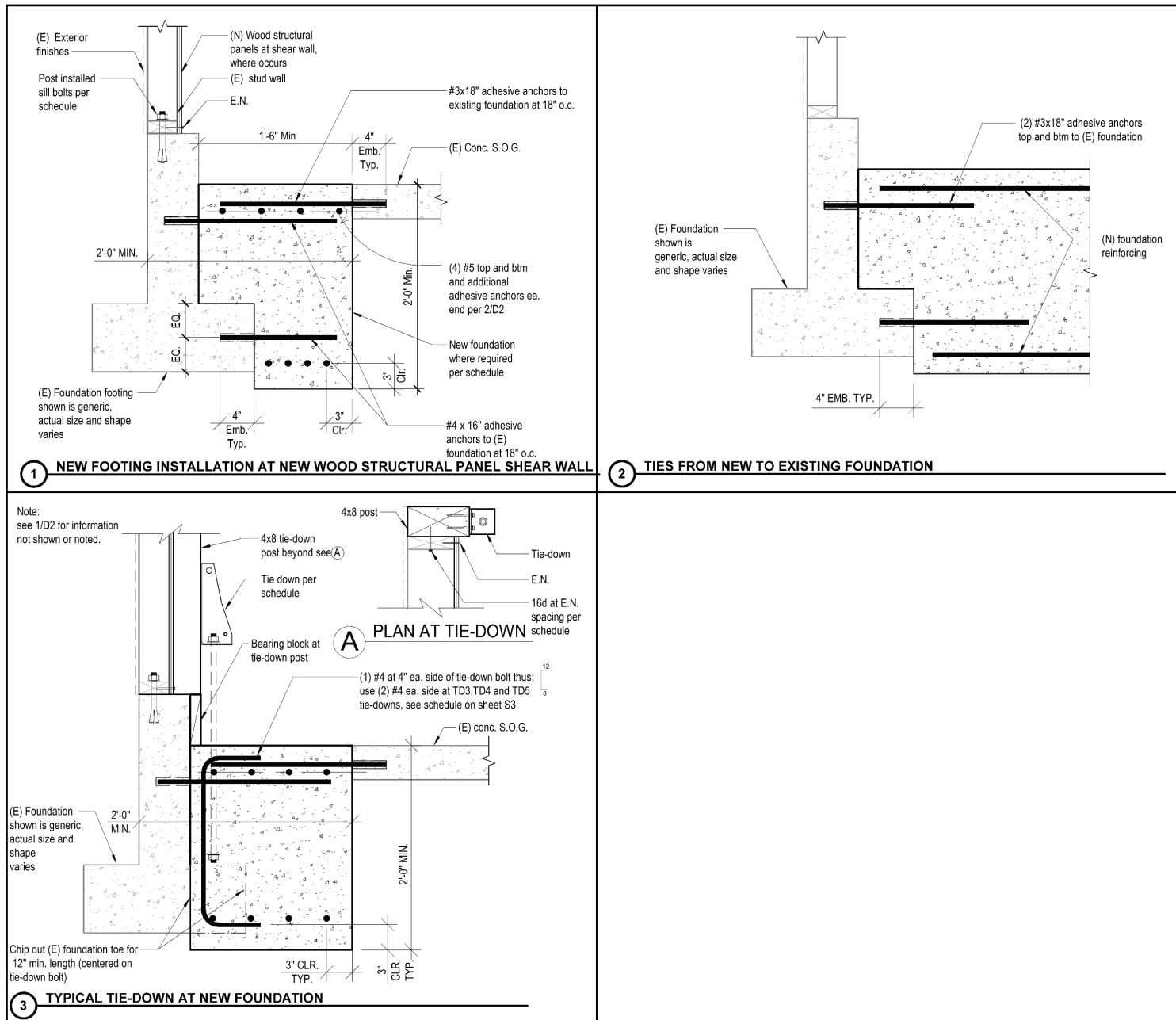


Figure 5.4-26 New foundation details at wood structural panel shear walls. Sheet D2.

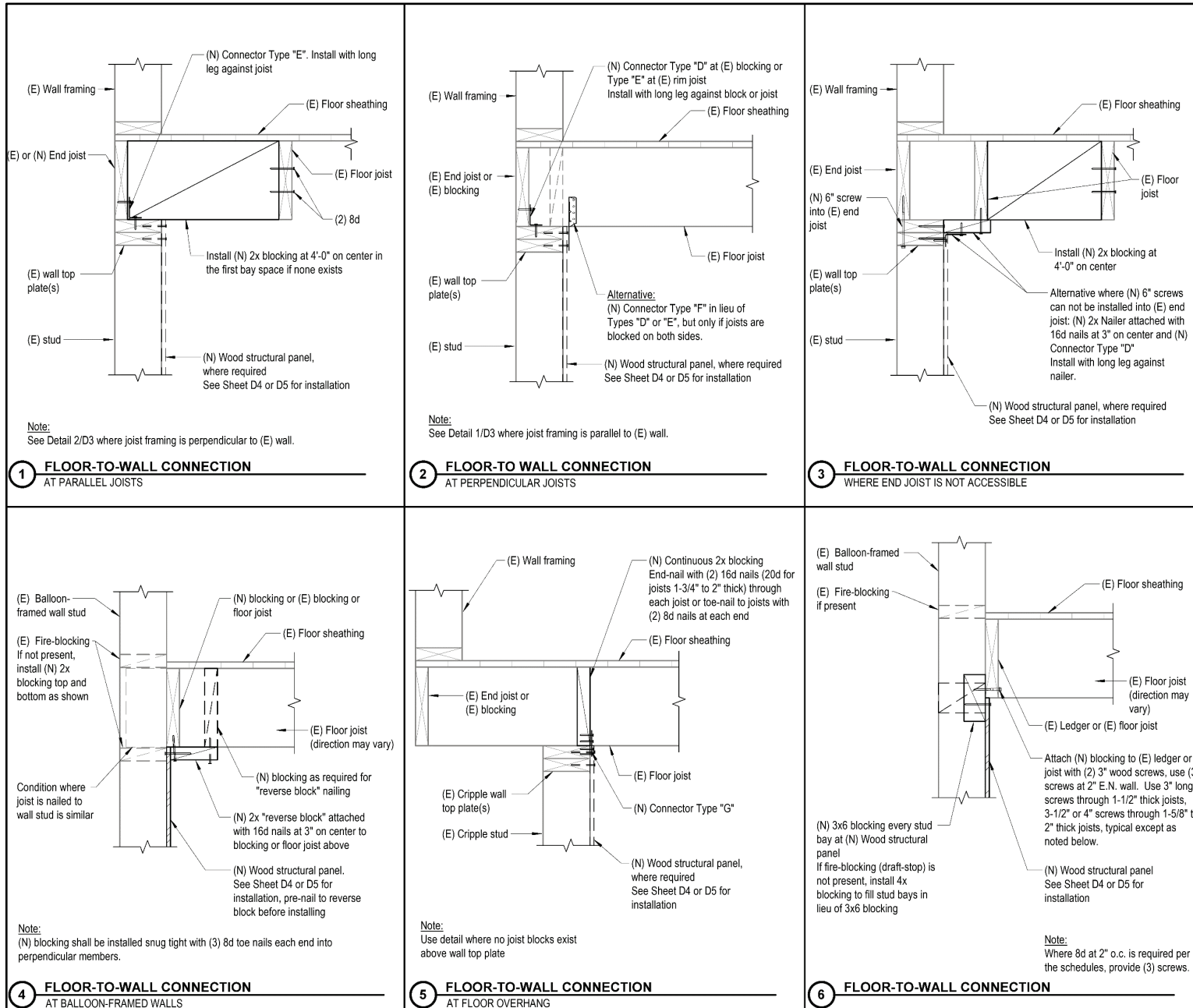


Figure 5.4-27 Floor framing to wall connections. Sheet D3.

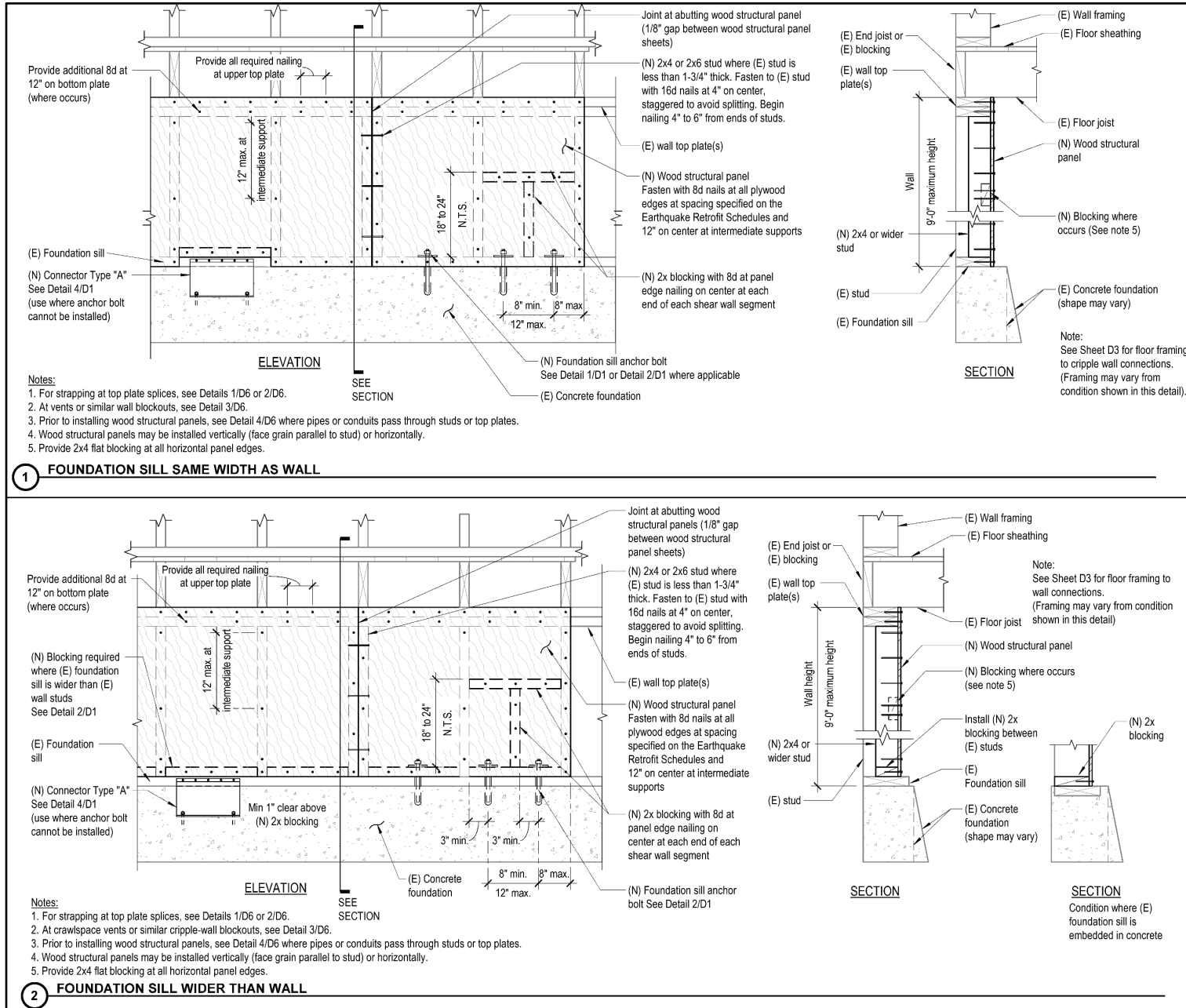


Figure 5.4-28 Wood structural panel installation at shear walls. Sheet D4.

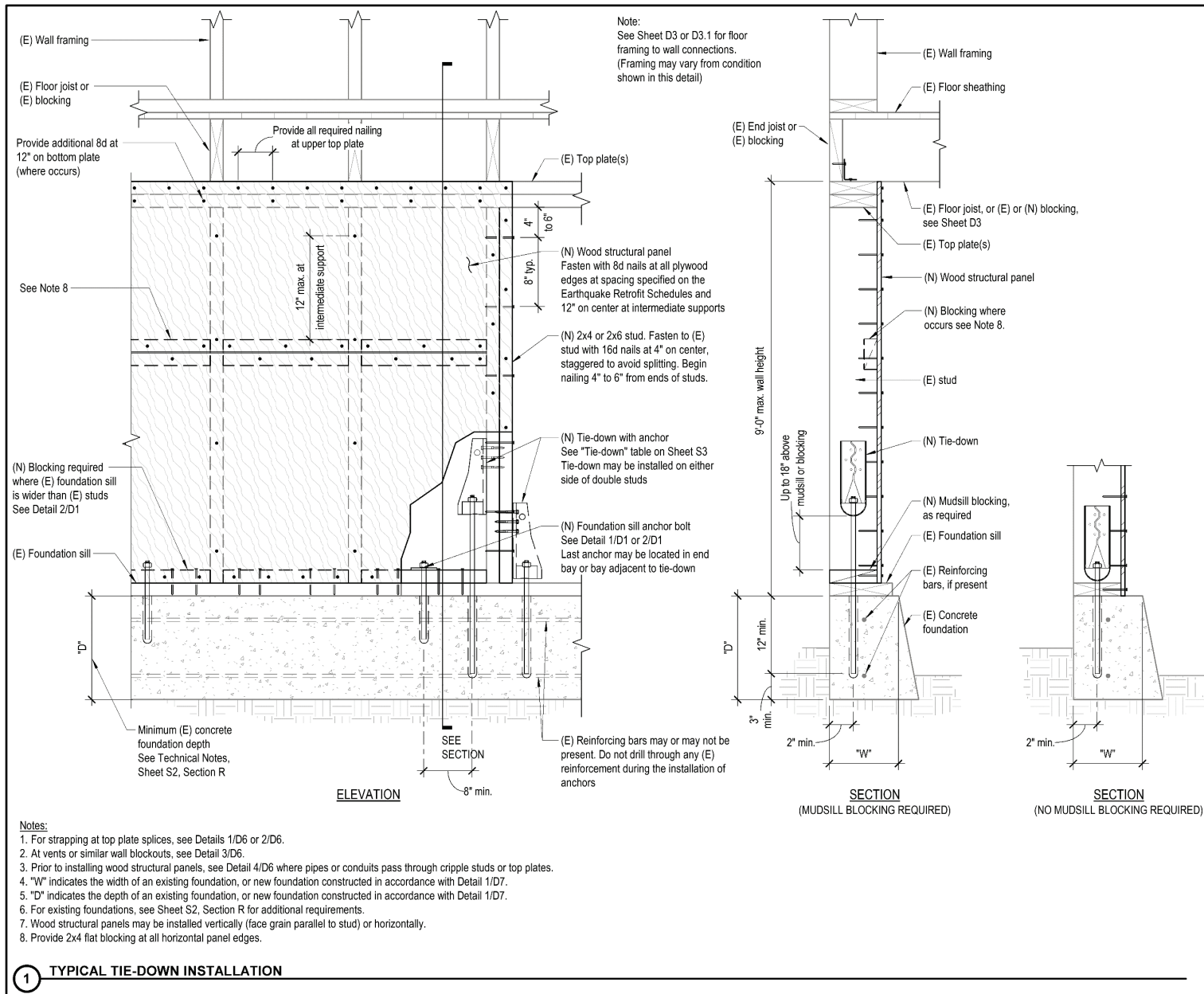


Figure 5.4-29 Wood structural panel with tie-downs. Sheet D5.

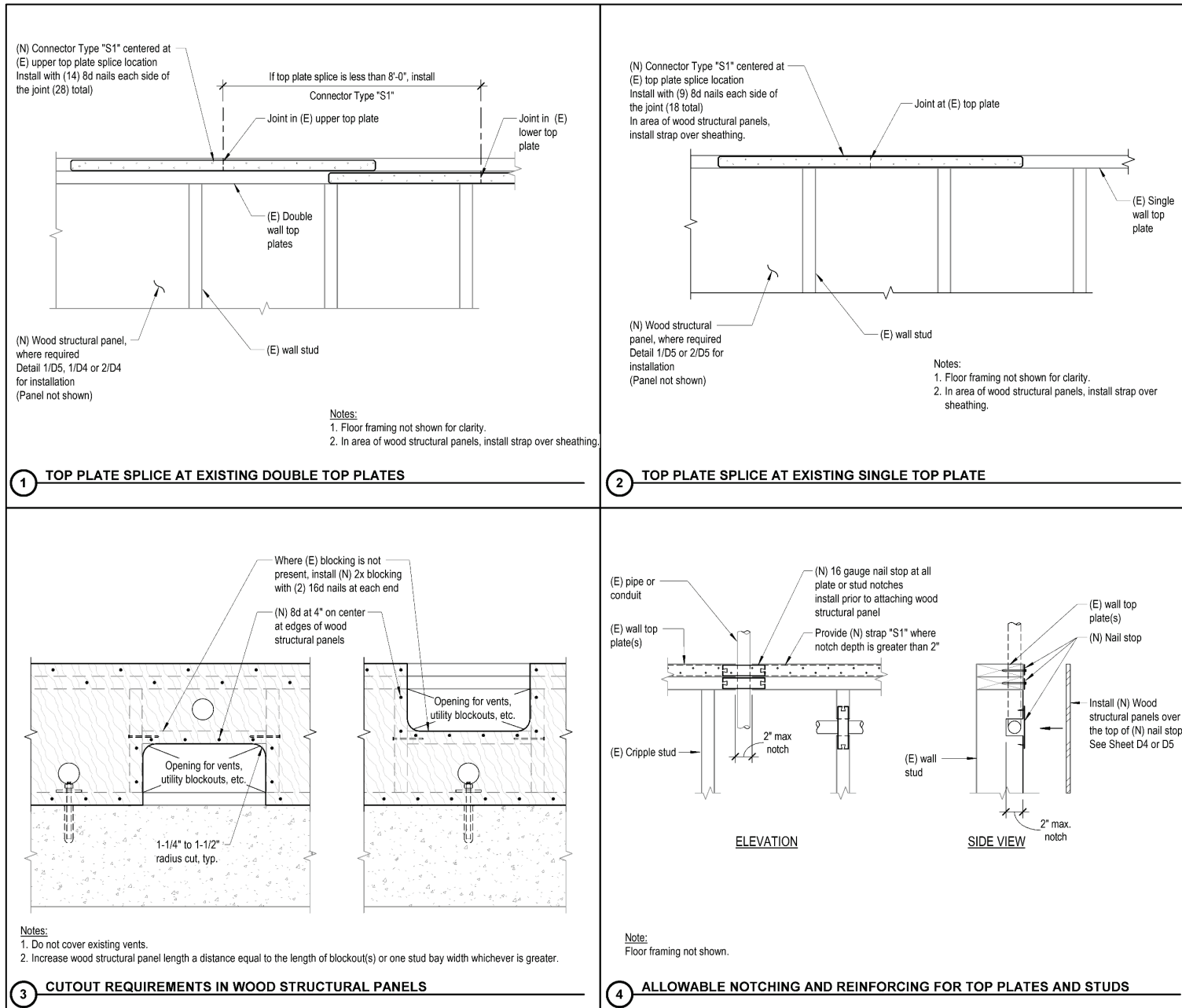


Figure 5.4-30 Venting at top plate details. Sheet D6.

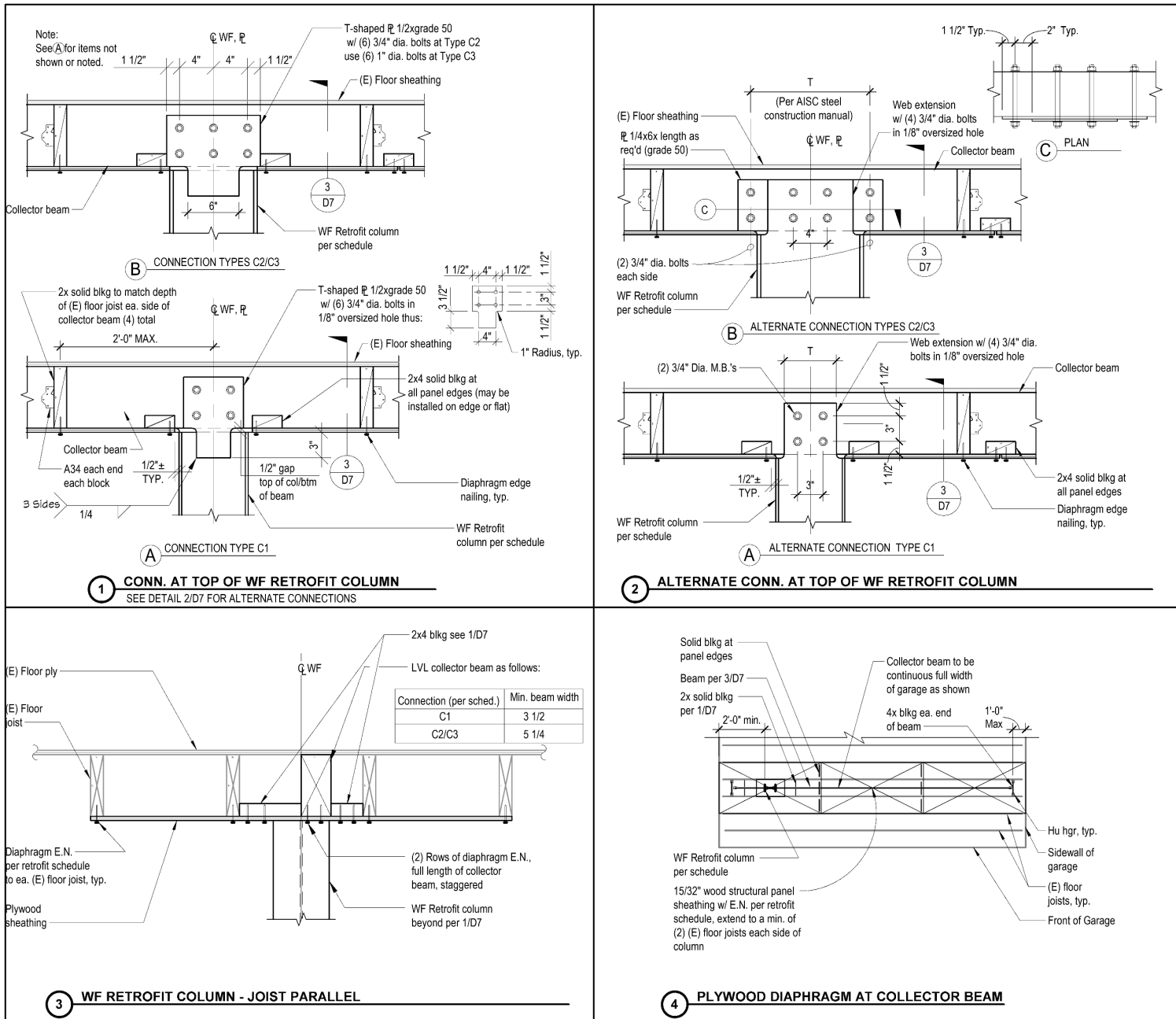


Figure 5.4-31 Details at steel column retrofits. Sheet D7.

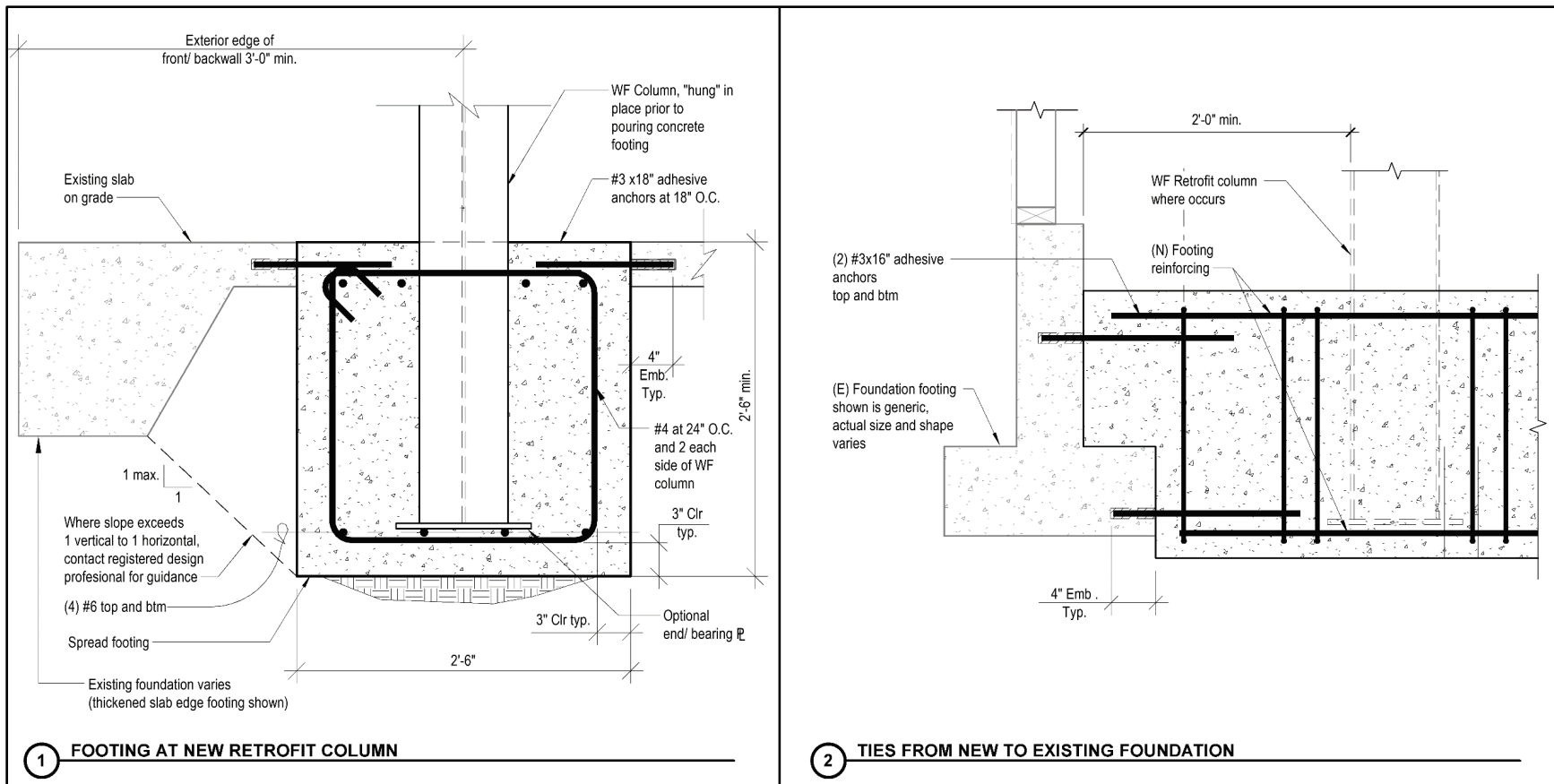


Figure 5.4-32 Foundation details at steel retrofit column. Sheet D7.1.

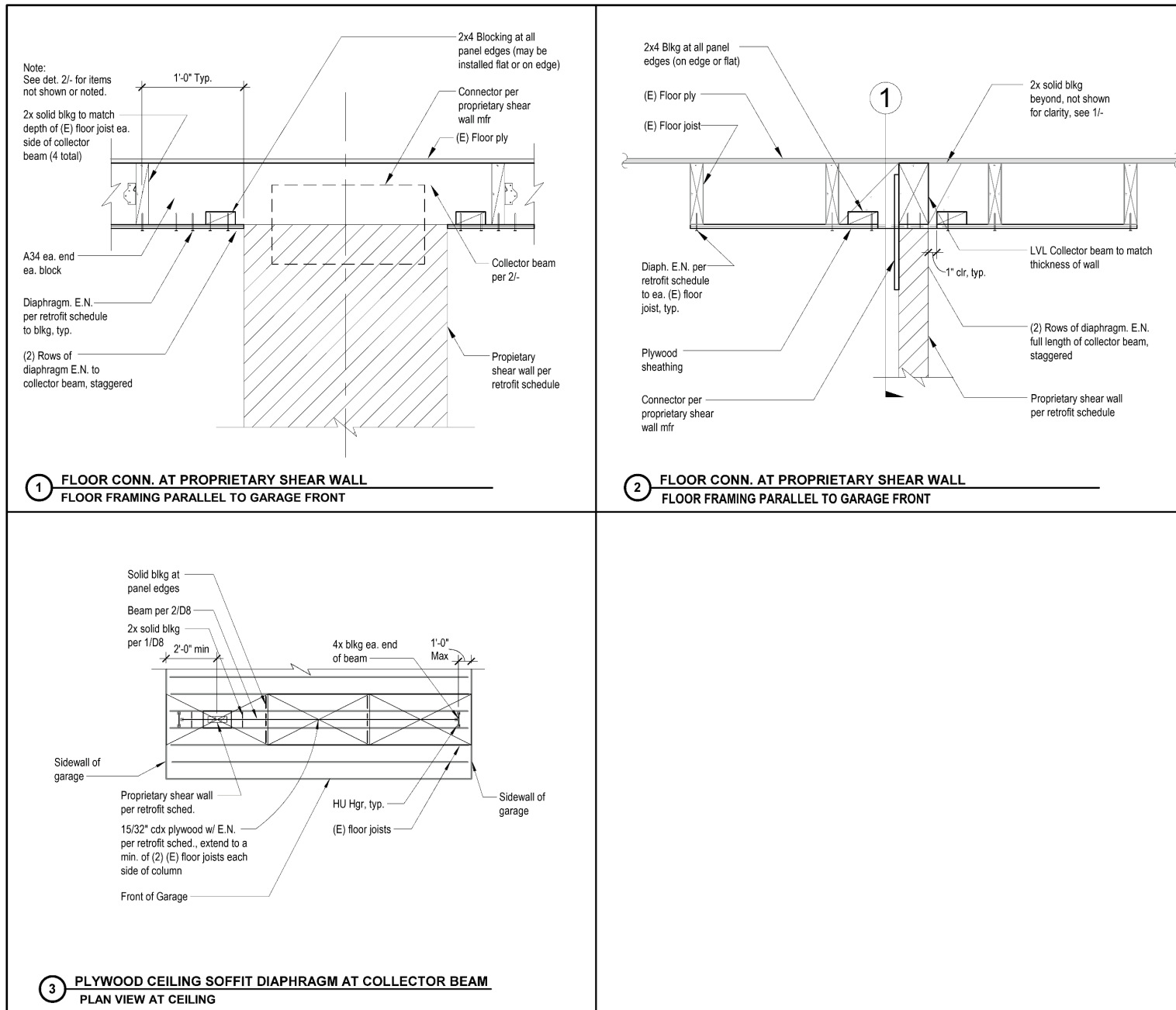


Figure 5.4-33 Details at propriety shear wall retrofits. Sheet D8.

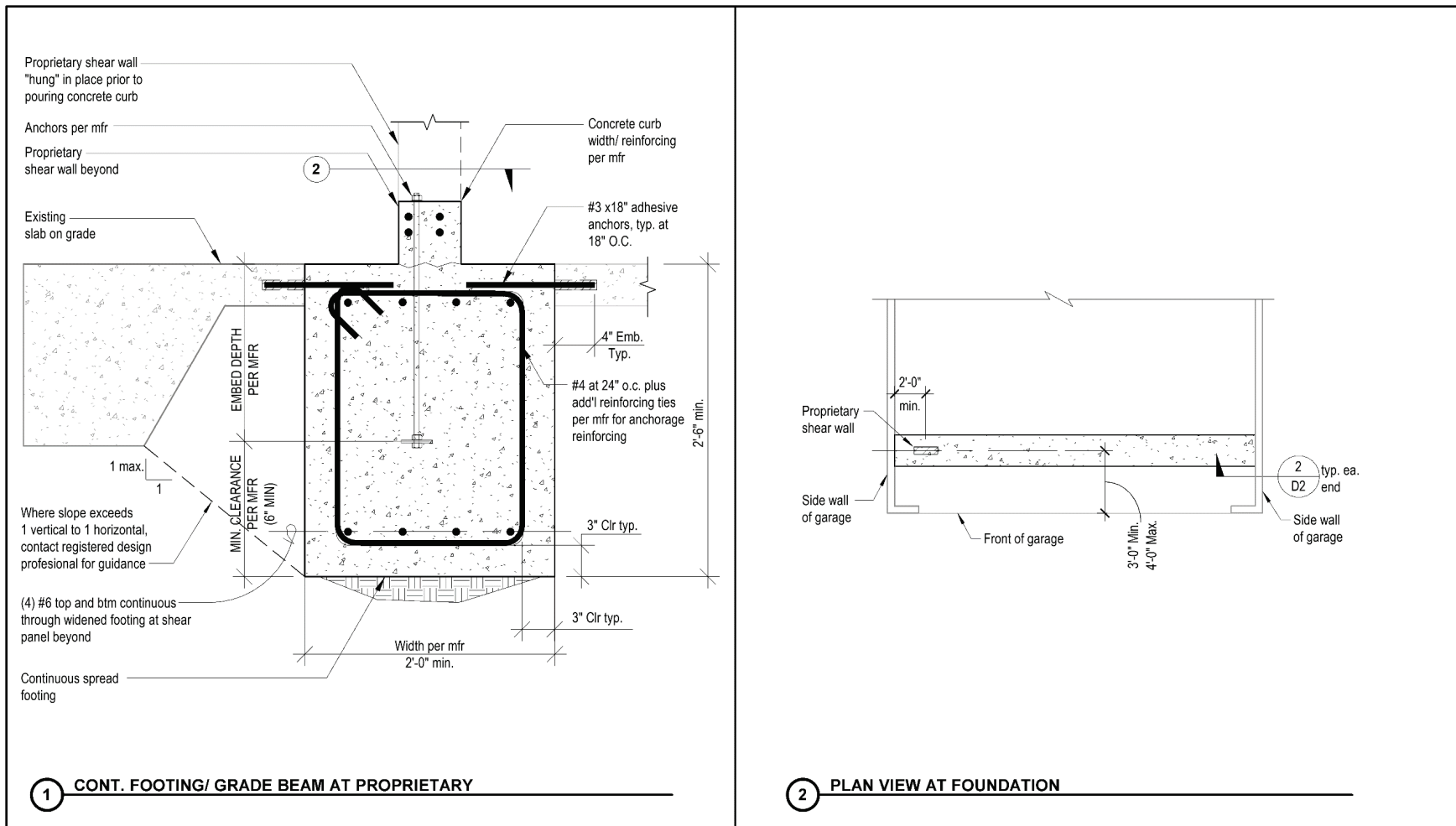


Figure 5.4-34 Foundation details at propriety shear wall retrofits. Sheet D8.1.

Chapter 6

Vulnerability-Based Assessment and Retrofit of Hillside Dwellings

6.1 General

This chapter contains provisions for vulnerability-based assessment and retrofit of *base-level diaphragm* anchorage and *crawlspace walls* in wood light-frame *hillside dwellings* (Figure 6.1-1).

Vulnerabilities addressed by this chapter are shown in Figure 6.1-2 and include:

- Anchorage of the base-level diaphragm to the *uphill foundation*
- Wood light-frame crawlspace walls between the base-level diaphragm and the foundation

The primary purpose of this chapter is the reduction of earthquake-induced damage to wood light-frame hillside dwellings. Not addressed by this chapter are potential site soil hazards. See Section 1.9 and non-mandatory Appendix S for further information.

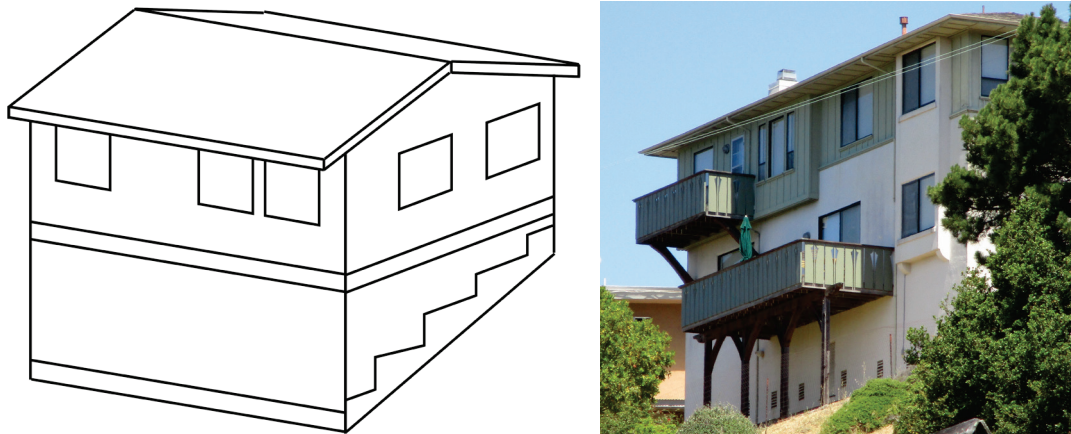


Figure 6.1-1 Hillside dwelling schematic isometric and photo.

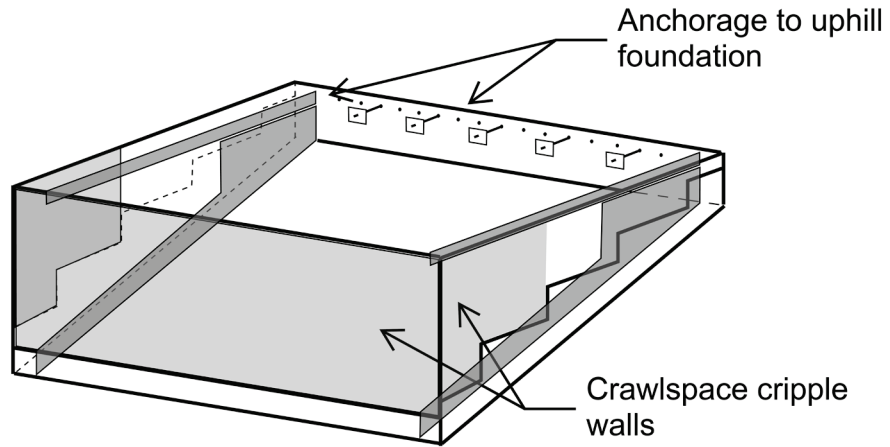


Figure 6.1-2 Hillside dwelling schematic isometric of dwelling crawlspace including anchorage to uphill foundation and crawlspace walls.

6.1.1 Use of this Chapter

In addition to the scope limits of Section 1.8, the dwelling shall comply with all of the eligibility criteria of Table 6.1-1. Where the dwelling is non-compliant with one or more of the eligibility criteria, assessment and retrofit in accordance with this chapter is not permitted.

6.1.2 Vulnerability-Based Assessment and Retrofit Methods

Assessment of dwellings shall be in accordance with Section 6.3. Where retrofit is required by Section 6.3, retrofit shall be in accordance with the simplified engineered vulnerability-based retrofit provisions of Section 6.5 or the general engineering retrofit provisions of Section 1.7. Prescriptive vulnerability-based retrofit provisions are not provided for hillside dwellings.

6.2 Definitions and Minimum Requirements

The definitions of Chapter 2 are applicable to all assessments and all retrofits designed in accordance with Chapter 6. The minimum requirements of Chapter 3 are applicable to all retrofits designed in accordance with Chapter 6.

Table 6.1-1 Eligibility Criteria for Use of Chapter 6

Eligibility Criteria		Compliant	Non-Compliant
1	The dwelling is a hillside dwelling, as defined in Chapter 2.		
2	The dwelling is a detached <i>one- or two-family dwelling</i> or the dwelling is a unit in a <i>townhouse</i> and assessment and retrofit will occur for each attached townhouse unit (the full <i>townhouse structure</i>).		

Table 6.1-1 Eligibility Criteria for Use of Chapter 6 (continued)

Eligibility Criteria	Compliant	Non-Compliant
3 The dwelling is two stories or less above the base-level diaphragm.		
4 The dwelling is of wood <i>light-frame construction</i> .		
5 Existing perimeter walls below the base-level diaphragm are of wood light-frame construction, or a combination of wood light-frame and concrete construction.		
6 Existing perimeter walls below the base-level diaphragm are supported on a continuous concrete foundation or will be retrofit to be supported on a continuous foundation. Continuous foundation includes continuous perimeter spread footing with stem wall, or continuous grade beams or tie-beams supported on pier or caisson foundations with or without continuous concrete piers.		
7 The clear height of the tallest crawlspace stud wall does not exceed 16 feet.		
8 The site slope as measured along the sides of the dwelling, starting from the highest uphill point to the lowest downhill point exceeds 1 to 5 (vertical to horizontal).		
9 The <i>base-level diaphragm</i> is of wood light-frame construction and is entirely in one plane without vertical offsets, such as a step in the floor or <i>split level</i> .		
10 The garage is detached from the dwelling.		
11 The exterior framed walls immediately above the uphill foundation sit directly above the uphill foundation for not less than 75% of the uphill foundation length.		
12 No masonry <i>chimney</i> is attached to the side of the dwelling, extends through the dwelling, or sits on any floor level of the dwelling.		

6.3 Vulnerability-Based Assessment

6.3.1 Scope

The assessment criteria of this section shall be used to determine whether existing diaphragm anchorage to the uphill foundation and existing framed *crawlspace walls* and their *load path connections* are in conformance with the requirements of this chapter. Where they are in compliance with the requirements of this chapter, retrofit is not required. Where they are found to not be in compliance with the requirements of this chapter, retrofit is required.

Assessment shall be in accordance with the detailed vulnerability-based assessment provisions of Section 6.3.2 and the engineered vulnerability-based assessment provisions of Section 6.3.3, or the general engineering assessment provisions of Section 1.7. Assessment using a simplified vulnerability-based assessment approach is not provided for hillside dwellings.

In lieu of assessment, the dwelling may be retrofit in accordance with the requirements of this chapter.

6.3.2 Detailed Assessment

This section provides detailed vulnerability-based assessment criteria for foundations and crawlspace walls in hillside dwellings. Anchorage to the uphill foundation is required to be assessed in accordance with the engineered vulnerability-based assessment method of Section 6.3.3.

Hillside dwelling crawlspace walls below the base-level diaphragm and their load path connections, shall be assessed in accordance with all of the following:

- Foundations shall be assessed in accordance with foundation detailed assessment methods of Section 8.1.
- Anchorage of framed crawlspace walls to the foundation shall be assessed in accordance with *foundation sill plate* anchorage to foundation detailed assessment method of Section 8.2.
- Crawlspace wall sheathing shall be assessed in accordance with *bracing wall* sheathing detailed assessment method of Section 8.3.

Retrofit shall be provided as required to address deficiencies identified by this section.

6.3.3 Engineered Assessment

Existing base-level diaphragm anchorage to the uphill foundation shall be assessed in accordance with this section. An evaluation by a *registered design professional* shall demonstrate that existing anchorage is in compliance with this prestandard, using the simplified engineered vulnerability-based retrofit design criteria of Section 6.5. Where the anchorage is found to be compliant with the provisions of Section 6.5, it shall be deemed in compliance with this chapter. Where the anchorage is not compliant, the anchorage shall be retrofit.

As an alternative to the detailed vulnerability-based assessment provisions of Section 6.3.2, the foundation and crawlspace walls and their load-path

connections shall be permitted to be assessed in accordance with this section. An evaluation by a registered design professional shall demonstrate that existing diaphragm and framed crawlspace walls, including their anchorage to the foundation and to floor framing above, are in compliance with this prestandard, using the simplified engineered vulnerability-based retrofit design criteria of Section 6.5. Where the crawlspace walls and load path connections are found to be compliant with the provisions of Section 6.5, it shall be deemed in compliance with this chapter. Where they are not compliant, the anchorage shall be retrofit.

6.4 Prescriptive Vulnerability-Based Retrofit

Use of a prescriptive vulnerability-based retrofit is not provided for hillside dwellings.

6.5 Simplified Engineered Vulnerability-Based Retrofit

6.5.1 Scope

This section provides simplified engineered vulnerability-based retrofit provisions for foundations, base-level diaphragm anchorage to the uphill foundation, and the framed crawlspace walls and their load path connections.

Dwellings identified by Section 6.3 to require foundation retrofit shall comply with Sections 6.5.2 and 6.5.3.

Dwellings identified by Section 6.3 to require retrofit of anchorage to the base-level diaphragm shall comply with Sections 6.5.2 and 6.5.4.

Dwellings identified by Section 6.3 to require retrofit of crawlspace wall bracing, crawlspace wall anchorage to the foundation, or crawlspace wall connection to the floor framing above shall comply with Sections 6.5.2 and 6.5.5.

6.5.2 General

Retrofit of hillside dwellings shall use seismic design forces as follows:

1. In accordance with Section 6.5 and, where specified, by ASCE/SEI 7, or the adopted building code.
2. The material design provisions of the adopted building code shall be used, except as modified by Section 6.5.

6.5.2.1 Seismic Base Shear for Foundation Retrofit

Where construction of a new foundation or retrofit of an existing foundation is required, the foundation design shall be in accordance with the following:

1. Loads and load combinations shall be in accordance with the adopted building code. The seismic response modification factor, R , shall be taken as 4.0. The foundation shall be designed for the effects of *primary anchor* forces and shear anchor forces as per Section 6.5.4, except that the R -factor for primary and shear anchor forces is permitted to be taken as 4.0 for design of the foundation and transmission of forces to supporting soils. The foundation need not be designed for the effects of *secondary anchor* forces.
2. Primary, secondary, and shear anchors and their anchorage to the foundation shall be in conformance with the requirements of Section 6.5.4.

6.5.2.2 Seismic Base Shear for Other Retrofits

The design seismic base shear for retrofit of base-level diaphragm anchorage to the uphill foundation and retrofit of crawlspace walls and their load path connections shall be determined in accordance with Equation 6.5-1, and shall be assumed to act on the system providing seismic bracing to the base-level diaphragm:

$$V = S_{DS}W / R \quad (6.5-1)$$

where:

S_{DS} = The short period design spectral response acceleration parameter determined in accordance with ASCE/SEI 7 Chapter 11

W = The effective seismic weight of the structure as defined in ASCE/SEI 7. The seismic weight shall include all dwelling weight from the base-level diaphragm and above, plus half of the weight of walls from the underside of the base-level diaphragm to the top of the foundations

R = The seismic response modification factor, as defined in Sections 6.5.4 through 6.5.5

Where seismic loads are acting in combination with other load types, the loads and load combinations shall be in accordance with the adopted building code. Use of seismic load combinations that include overstrength are not required when using the seismic design forces of this section. Overstrength factors required for design of anchorage to concrete shall be used.

6.5.3 Retrofit of Foundations

New foundations or retrofits of existing foundations shall be designed in accordance with the loads and forces specified in Section 6.5.2.1, the seismic

design provisions of ASCE/SEI 7, and the material design provisions of the adopted building code.

6.5.4 Retrofit of Base-Level Diaphragm Anchorage

The scope of retrofit for anchorage of the base-level diaphragm to the uphill foundation shall include primary anchors, secondary anchors, and shear anchors, as identified in Figure 6.5-1.

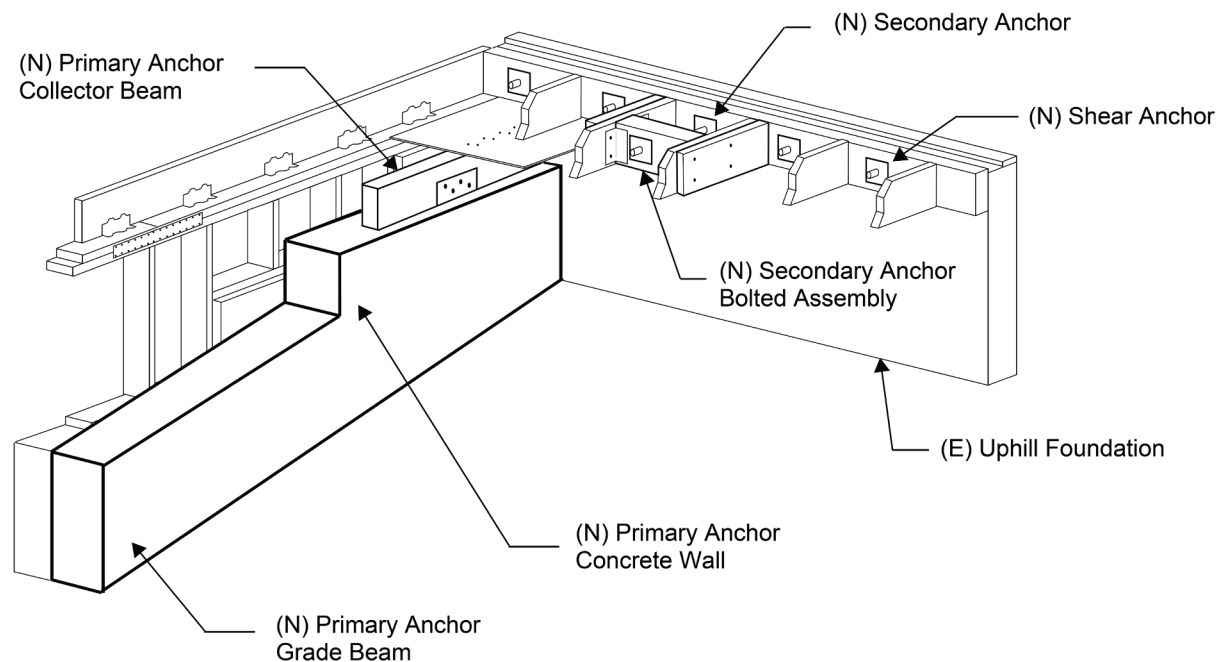


Figure 6.5-1 Interior uphill foundation corner isometric.

6.5.4.1 Design of Primary Anchors

Primary anchors shall be provided between the base-level diaphragm and the uphill foundation at each end of the dwelling uphill foundation. Additional primary anchors shall be provided at any location where a horizontal offset of four feet or more occurs in the uphill foundation between the foundation ends. Primary anchors, at locations referenced above, shall be located in line with existing walls in the story above, or as close thereto as possible.

The base shear, V , for design of primary anchors shall be determined in accordance with Equation 6.5-1, using a response modification factor, R , of 2.0. The primary anchors shall be designed to resist the entire base shear, V , for the most critical of the following three load conditions. Design of the primary anchors shall neglect the resistance provided by secondary anchors, crawlspace walls, and other existing lateral force resisting elements.

1. For *out-of-hill loading*, where two primary anchors are provided, each primary anchor at the ends of the uphill foundation shall be designed for

a seismic force of $V/2$. Where primary anchors are provided between the ends of the uphill foundation, each primary anchor shall be designed for a portion of V in accordance with the base-level diaphragm area tributary to the anchor

2. For *cross-slope loading*, the seismic base shear, V , shall be applied at the dwelling center of mass, with the base-level diaphragm treated as cantilevered from, and laterally supported only by, the uphill foundation. Each primary anchor, and its associated collector, shall be designed for the cantilever diaphragm chord force calculated at each end of the diaphragm as a result of the diaphragm cantilever.
3. In no case shall a primary anchor be designed to resist a seismic force of less than the larger of $V/4$ or 3 times the secondary anchor design force.

The primary anchor shall include a chord or collector element, extending the depth of the diaphragm at the anchor location and designed to resist applicable seismic forces.

The scope of retrofit for primary anchors shall include load path connections between the base-level diaphragm and the primary anchor chord or collector element, the design of the chord/collector element, and the anchorage of the chord/collector element to the uphill foundation.

The scope of retrofit need not include evaluation or strengthening of the base-level diaphragm, provided the primary anchor chord or collector element extends and is connected to the base-level diaphragm over the full depth of the diaphragm cantilever at the primary anchor location.

The scope of retrofit need not include evaluation or strengthening of the load path from the point of anchorage to the uphill foundation, into the supporting soils, provided that it can be demonstrated that the anchorage forces will engage the foundation system without causing a local (e.g., punching or shear) failure of the concrete foundation. Where retrofit element load paths impose overturning forces, the retrofit elements shall be capable of distributing the overturning to the existing foundation.

The scope of retrofit is permitted to include strengthening of existing foundations or new foundation elements for purposes of primary anchor load path.

Design capacities and detailing for all components shall be as specified in the adopted building code.

6.5.4.2 Design of Secondary Anchors

Secondary anchors shall be provided between the base-level diaphragm and uphill foundation, distributed along the length of the uphill foundation. Secondary anchors shall be provided at no more than four feet on center.

The base shear, V , for design of secondary anchors shall be determined in accordance with Equation 6.5-1, using a response modification factor, R , of 1.0. The secondary anchors shall be designed to collectively resist the entire base shear, V , for the out-of-hill force direction, neglecting the resistance provided by primary anchors, crawlspace walls, and other lateral force-resisting elements. Each secondary anchor shall be designed for a portion of the base shear, V , in accordance with the base-level diaphragm area tributary to the anchor.

The secondary anchor shall include a collector element, extending the depth of the diaphragm at the anchor location and designed to resist applicable seismic forces.

The scope of retrofit for secondary anchors shall include load path connections between the base-level diaphragm and the secondary anchor collector element, the design of the collector element, and the anchorage of the collector element to the uphill foundation.

The scope of retrofit need not include evaluation or strengthening of the base-level diaphragm, provided the secondary anchor collector element extends and is connected to the base-level diaphragm over the full depth of the diaphragm at the secondary anchor location.

The scope of retrofit need not include evaluation or strengthening of the load path beyond the anchorage to the uphill foundation.

Design capacities and detailing for all secondary anchor components shall be as specified in the adopted building code. Where the secondary anchor consists of a tie rod to the uphill foundation, its diameter shall not be less than that of the shear anchor.

6.5.4.3 Design of Shear Anchors

Shear anchors shall be provided between the base-level diaphragm and uphill foundation and shall be distributed along the length of the foundation. Shear anchorage to the foundation shall be spaced at not more than 32 inches on center.

The base shear, V , for design of shear anchors shall be determined in accordance with Equation 6.5-1, using a response modification factor, R , of

1.0. The shear anchors shall be designed to collectively resist the entire base shear, V , in the cross-slope force direction, neglecting the resistance provided by primary anchors, crawlspace walls, and other lateral resisting elements. Each shear anchor shall be designed for a portion of the base shear, V , in accordance with the base-level diaphragm area tributary to the anchor.

The scope of retrofit for shear anchors shall include load path connections between the base-level diaphragm framing and the uphill foundation.

The scope of retrofit need not include evaluation or strengthening of the base-level diaphragm in-plane shear capacity.

The scope of retrofit need not include evaluation or strengthening of the load path beyond the anchorage into the uphill foundation.

Design capacities and detailing for all components shall be as specified in the adopted building code. Where the shear anchor consists of a tie rod to the uphill foundation, its diameter shall not be less than that of the secondary anchor.

Anchors serving as secondary anchors are permitted to also serve as shear anchors provided that anchorage is designed considering both tension and shear forces occurring concurrently.

6.5.5 Retrofit of Perimeter-Framed Crawlspace Walls

The scope of seismic retrofit for crawlspace walls shall include full height concrete or masonry walls over 4'-0" tall and wood light-frame crawlspace walls. The framed crawlspace walls shall include perimeter walls at the sloping sidewalls, at the downhill wall, any interior crawlspace walls, and the crawlspace wall supported on the uphill foundation, where applicable. Retrofit shall include the wall strength, anchorage to the foundation, and connection to floor framing above.

The base shear, V , for design of crawlspace walls and their load path connections shall be determined in accordance with Equation 6.5-1, using a response modification factor, R , of 4.0. Where a crawlspace wall occurs between the base-level diaphragm and the top of the uphill foundation, this crawlspace wall shall be designed to resist the full calculated base shear, V , and resulting overturning moment, neglecting resistance provided by primary anchors, secondary anchors, and other crawlspace walls. All other crawlspace walls shall be designed to resist the portion of the base shear tributary to the crawlspace wall, neglecting the resistance provided by primary anchors, secondary anchors, and other lateral resisting elements. Use of wood light frame crawlspace walls within the interior of the

crawlspace resisting the portion of the base shear tributary to the crawlspace wall shall be permitted, but shall not be used to reduce the seismic loading to the crawlspace wall sitting on top of the uphill foundation. If interior concrete or masonry cross slope crawlspace walls are located downslope of the uphill foundation, their tributary area can be used to reduce the seismic loading to the uphill foundation shear anchorage, but shall not be used to reduce primary or secondary anchor seismic forces.

The scope of retrofit need not include evaluation or strengthening of the base-level diaphragm capacity.

The scope of retrofit need not include evaluation or strengthening of the load path beyond anchorage of the crawlspace wall top plates to the base-level diaphragm framing or the anchorage to the foundation, except as required for *proprietary shear walls*.

Design capacities and detailing shall be as specified in the adopted building code. All framed crawlspace walls shall be retrofit to be sheathed with wood structural panel shear walls. The deflection of the crawlspace wall line, as defined by ASCE/SEI 7 Equation 12.8-15 and using $C_d = 4$, shall not exceed an allowable wall line drift of $0.02h_{sx}$. Where sheathed wood structural panel shear walls are stepped along their line, distribution of forces shall be based upon the relative stiffness of each step, and h_{sx} shall be taken as the average at the wall heights at each end.

All crawlspace concrete or concrete masonry unit (CMU) walls taller than 4'-0" and connected directly to the base-level diaphragm floor framing shall be anchored to the existing diaphragm per ASCE/SEI 7 Section 12.14.7.5, Anchorage of Structural Walls. Where CMU or concrete *stem walls* occur in the same line as wood light-frame crawlspace walls, the wood light-frame crawlspace walls shall be designed to resist seismic forces based on tributary area, irrespective of relative stiffness.

The load path connections of crawlspace walls to the base-level diaphragm and foundation shall be designed using the seismic forces specified in this section for crawlspace walls, amplified by an overstrength factor, Ω_0 , of 1.5.

Crawlspace walls shall be designed for overturning forces using the seismic forces specified in this section for crawlspace walls.

Exception:

Overturning of perimeter crawlspace walls, other than crawlspace walls between the base-level diaphragm and uphill foundation, need not be calculated provided:

1. Not less than 80% of the stud or crawlspace wall length is sheathed full height.
2. Ventilation and access openings in otherwise sheathed walls are permitted to be neglected for purposes of determining percent sheathed, as long as the length of openings does not exceed 20% of the crawlspace wall's entire length
3. A tie-down is provided at each downhill corner and at the end of each full-height sheathed segment, with an ASD capacity not less than the larger of $(1.6 \times S_{DS})$ and 2.5 kips. Tie-down design need not include evaluation or strengthening of the load path beyond the anchorage into the foundation, except as required for proprietary shear walls.

When designing crawlspace walls for overturning, using the exception above, in lieu of a more detailed overturning analysis of the entire dwelling, each crawlspace wall line shall be permitted to be designed to resist the overturning moment generated in the crawlspace wall based on the average height of the wall or wall segment, plus 10 percent of the total overturning moment of the superstructure above, calculated in accordance with the provisions of ASCE/SEI 7 Section 12.8 or 12.14 and using $R = 4.0$.

When the crawlspace wall occurs between the base-level diaphragm and uphill foundation, the crawlspace wall line shall be designed to resist the overturning moment generated in the crawlspace wall based on the average height of the wall or wall segment, plus not less than 50 percent of the total overturning moment of the superstructure above, calculated in accordance with the provisions of ASCE/SEI 7 Section 12.8 or 12.4 and using $R = 4.0$.

First story shear walls above the base-level diaphragms and over the uphill foundations shall be retrofit with tie-downs extending down into the uphill foundations and for the smaller of the force level noted above or the overturning strength capacity of the existing first floor shear wall above. Shear walls above the base-level diaphragm, over the uphill foundation, are not required to be strengthened. Proprietary shear walls are permitted to be used as an alternative to wood structural panel crawlspace walls provided they comply with all of the following requirements:

1. The proprietary shear walls complying with the requirements of ICC--ES AC 436, FEMA P-795, or shall have been tested in accordance with ASTM D7989 in a manner and with documentation acceptable to the *building official*, or shall be an *approved* equal.
2. The proprietary shear walls are designed using the seismic forces specified in Section 6.5.5.

3. The design of the collector and collector connection to the base-level diaphragm, up to but not including connections provided by the manufacturer, use the seismic forces of this section amplified by an overstrength factor, Ω_0 , of 1.5.
4. The design of the foundation, up to, but not including anchorage provided by the manufacturer, use the seismic forces of this section amplified by an overstrength factor, Ω_0 , of 1.5.
5. The proprietary shear wall demand to capacity ratio for wall shear strength does not exceed 1.5.
6. If multiple proprietary walls are used in a wall line, the seismic forces shall be distributed between them in accordance with their relative stiffness.

New foundations, where provided for proprietary walls, shall conform to Section 6.5.3.

Chapter 7

Vulnerability-Based Assessment and Retrofit of Masonry Chimneys and Fireplace Surrounds

7.1 General

This chapter contains provisions for the assessment and seismic retrofit of existing brick *masonry chimneys* and *masonry fireplace surrounds* in wood light-frame dwellings. Prior to selecting a retrofit, the *building official* shall be consulted to identify local ordinances that might regulate wood burning and wood burning appliances.

The primary purpose of this chapter is the reduction of earthquake-induced falling hazards associated with masonry chimneys and masonry fireplace surrounds.

7.1.1 Use of this Chapter

In addition to the scope limits of Section 1.8, the provisions of this chapter are limited to masonry chimneys and masonry fireplace surrounds in one- and two-family, wood light-frame dwellings of three stories or less.

Considerations and methods beyond those discussed in the chapter may be appropriate for dwellings listed in, or eligible for listing in, the National Register of Historic Places, or designated as historic under state or local law.

7.1.2 Vulnerability-Based Assessment and Retrofit Methods

Assessment of masonry chimneys for compliance with this chapter shall be in accordance with Section 7.3. Where retrofit is required by Section 7.3.1, retrofit shall be in accordance with Section 7.1.3 or Section 7.1.4.

Assessment of masonry fireplace surrounds for compliance with this chapter shall be in accordance with Section 7.3. Where retrofit is required by Section 7.3, retrofit shall be in accordance with Section 7.5.

7.1.3 Prescriptive Retrofit of Masonry Chimneys

Chimneys compliant with all of the eligibility criteria of Table 7.1-1 shall be permitted to use the prescriptive retrofit provisions of Section 7.4.

Table 7.1-1 Eligibility Criteria for Use of Prescriptive Chimney Retrofit Provisions (Section 7.4)

Eligibility Criteria		Compliant	Non-Compliant
1	The dwelling is a detached <i>one- or two-family dwelling</i> or the dwelling is a unit in a <i>townhouse</i> .		
2	The dwelling is a wood light-frame dwelling that is three stories or less above grade plane.		
3	The chimney is constructed of solid brick masonry.		
4	The chimney's largest plan dimension is not more than 40 inches.		
5	The chimney is either an <i>interior chimney</i> , or an <i>exterior chimney</i> engaging only one exterior wall (i.e. not at the dwelling corner).		

7.1.4 Engineered Retrofit of Masonry Chimneys

Where the prescriptive retrofit provisions of Section 7.1.3 are not used, an engineered retrofit shall be provided in accordance with Section 7.6.

7.2 Definitions and Minimum Requirements

The definitions of Chapter 2 are applicable to all assessments and to all retrofits designed in accordance with this chapter. The minimum requirements of Chapter 3 are applicable to all retrofits designed in accordance with this chapter.

7.3 Vulnerability-Based Assessment

7.3.1 Scope

The assessment criteria of this section shall be used to determine whether the masonry chimney and the masonry fireplace surround comply with the requirements of this chapter. Where they are in compliance with the requirements of this chapter, retrofit is not required. Where they are found to not be in compliance with the requirements of this chapter, retrofit is required.

7.3.2 Simplified Assessment of Chimneys

Chimneys shall be assessed in accordance with Item 1 or 2 of Table 7.3-1.

Existing chimney elements and members to which these elements are directly attached, shall be assessed to identify incomplete or inadequate installation, damage, and deterioration that might significantly affect seismic

performance. Where this assessment identifies incomplete or inadequate installation, damage or deterioration, the elements shall be deemed not adequate for use. For these conditions, the applicable assessment statement within Table 7.3-1 shall be determined to be false and the indicated compliance step taken.

Table 7.3-1 Simplified Structural Assessment for Masonry Chimneys

Item	Assessment Statement	Compliance Step if True	Compliance Step if False	Compliance step if Unknown
1	Interior brick masonry chimneys of single-story dwellings that extend no more than twice the least plan dimension of the chimney above the roof, have no portion more than 6 feet tall that is not enclosed by full-height, finished walls on at least three faces, and whose greatest plan dimension does not exceed 40 inches.	Retrofit of chimney is not required.	Provide detailed assessment or retrofit of chimney.	Provide detailed assessment or retrofit of chimney.
2	Chimneys constructed on or after January 1, 1995.	Retrofit of chimney is not required.	Provide detailed assessment or retrofit of chimney.	Provide detailed assessment or retrofit of chimney.

7.3.3 Detailed Assessment of Chimneys

Chimneys constructed prior to 1995 shall be deemed to comply with the requirements of this chapter without retrofit if a licensed contractor or *registered design professional* verifies that all the following conditions are met:

1. Mortar is Portland cement based, fully intact, and exhibits no more than minor cracking.
2. Masonry units are fully intact and exhibit no more than minor cracking.
3. Reinforcing consists of at least four 1/2-inch diameter continuous vertical bars set in fully grouted interior spaces between wythes of *solid masonry* and/or *flue* liner. Vertical reinforcing is tied at spacing not greater than 24 inches with 1/4-inch diameter ties.
4. The chimney is attached to the structural framing at all floor and roof diaphragms more than 6 feet above grade with a minimum of two anchor straps. Each *anchor strap* is of steel with a minimum cross section area of 0.1875 square inches and secured to the chimney reinforcement. Each anchor is fastened to the structural framing with at least six 16d common nails, and framing members are properly detailed to support the strap loads.
5. The chimney does not extend vertically more than 6 feet above the lowest adjacent roof surface and whose greatest plan dimension does not exceed 40 inches.

7.3.4 Simplified Assessment of Masonry Fireplace Surrounds

Masonry fireplace surrounds shall be assessed in accordance with Item 1 or 2 of Table 7.3-2.

Existing fireplace surround elements and members to which these elements are directly attached shall be assessed to identify incomplete or inadequate installation, damage, and deterioration that might significantly affect seismic performance. Where this assessment identifies incomplete or inadequate installation, damage, or deterioration, the elements shall be deemed not adequate for use. For these conditions, the applicable assessment statement within Table 7.3-2 shall be determined to be false and the indicated compliance step taken.

Table 7.3-2 Simplified Structural Assessment for Masonry Fireplace Surrounds

Item	Assessment Statement	Compliance Step if True	Compliance Step if False	Compliance step if Unknown
1	Masonry surrounds that extend vertically less than 4 feet above the finished floor or horizontally less than 3 feet from the edge of the <i>firebox</i> , OR	Retrofit of masonry surround is not required.	Provide detailed assessment or retrofit of masonry surround.	Provide detailed assessment or retrofit of masonry surround.
2	Masonry surrounds constructed on or after January 1, 1995.	Retrofit of masonry surround is not required.	Provide detailed assessment or retrofit of masonry surround.	Provide detailed assessment or retrofit of masonry surround.

7.3.5 Detailed Assessment of Masonry Fireplace Surrounds

Surrounds constructed prior to 1995 shall be deemed to comply with the requirements of this chapter without retrofit if a licensed contractor or registered design professional verifies that one of the following conditions are met:

1. *Anchored masonry fireplace surrounds* constructed prior to 1995 for which a licensed contractor or registered design professional verifies that all the following conditions are met:
 - a. Mortar is Portland cement based, fully intact, and exhibit only minor cracking.
 - b. Masonry units are fully intact, exhibit only minor cracking, and do not exceed 5 inch thickness.
 - c. Tie attachments support no more than two square feet of surround area.
 - d. Tie attachments to wood are, at minimum, 22-gage (0.0299-inch thick) and 7/8-inch wide corrugated sheet metal, or a 9-gage strand

wire with a hook embedded in the mortar joint, fastened to the wood framing with at least one 8d ring shank nail. Tie attachments to steel studs are minimum 9-gage strand wire with a hook embedded in the mortar joint, fastened with at least one No. 10 screw through the framing a minimum of three exposed threads.

- e. Wood or steel studs, including attachments to top and bottom plates, are designed to support the imposed loads.
2. *Adhered masonry fireplace surrounds* constructed prior to 1995 for which a licensed contractor or registered design professional verifies that all the following conditions are met:
- a. Mortar is Portland cement based, fully intact, and exhibit only minor cracking.
 - b. Each masonry veneer unit does not exceed 2-5/8 inches thickness, 36 inches length in either direction, or 5 square feet of wall surface area coverage (per unit).
 - c. The masonry wall covering weight does not exceed 15 pounds per square foot.
 - d. Veneer is adhered to continuous backing with a minimum shear strength of 50 pounds per square inch in accordance with ASTM C482.

7.4 Chimney Prescriptive Retrofit

This section provides seismic retrofit provisions for existing masonry chimneys.

Prior to retrofit any other flue(s) discharging products of combustion through the main chimney flue shall be first re-routed per the currently adopted building or residential code.

7.4.1 Scope

Existing masonry chimneys shall be retrofit in accordance with this section.

- 1. Exterior chimneys of dwellings of any height shall be demolished down to the base of the chimney at the lowest firebox.
- 2. Interior chimneys of dwellings of two or more stories shall be demolished down to the base of the chimney at the lowest firebox.
- 3. Interior chimneys having some portion more than 6 feet long not enclosed by full-height, finished walls on at least three faces, such as chimneys extending through a tall, unfinished *attic* space, shall be

demolished down to the floor or ceiling immediately below the unenclosed portion.

4. Interior chimneys that extend more than twice the least plan dimension above the roof, and are not subject to the requirements of Item 3, shall be demolished down to the roof.
5. Chimneys demolished down to a roof, floor, or ceiling level shall be capped per Section 7.4.2.
6. Chimneys demolished down to the base shall be capped similar to Section 7.4.2 or rebuilt per Section 7.4.3 or Section 7.4.4.
7. Chimney demolished down to and including the foundation shall be permitted to be reconstructed in accordance with the adopted building or residential code, where permitted by the local jurisdiction.

7.4.2 Capping of Chimney at Roof, Floor, or Ceiling Level

This section provides prescriptive methods for partial removal and capping of masonry chimneys at the firebox, roof, or ceiling level.

7.4.2.1 Chimney Partial Removal and Capping

Chimneys demolished to the roof shall be removed to the top of the course of masonry just above the highest existing roof flashing, but not less than 7 inches, leaving the upper course undisturbed. A sheet metal *chimney cap* of galvanized steel or stainless steel shall be provided as shown in Figure 7.4-1. The cap shall extend not less than 3 inches down each side of the chimney, overlapping any existing flashing by at least 2 inches where it occurs. The cap shall be secured to the chimney with corrosion-resistant fasteners. New fasteners shall not penetrate existing flashing.

Chimneys demolished to a floor or ceiling level shall be removed to a distance of not more than 8 inches above the top of ceiling or floor framing. The chimney shall be capped with sheet metal as shown in Figure 7.4-2. The roof opening should be closed and weatherproofed using framing and roofing materials to match the existing construction.

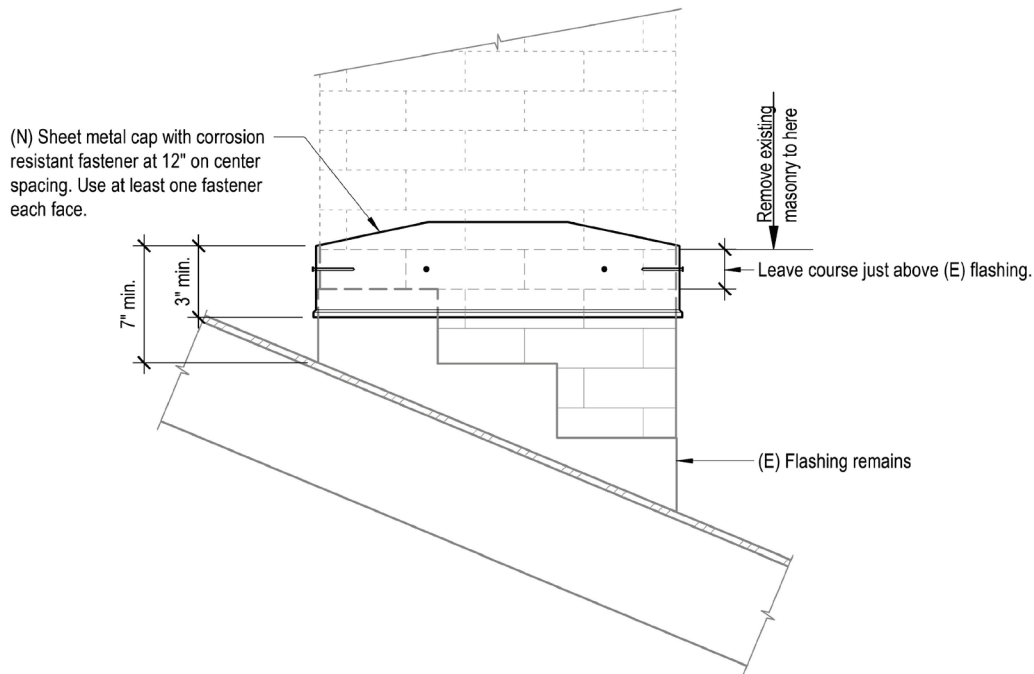


Figure 7.4-1 Capping of chimney removed to roof level (similar to chimney removed to top of firebox).

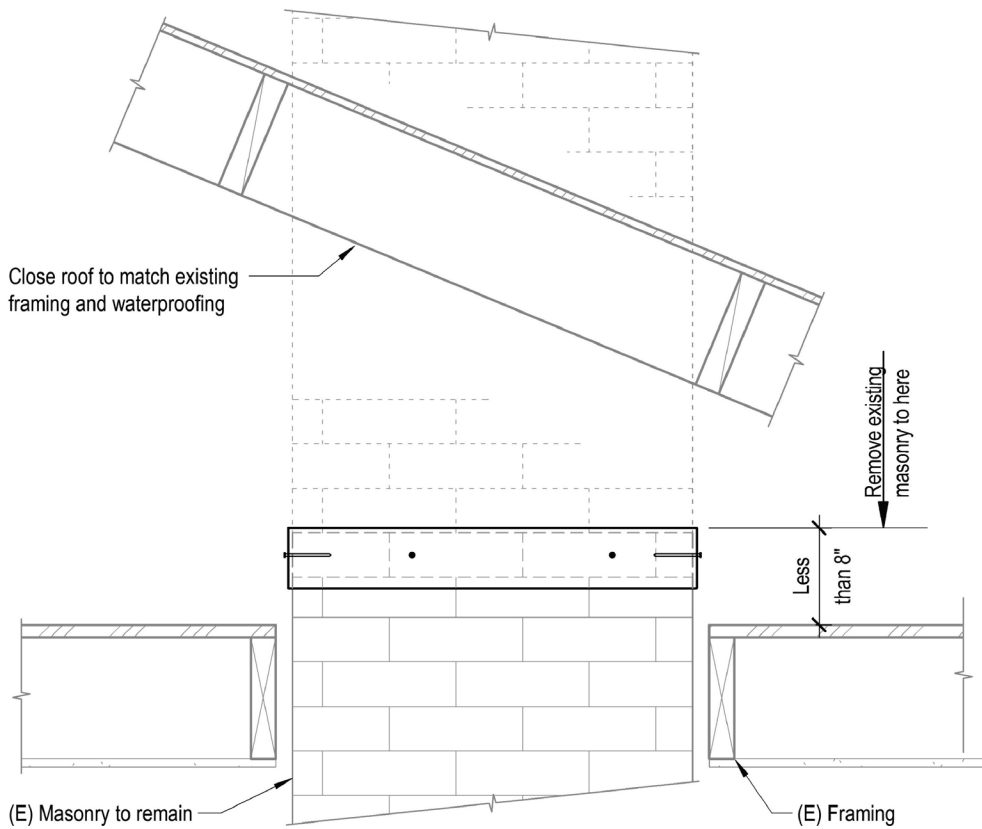


Figure 7.4-2 Capping of chimney removed to floor level (similar to chimney removed to ceiling level).

7.4.2.2 Interior of the Firebox

Access to the interior of the firebox shall be completely closed off from the dwelling interior with an infill of gypsum wallboard, wood structural panel sheathing, or masonry that is permanently affixed to the existing firebox or surrounding framing.

7.4.3 Reconstruction from the Chimney Base

This section provides prescriptive methods for removal of the masonry chimney to its base, and reconstruction using a *factory-built chimney* enclosed in a framed chimney chase.

7.4.3.1 Chimney Partial Removal

The chimney shall be removed down to its base as shown in Figure 7.4-3.

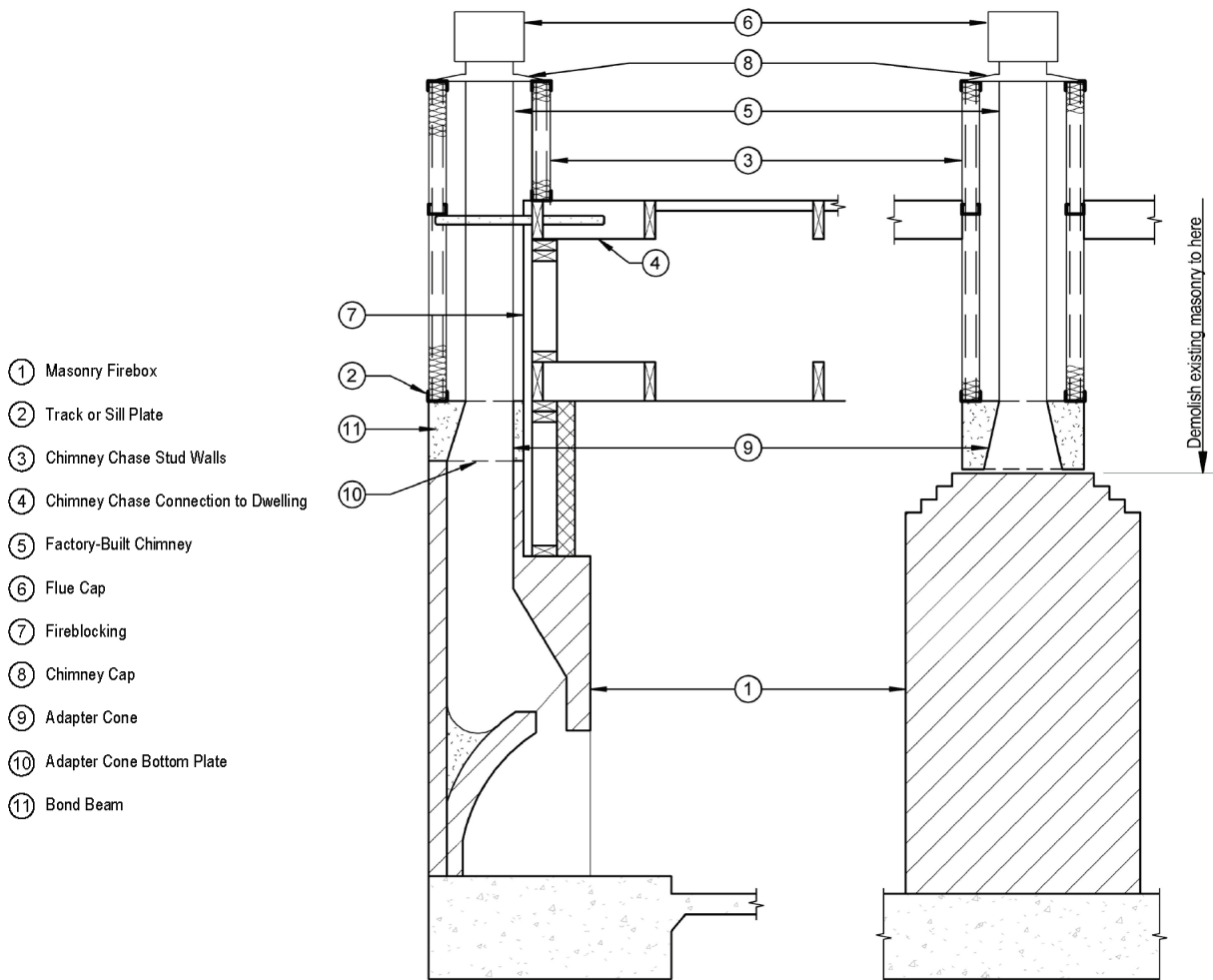


Figure 7.4-3 Components of a masonry firebox in combination with light-factory-built chimney and light-framed chimney chase.

7.4.3.2 Reconstruction

Reconstruction shall be in accordance with the factory-built chimney manufacturer's installation instructions, the requirements of this section, and Figure 7.4-3. All clearances required by the manufacturer and listing shall be maintained. The reconstruction shall incorporate a UL 103-listed, factory-built chimney with a masonry fireplace adapter, tested per UL 103A and listed for use with the specific factory-built chimney.

1. **Masonry firebox.** The existing masonry firebox shall remain up to the base of the flue as shown in Figure 7.4-3.
2. **Track or sill plate.** Cold-formed steel track sections matching the thickness of the studs shall be provided at the bottom of cold-formed steel chimney chase walls. Wood sill or sole plates having a width not less than the supported studs shall be provided at the bottom of wood chimney chase walls. Wood sill or sole plates shall be protected against decay by the use of *naturally durable wood* or wood that is *preservative treated*. Fasteners in contact with wood sill or sole plates shall be of hot-dipped, zinc-coated galvanized steel or of stainless steel. Tracks and sill or sole plates shall be anchored to the concrete beam per Figure 7.4-4.

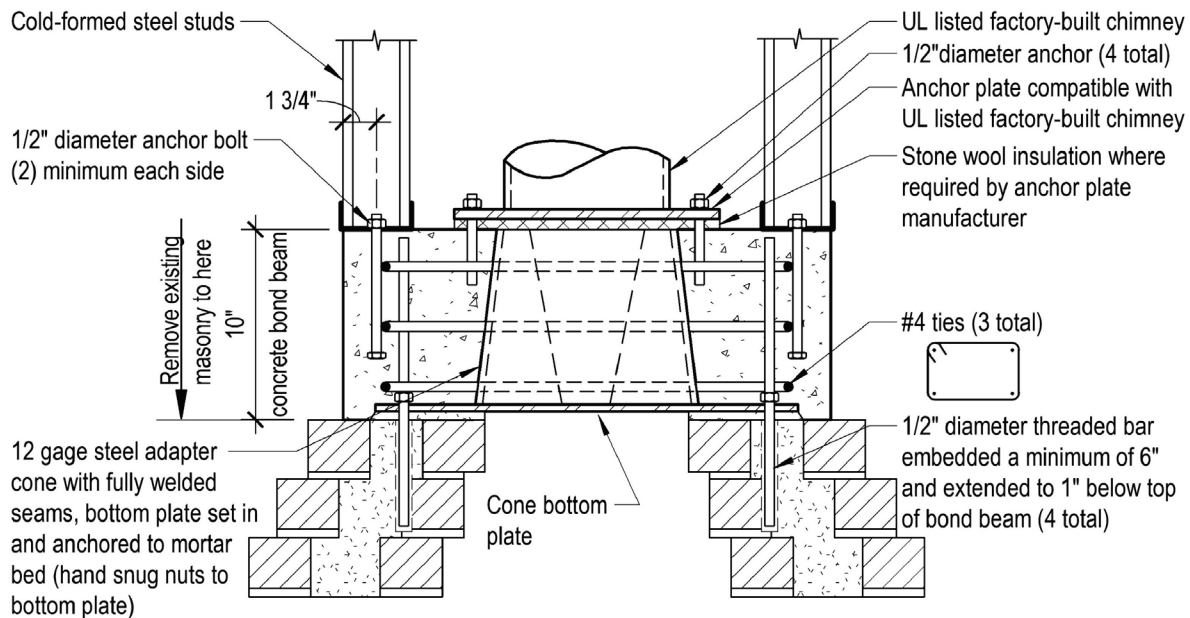


Figure 7.4-4 Transition between factory-built chimney and masonry fireplace.

3. **Chimney chase stud walls.** Chimney chases shall be constructed of full height studs spaced at no more than 12 inches on center. Stud sizes shall be selected based on story-to-story height. Wood studs shall not be less than nominal two-inch by three-inch. Cold-formed steel studs shall be not less than 43 mil thickness (18 gage) by 2-1/2 inches deep. The top of

the chimney chase shall extend not less than 3 feet above the edge of the roof and not less than 2 feet above the maximum roof elevation, or maximum elevation of other construction located within a 10-foot horizontal dimension in any direction from the chimney (Figure 7.4-5). Where the exterior walls adjacent to the chase are less than 5 feet from the lot line, they shall be constructed with full 2×4 wood or 54 mil (16 gage) 3 5/8-inch steel studs with exterior sheathing that includes 7/8-inch thick conventional stucco or minimum 1/2-inch thick Type X gypsum sheathing. Additional fire protection requirements in the currently adopted building or residential code should be confirmed with the building official. The chimney chase shall be capped, with roofing and flashing to be weatherproof and to match existing construction.

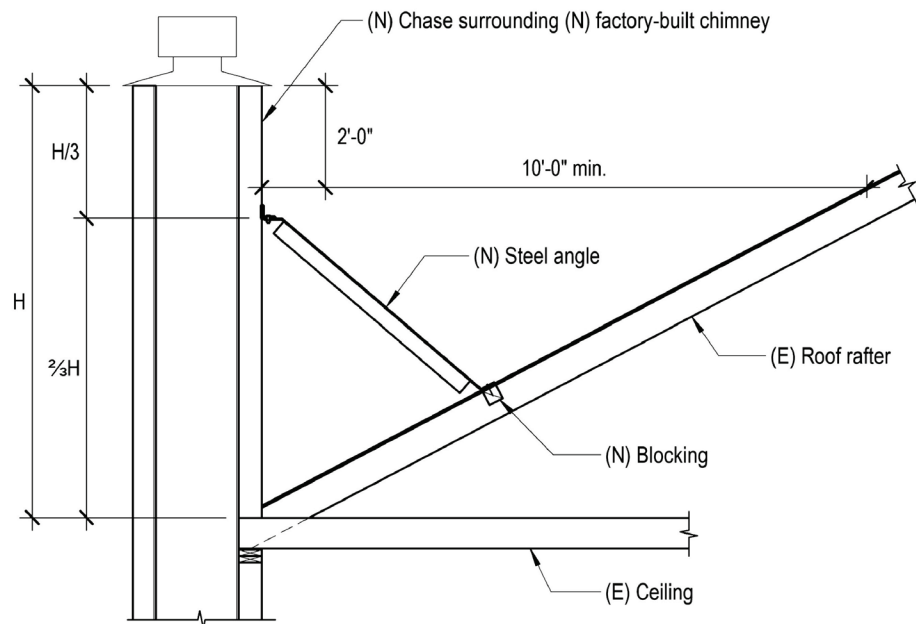


Figure 7.4-5 Brace for new chase, where H exceeds 4 feet.

4. **Chimney chase connection to dwelling.** The chimney chase studs shall be fastened to the existing residence exterior wall with minimum No. 8 wood screws at 12 inches on center. The chimney chase framing shall be strapped to the existing floor, ceiling, and roof framing with not less than two steel straps 1-1/4 inches minimum in width and 33 mil (20 gage) minimum in thickness, with each strap located on an opposing face of the chase. Each strap shall be fastened to steel blocking between steel studs of the chimney chase with minimum four No. 8 sheet metal screws, or to wood blocking between wood studs of the chimney chase with not less than four 8d common nails. Each strap shall be fastened to existing steel floor, roof, or ceiling framing with minimum four No. 8 sheet steel screws, or to existing wood floor, ceiling or roof framing with minimum

four 8d common nails. Where chimney chase stud walls extend more than 4 feet above the highest roof elevation immediately adjacent to the chimney, bracing shall be provided in accordance with this section or in a manner acceptable to the building official. The bracing shall be connected to the chimney chase in the upper third of the chase clear height above the roof ($H/3$ as shown in Figure 7.4-5). Bracing steel angles shall be galvanized or otherwise corrosion resistant and not less than $2\text{-}1/2 \times 2\text{-}1/2 \times 1/4$ -inch installed per Figure 7.4-6. Not less than two braces shall be provided. The bracing slope shall be not less than 30 degrees and not more than 60 degrees from vertical.

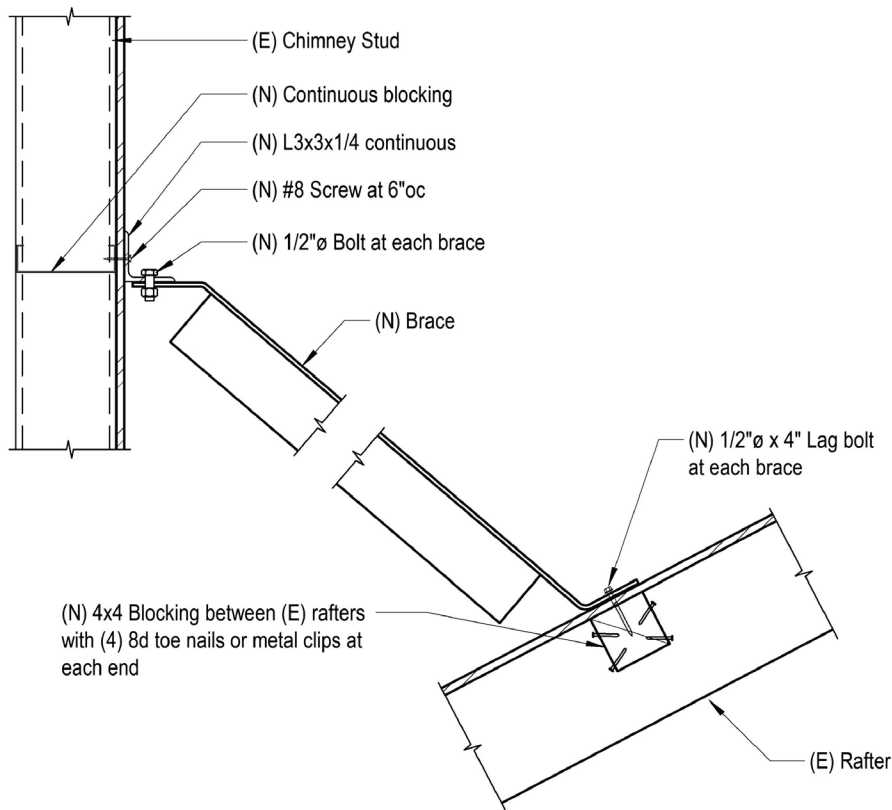


Figure 7.4-6 Brace connection for new chase.

5. **Factory-built chimney.** Factory-built chimneys shall be sized such that round chimney flues shall have a minimum net cross-sectional area of not less than $1/12$ of the fireplace opening. Square chimney flues shall have a minimum net cross-sectional area of $1/10$ of the fireplace opening. Rectangular chimney flues with an aspect ratio less than 2 to 1 shall have a minimum net cross-sectional area of $1/10$ of the fireplace opening. Rectangular chimney flues with an aspect ratio of 2 to 1 or more shall have a minimum net cross-sectional area of $1/8$ of the fireplace opening. Factory-built chimneys shall be listed and *labeled* and shall be installed and terminated in accordance with the manufacturer's instructions.

Decorative shrouds shall not be installed at the termination of factory-built chimneys except where the shrouds are listed and labeled for use with the specific factory-built chimney system and installed in accordance with the manufacturer's instructions. No part of the chimney shall be at an angle of more than 30 degrees (0.52 rad) from vertical at any point in the assembly and the chimney assembly shall not include more than four elbows.

6. **Flue cap.** Factory-built cap installed in accordance with manufacturer's instructions and complying with the metal chimney UL listing.
7. **Fireblocking.** Spaces between chimneys and floors and ceilings through which chimneys pass shall be fireblocked with noncombustible material securely fastened in place. The fireblocking of spaces between chimneys and wood joists, beams or headers shall be self-supporting or be placed on strips of metal or metal lath laid across the spaces between combustible material and the chimney. Draft stops consisting of drywall, plywood, or OSB shall be provided to separate the chase from wood framing of the dwelling.
8. **Chimney cap.** A framed chimney cap shall be constructed at the top of the chimney chase.

7.4.3.3 Chimney Transition

The transition to the factory-built chimney and chimney chase shall be in accordance with the factory-built chimney manufacturer's installation instructions, the following requirements, and Figure 7.4-4.

1. **Adapter cone.** A 12 gage (97 mil) minimum thickness galvanized sheet steel adapter cone shall be provided. The cone shall have minimum 12 gage (97 mil) thickness sheet steel top and bottom plates, and shall provide a smooth-surfaced transition between the flue opening from the top of the firebox and into the flue. The bottom plate geometry shall match the masonry opening, and the anchor plate geometry shall be coordinated with the flue. The adapter cone shall be set in cementitious grout, and all cone seams shall be continuously welded.
2. **Cone bottom plate.** The adapter cone bottom plate shall be anchored to the masonry with not less than four 1/2-inch diameter galvanized threaded rod anchors. The threaded rods shall extend upward to 1 inch below the top of the concrete beam, shall be embedded 6 inches into masonry and shall be set in cementitious mortar.
3. **Bond beam.** A reinforced concrete beam shall be constructed around the adapter cone, using the cone as the inside form. A minimum 1-1/2 inch

cover shall be maintained between the reinforcing steel and the outside face of concrete.

7.4.4 Reconstruction from Chimney Base using a Factory-Built Fireplace Insert

This section provides prescriptive methods for partial removal of the masonry chimney and reconstruction using a *factory-built fireplace insert* with a factory-built chimney enclosed in a light-framed chimney chase.

7.4.4.1 Chimney Partial Removal

The chimney shall be removed down to its base as shown in Figure 7.4-7.

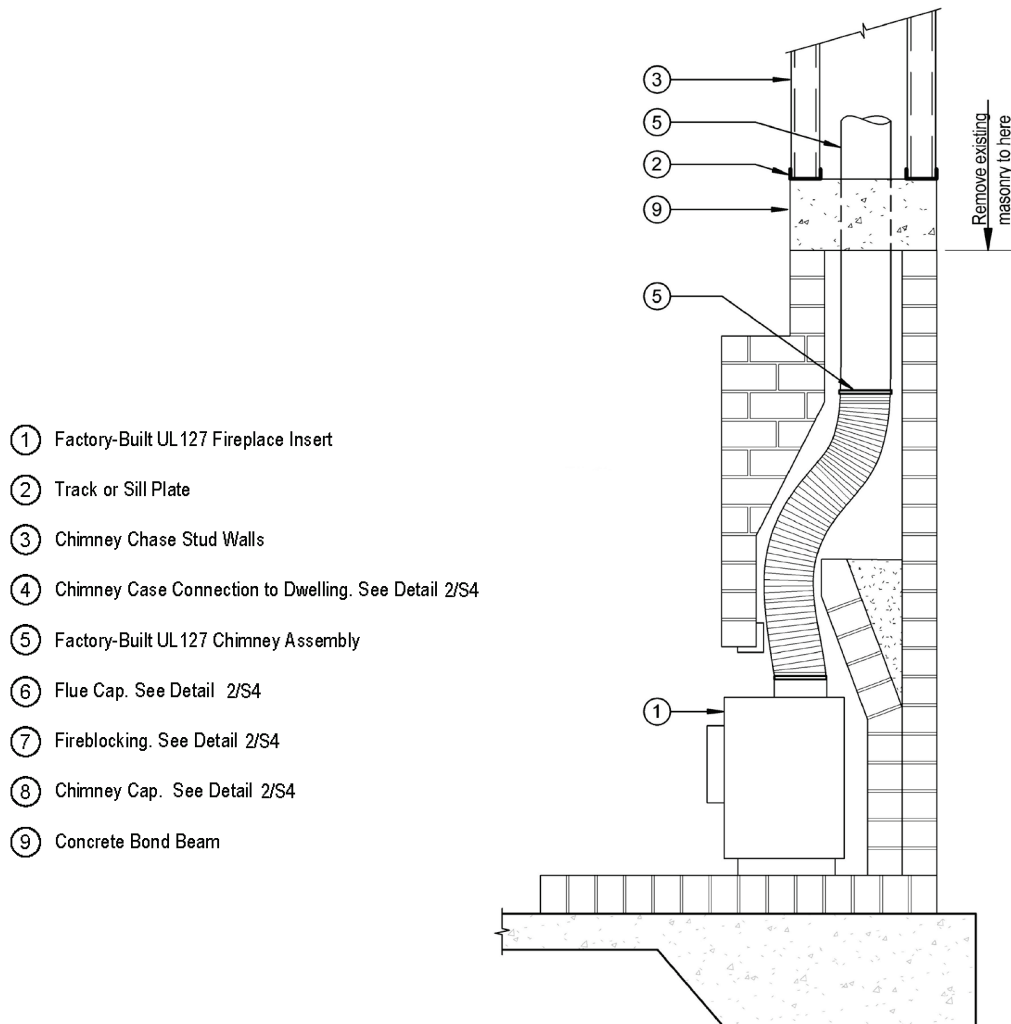


Figure 7.4-7 Transition to chimney where factory-built fireplace insert is used.

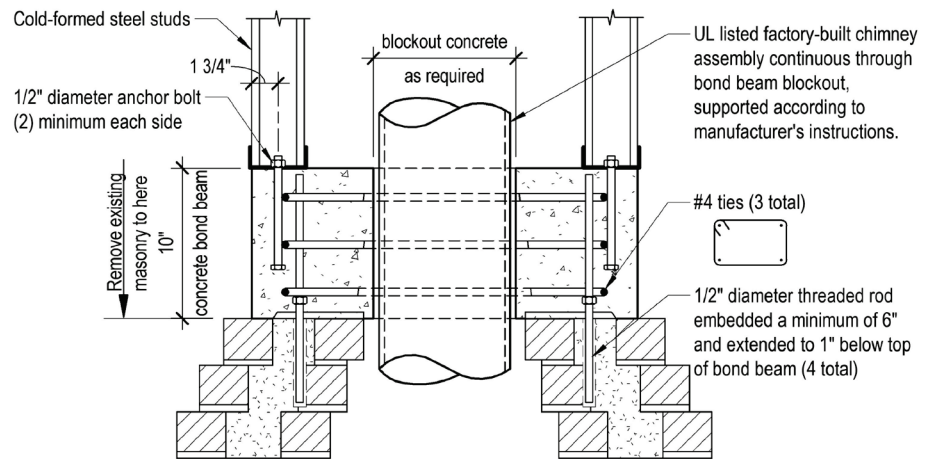
7.4.4.2 Reconstruction

Reconstruction shall be in accordance with the insert manufacturer's installation instructions, the requirements of this section, and Figure 7.4-7.

All clearances required by the manufacturer and listing shall be maintained. The reconstruction shall incorporate a factory-built, UL 127-listed insert and chimney. Reconstruction shall be in accordance with Items 2 through 8 of Section 7.4.3.2.

7.4.4.3 Insert-to-Chimney Transition

The insert and chimney shall be an uninterrupted, UL listed, factory-built assembly installed per the manufacturer’s instructions. The transition from masonry to light-framed chimney chase shall be per the requirements of this section and Figure 7.4-8.



Note: Material used to form and blockout concrete bond beam to allow passage of factory-built chimney assembly must be completely removed after concrete has cured.

Figure 7.4-8 Masonry transition to chimney chase where factory-built fireplace insert is used.

A reinforced concrete beam shall be constructed at the base of the chimney chase as shown in Figure 7.4-7. A minimum 1-1/2-inch cover shall be maintained between the reinforcing steel and the outside face of concrete. The bond beam shall be blocked-out to allow minimum 1/2-inch free space between the concrete and the factory-built chimney assembly. Any material used to form block-out must be completely removed after concrete cure.

7.4.5 Full Reconstruction of Firebox and Chimney Using Factory-Built Components

This section provides prescriptive methods for removal of the masonry chimney and firebox, and reconstruction using a factory-built chimney enclosed in a chimney chase. Use of these provisions is limited to exterior chimneys. Alternatively, interior or exterior chimneys shall be permitted to be fully reconstructed in accordance with the adopted building or residential code.

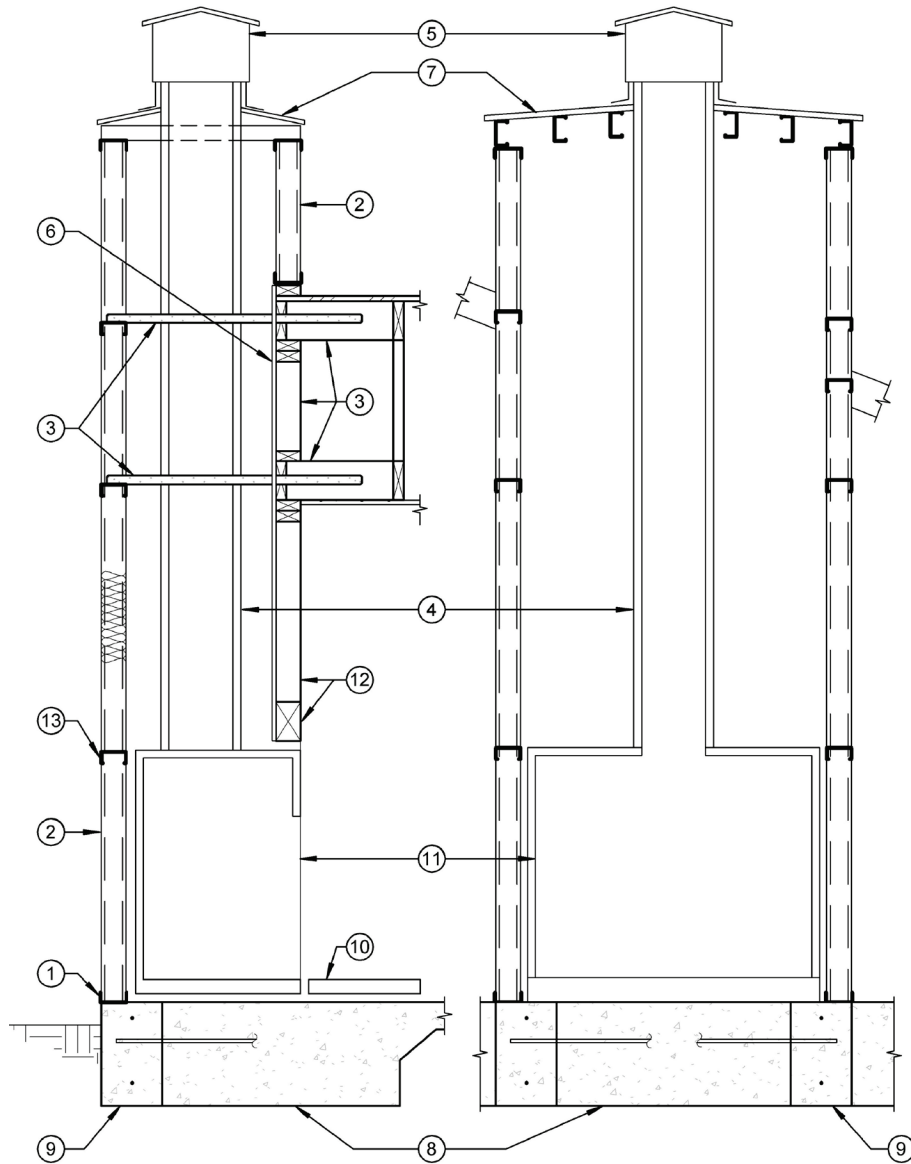
7.4.5.1 Chimney and Firebox Removal

The chimney and firebox shall be completely removed.

7.4.5.2 Reconstruction

Reconstruction shall be in accordance with the factory-built fireplace manufacturer's installation instructions, Items 2 through 8 of Section 7.4.3.2 and the following requirements as shown in Figure 7.4-9.

1. **Existing foundation.** An existing concrete foundation in good condition is permitted to be retained and incorporated. Where the existing foundation is deemed to be in poor condition or constructed of material other than concrete, it shall be removed and replaced in accordance with the fireplace manufacturer and this section. At minimum, the footings shall be constructed of concrete not less than 12 inches thick and shall extend not less than 6 inches beyond the face of the fireplace or foundation wall on all sides. Foundations shall be founded on natural, undisturbed earth or engineered fill below frost depth, but not less than 12 inches below finished grade.
2. **Extension of existing foundation.** Where required to meet dimensional requirements specified by the fireplace manufacturer or the requirements in Item 1 above, the existing concrete footing shall be extended as shown in Figure 7.4-9. The depth of the new foundation shall match the depth of the existing foundation, but the bottom of the foundation shall not be less than 12 inches below grade. The foundation extension shall be reinforced with one No. 4 bar top and bottom and epoxy dowels into the existing foundation spaced not more than 12 inches on center.
3. **Non-combustible hearth extension.** Where required to meet manufacturer's requirements or fireplace listing, a hearth extension listed and *labeled* per UL 1618 shall be provided.
4. **Factory-built fireplace.** Factory-built fireplaces shall be listed, labeled, and installed per the conditions of the listing.
5. **Existing framing.** Existing roof, wall, and ceiling framing shall remain. Where existing wall framing requires modification to accommodate a new fireplace opening, it shall be verified to be in good condition and in accordance with conventional construction provisions. New framing shall match existing construction.
6. **Stud blocking.** Continuous blocking between new studs shall be installed at 4 foot maximum vertical spacing. Blocking size shall match studs.



- | | |
|---|-------------------------------------|
| ① Track or Sill Plate. | ⑧ Existing Foundation. |
| ② Chimney Chase Stud Walls. | ⑨ Extension of Existing Foundation. |
| ③ Chimney Chase Connection to Dwelling. | ⑩ Non-combustible Hearth Extension. |
| ④ Factory-built Chimney. | ⑪ Factory-built Fireplace. |
| ⑤ Flue Cap. | ⑫ Existing Framing. |
| ⑥ Fireblocking. | ⑬ Stud Blocking. |
| ⑦ Chimney Cap. | |

Figure 7.4-9 Components of a factory-built fireplace in light-frame chimney.

7.5 Masonry Fireplace Surround Prescriptive Retrofit

In lieu of an engineered retrofit by a registered design professional, noncompliant masonry fireplace surrounds can be removed and reconstructed as anchored masonry veneer meeting the all of the following requirements:

1. Mortar shall be ASTM C270 Type S.
2. Masonry units shall not exceed 5 inches thickness.
3. Tie attachments shall support no more than two square feet of tributary wall area.
4. Tie attachments to wood shall be, at minimum, 22-gage (0.0299-inch thick) and 7/8-inch wide corrugated sheet metal, or 9-gage strand wire with a hook embedded in the mortar joint, fastened to the wood framing with an 8d ring shank nail. Tie attachments to steel studs shall be minimum 9-gage strand wire with a hook embedded in the mortar joint, fastened with a No. 10 screw through the framing a minimum of three exposed threads. A registered design professional shall check the strength of supporting wall studs, including attachments to top and bottom plates, to support all imposed loads.

7.6 Engineered Retrofit of Masonry Chimneys

Engineered retrofit of reinforced masonry chimneys shall conform to the requirements of Section 7.6.1 or Section 7.6.2. Engineered retrofit of unreinforced masonry chimneys shall conform to the requirements of Section 7.6.2.

Any flue(s) discharging products of combustion through the chimney shall be first re-routed per all requirements of the currently adopted building or residential code.

7.6.1 Building Code-Based Retrofit

Where the seismic weight of a chimney is greater than or equal to 25 percent of the effective seismic weight of the dwelling, the chimney retrofit shall be designed as a nonbuilding structure in accordance with the currently adopted building or residential code. Other masonry chimney retrofits shall be designed as a nonstructural component, anchored to and braced by the dwelling in accordance with ASCE/SEI 7 and the additional requirements of this section. Seismic loads shall be determined as either 75 percent of those specified by ASCE/SEI 7 for new construction, or those specified by the latest edition of ASCE/SEI 41 for the BSE-1E hazard level.

1. The seismic design force for the anchor straps shall be no less than F_p as defined for nonstructural components by ASCE/SEI 7.
2. Unless adequate strength of the foundation, soil, and chimney anchorage can be shown by calculation based on site conditions, anchor strap forces between the chimney and dwelling structure shall be calculated assuming zero resisting moment at the chimney base. For chimneys anchored at more than one diaphragm level, the chimney may be assumed rigid.
3. New chimney anchor straps shall wrap or otherwise engage the chimney. If existing embedded anchor straps are being used as part of the retrofit, engagement with the longitudinal chimney reinforcement shall be verified to conform to ASCE/SEI 7 provisions for flat strap anchorage of nonstructural components by exposing at least one anchor strap.
4. Connections of anchor straps to the diaphragm framing shall be designed per the currently adopted building or residential code.
5. Diaphragms supporting chimney anchor straps shall be evaluated pursuant to ANSI/AWC SDPWS, including collectors, where required to distribute diaphragm shear. The use of subdiaphragms designed to carry chimney anchor strap forces is acceptable.
6. The capacity of the reinforced chimney to carry moment and shear shall be determined according to TMS 402.
7. Retrofit design calculations and drawings shall be prepared by a registered design professional and submitted for approval to the building official.
8. All aspects of the construction shall require structural observation and shall be clearly stated as such on the design drawings and communicated to the contractor.

7.6.2 Performance-Based Retrofit

Masonry chimney retrofits designed according to ASCE/SEI 41 using a Partial Retrofit Objective with Life Safety Nonstructural Performance Level N-C are deemed to be in compliance with this chapter. Forces in anchor straps between chimney and dwelling shall be determined using dynamic analysis using a model that considers the mass, stiffness and damping of the dwelling, chimney and anchor straps separately. The properties and acceptance criteria for the various materials including the unreinforced or reinforced masonry chimney, steel anchor straps, anchor strap connections to light-framed diaphragms and shear walls shall be taken from the appropriate chapters of ASCE/SEI 41.

Chapter 8

Detailed Vulnerability-Based Assessment

The detailed vulnerability-based assessment provisions of this chapter shall be used when required by provisions in Chapters 4 through 6. Those elements that are in compliance with the simplified assessment of Chapter 4 or 5 or those that will be retrofit need not be assessed in accordance with this section.

8.1 Foundation

The foundations at the dwelling perimeter, not including porches or other unenclosed appurtenances, shall be assessed in accordance with this section.

1. Where there is a continuous concrete or masonry foundation, or continuous grade or tie-beams that are part of a deep foundation system at the dwelling perimeter, the foundation shall be assessed in accordance with Table 8.1-1. Where the foundation is compliant with all the assessment statements, the foundation shall be deemed in compliance with this section. Where the foundation is non-compliant with one or more assessment statements, the foundation shall be retrofit. Where it is possible to repair the non-compliant condition or conditions, repair to bring the condition into compliance shall be permitted.
2. Where there is a wood foundation, the foundation shall have an engineered vulnerability-based assessment or a general engineered assessment.
3. Where there is a discontinuous pier foundation with deep piers including drilled piers and caissons not connected at the dwelling perimeter with grade or tie-beams, the foundation shall have a general engineered assessment.
4. Where there is a discontinuous foundation with shallow piers or pier blocks, the foundation shall be retrofit in accordance with Chapter 4 through Chapter 6 as applicable, or shall have an engineered vulnerability-based assessment or a general engineered assessment.
5. Where there is no foundation, retrofitting to add a foundation shall be provided in accordance with Chapters 4 through Chapter 6, as applicable.

Table 8.1-1 Foundation (F) Assessment Checklist

Item	Assessment Statement	Compliant	Non-Compliant
F1	Foundation is in moderate to good condition, with any reduction in cross sectional area of the existing concrete or masonry and of any existing reinforcing due to deterioration is limited to 20% of its original area.		
F2	Individual foundation cracks are less than 1/2 inches in width. In addition, multiple vertical or diagonal cracks greater than 1/4 inch wide are not closer than 4 feet on center.		
F3	There is no projection of cracking greater than 1/4 inch width into the wall or floor systems above.		
F4	There is no undermining of supporting soils below the existing foundation system greater than 4 square feet at any single location.		
F5	There is no continuous horizontal spalling due to badly corroded horizontal reinforcing measuring more than 16 inches in length in the <i>perimeter foundation</i> .		

8.2 Foundation Sill Plate Anchorage to Foundation

The *foundation sill plate* to foundation anchorage at the dwelling perimeter, not including porches or other unenclosed appurtenances, shall be assessed in accordance with this section.

Anchorage need not be assessed at foundations cast monolithically with the *slab-on-ground* in dwellings or portions of dwellings constructed in 1950 or later, if anchorage is behind wall finishes.

1. Where there are existing anchor bolts, the anchor bolts shall be assessed in accordance with Table 8.2-1. Where these anchor bolts are compliant with all assessment statements, the foundation anchorage shall be deemed in compliance with this chapter. Where the foundation anchorage is non-compliant with one or more assessment statements, the anchorage shall be retrofit.
2. Where there are proprietary retrofit anchors, the anchors shall be assessed in accordance with Table 8.2-2. Where the foundation anchorage is compliant with all assessment statements, the foundation anchorage shall be deemed in compliance with this chapter. Where the foundation anchorage is non-compliant with one or more assessment statements, the foundation anchorage shall be retrofit.

Table 8.2-1 Anchor Bolt (AB) Assessment Checklist

Item	Assessment Statement	Compliant	Non-Compliant
AB1	Anchor bolts installed as part of original construction are 1/2 inch in diameter or larger with on average spaced not more than 6 feet on center for one-story dwellings and four feet on center for two-story dwellings, and are provided for the full extent of the perimeter foundation.		
AB2	Anchor bolts installed as part of a previous seismic retrofit are 1/2 inch in diameter or larger with on average spaced not more than 64 inches on center for one-story dwellings and 32 inches on center for two-story dwellings, and are provided for the full extent of the perimeter foundation.		
AB3	Anchor bolts installed as part of original construction shall have nuts, whether bearing directly on sill or having a gap between nut and sill. Nuts are to be threaded sufficiently to engage at least 2/3 of the nut height.		
AB4	Anchor bolts installed as part of a previous seismic retrofit shall have a minimum 2"×2"×3/16" steel plate washers.		
AB5	<p>No more than 10% of the anchor bolts have reduced capacity due to one or more of the following conditions, and No more than 20% of the anchor bolts on a particular wall line have reduced capacity due to one or more of the following conditions:</p> <ul style="list-style-type: none"> • Decay of the foundation sill plate in the immediate vicinity of the anchor bolt • Corrosion of the anchor bolt reducing the bolt cross sectional area by 20% or more • Placement of the anchor bolt centerline closer than 1-1/4 inches to the face of foundation sill plate or face of foundation • Countersinking of the washer or nut into the foundation sill plate such that the sill plate is less than one inch high at the anchor bolt location • Post-installed anchors with visible indications that they are not properly installed 		

Table 8.2-2 Proprietary Anchor (PA) Assessment Checklist

Item	Assessment Statement Description	Compliant	Non-Compliant
PA1	Proprietary anchors that have published capacities of not less than 875 pounds for shear along the length of the foundation of at least and on average spaced at not more than 64 inches on center for one story dwellings and 32 inches on center for two story dwellings.		
PA2	Proprietary anchors are installed in accordance with manufacturer's installation instructions.		
PA3	Proprietary anchors and the elements to which they are directly attached have not significantly deteriorated.		

3. Where there is another anchorage type other than anchor bolts or proprietary retrofit anchors, an engineered vulnerability-based assessment, or a general engineered assessment shall be provided.
4. Where there is no anchorage, anchorage retrofit shall be provided.

8.3 Bracing Wall Sheathing

Cripple wall or crawlspace wall sheathing at the perimeter of a crawlspace dwelling or hillside dwelling crawlspace shall be assessed in accordance with this section. Bracing wall sheathing in the ground story of living-space-over-garage dwellings shall be assessed in accordance with Section 8.5.

1. Where there is plywood panel siding, the siding shall be assessed in accordance with Table 8.3-1. Where panel siding is found to be compliant with the assessment statements, the siding shall be deemed in compliance with this chapter. Where the panel siding is non-compliant with one or more of the assessment statements, the siding shall be retrofit. Where it is possible to repair the non-compliant condition, repair to bring the condition into compliance is permitted.
2. Where there is existing plywood or orientated strand board (OSB) sheathing installed as part of the original construction, the existing plywood or OSB shall be assessed in accordance with Table 8.3-2. Where the plywood or OSB sheathing is found to be compliant with all assessment statements, the sheathing shall be deemed in compliance with this chapter. Where the plywood or OSB is non-compliant with one or more of the assessment statements, the sheathing shall be retrofit.
3. Where there is existing plywood or OSB sheathing installed as part of a previous seismic retrofit, the existing plywood or OSB shall be assessed in accordance with Table 8.3-3. Where the plywood or OSB is found to be compliant with all assessment statements, the sheathing shall be

deemed in conformance with this chapter. Where the plywood or OSB is non-compliant with one or more of the assessment statements, the sheathing shall be retrofit. Where it is possible to repair the non-compliant condition, repair to bring the condition into compliance is permitted.

Table 8.3-1 Exterior Plywood Panel Siding (PS) Assessment Checklist

Item	Assessment Statement	Compliant	Non-Compliant
PS1	All perimeter cripple walls or crawlspace walls are continuously sheathed with plywood panel siding except for ventilation and access openings.		
PS2	The siding is in good condition, with no significant deterioration or damage.		
PS3	The sheathing is nailed with not less than 6d common nails (2" x 0.113") for 1/2-inch sheathing and 8d common nails (2-1/2" x 0.131") for 5/8-inch sheathing.		
PS4	The sheathing is edge nailed at not more than 6 inches on center at the full perimeter of each sheathing sheet and a minimum 3/8 inches edge distance is maintained for the full siding thickened at the edge each panel for 6d or 8d common nails.		
PS5	The sheathing is field nailed at not more than 12 inches on center.		

Table 8.3-2 Wall Sheathing from Original Construction (OC) Assessment Checklist

Item	Assessment Statement	Compliant	Non-Compliant
OC1	All perimeter cripple walls or crawlspace walls are continuously sheathed in plywood or oriented strand board (OSB) <i>wood structural panel</i> sheathing except for ventilation and access openings.		
OC2	The sheathing is in good condition, with no significant deterioration or damage.		
OC3	The sheathing is not less than 3/8-inch thick.		
OC4	There is no visible indication that the sheathing installation does not conform with general construction practice or edge nail spacing is greater than six inches on center.		

4. Where there is another type of panel or siding product, the panel or siding shall have an engineered vulnerability-based assessment or a general engineered assessment, or be retrofit.
5. Where there is no plywood or OSB sheathing, retrofit shall be provided in accordance with Chapter 4.

Table 8.3-3 Existing Wall Sheathing from Previous Retrofit (PR) Assessment Checklist

Item	Assessment Statement	Compliant	Non-Compliant
PR1	The length of cripple wall sheathing (crawl-space dwellings) provided at each exterior wall line is not less than required by Table 8.3-4 and does not exceed 4'-0" in height., OR The length of crawl-space wall sheathing (hillside dwellings) is not less than 80% of the accessible crawl-space wall length at each perimeter crawl-space wall line.		
PR2	The plywood or OSB sheathing is in good condition, with no significant deterioration or damage.		
PR3	The sheathing is not less than 3/8-inch thick.		
PR4	The sheathing is nailed with not less than 8d nails.		
PR5	The sheathing is edge nailed at not more than 4 inches on center at the full perimeter of each sheathing sheet and a minimum 3/8 inch edge distance is maintained at the edge each panel for 8d common nails.		
PR6	The sheathing is field nailed at not more than 12 inches on center.		
PR7	The sheathing extends the full height of the cripple wall and is edge nailed to the foundation sill and the top plate.		
PR8	The framing to which the sheathing is attached has not been compromised by deterioration or will be replaced to its original condition.		
PR9	The perimeter cripple wall is enclosed by finish materials over only a limited area of an otherwise unfinished crawl-space.		

Table 8.3-4 Minimum Required Retrofit Sheathing Length [IEBC Table A3-1]

Number of Stories Above Cripple Wall	Amount of Bracing Each Perimeter Cripple Wall	
	Dwellings with a Combination of Exterior Walls finished with Stucco and a Roofing System using Clay or Concrete Tiles Weighing more than 6 psf	All Other Conditions
One	Each end and not less than 50% of wall length	Each end and not less than 40% of wall length
Two	Each end and not less than 70% of wall length	Each end and not less than 50% of wall length

8.4 Floor Framing Rim Joist and Blocking

The connection of dwelling floor framing to the cripple wall below shall be assessed in accordance with this section. Where the dwelling sits directly on a foundation sill plate without a cripple wall, the connection of the dwelling floor framing to the foundation sill plate below shall also be assessed in accordance with this section.

1. The rim joist and or blocking at the perimeter of the crawlspace shall be assessed in accordance with Table 8.4-1 for one story dwelling and Table 8.4-2 for two story dwelling, respectively. When at all locations either blocking or a rim joist are present as specified in Table 8.4-1 or Table 8.4-2, and existing or retrofitted connections are found to be compliant with all assessment statements, the existing connections for the rim joist or blocking shall be deemed to meet the requirements of this section. At any location where either the blocking, rim joist, or existing connection are non-compliant with one or more of the assessment statements, retrofit shall be provided. Where existing connections as specified in Table 8.4-1 and Table 8.4-2 cannot be verified, retrofit will be required.

**Table 8.4-1 Rim Joist and or Blocking (RJB1) Assessment Checklist—
One-Story Dwelling**

Item	Assessment Statement	Compliant	Non-Compliant
RJB1-1	At the perimeter of the dwelling, either a continuous rim joist or floor joist blocking in all or alternate joist bays shall occur directly on top of perimeter foundation sill plate or cripple wall top plate and shall have full bearing.		
RJB1-2	Continuous rim joists and blocking are in good condition with no significant deterioration.		
RJB1-3	For assessment of original construction, continuous rim joists or blocking are attached to the continuous cripple wall top plates or foundation sill plate below with a minimum of 8d common toenails at 12 inches on center.		
RJB1-4	For assessment of previous retrofit construction, <i>connectors</i> (shear clips) have been provided between the existing continuous rim joist or blocking to the cripple wall top plates or foundation sill plate below, spaced at not more than 32 inches on center and shall have a manufacturer's listed ASD capacity of not less than 450 pounds per connector in load direction parallel to the length of the foundation.		

**Table 8.4-2 Rim Joist and or Blocking (RJB2) Assessment Checklist—
Two-Story Dwelling**

Item	Assessment Statement	Compliant	Non-Compliant
RJB2-1	At the perimeter of the dwelling, either a continuous rim joist or floor joist blocking in all joist bays shall occur directly on top of perimeter foundation sill plate or cripple wall top plate and shall have full bearing.		
RJB2-2	Continuous rim joists and blocking are in good condition with no significant deterioration.		
RJB2-3	For assessment of original construction, continuous rim joists or blocking are attached to the continuous cripple wall top plates or foundation sill plate below with a minimum of 8d common toenails at 6 inches on center.		
RJB2-4	For assessment of previous retrofit construction, connectors (shear clips) have been provided between the existing continuous rim joist or blocking to the cripple wall top plates or foundation sill plate below, spaced at not more than 16 inches on center and shall have a manufacturer's listed ASD capacity of not less than 450 pounds per connector in load direction parallel to the length of the foundation.		

8.5 Requirements for Ground Story Bracing Walls for Living-Space-Over Garage Dwellings

Bracing walls throughout the ground story of *living-space-over-garage dwellings* shall be assessed in accordance with one of the methods provided in this section. Where the bracing walls are compliant with one of the methods in this section, the bracing walls shall be deemed in compliance with this section. Where the bracing walls are non-compliant, the bracing walls shall be retrofit.

8.5.1 1994 or 1997 UBC Conventional Construction Provisions

Existing ground story bracing walls being checked for compliance with the 1994 or 1997 Uniform Building Code (UBC) conventional construction provisions shall conform to all of the following:

1. *Braced wall lines* in each horizontal direction shall not exceed the on-center spacing specified in Table 8.5-1.
2. *Braced wall panels* in each braced wall line shall conform to the type, placement, and minimum length specified in Table 8.5-2.

3. Construction of braced wall panels shall meet the provisions of Table 8.5-3.
4. Minimum lengths of braced wall panels shall meet the provisions of Table 8.5-4.
5. Bracing shall be in good condition with no significant deterioration or damage.

Table 8.5-1 Maximum on-Center Spacing of Braced Wall Lines (Based on 1997 UBC Sec. 2320)

Seismic Design Category	Maximum on-Center Braced Wall Line Spacing (feet)	
	Basic	Exception
B, C, D ₀ , D ₁	34	NA
D ₂ , E	25	In one- and two-story single-family dwellings, interior braced wall line spacing shall be permitted to be increased to not more than 34 feet on center in order to accommodate one single room per dwelling, not to exceed 900 square feet.

Table 8.5-2 Braced Wall Panels (Based on 1997 UBC Table 23-I-W)

Seismic Design Category	Condition	Construction Method								
		1	2	3	4	5	6	7	8	
B, C, D ₀ , D ₁	First story of 2 story		×	×	×	×	×	×	×	Each end and not more than 25 feet on center
D ₂ , E	First Story of 2 story		×	×	×	×	×	×	×	Each end and not more than 25 feet on center, but not less than 25% of buildings length

Table 8.5-3 Braced Wall Panel Construction Methods (Based on 1997 UBC Sec. 2320.11.3)

Construction Method	Description	
	Material	Construction
2	Diagonal wood sheathing	Wood boards of 5/8-inch net minimum thickness applied diagonally on studs spaced not over 24 inches on center
3	Wood structural panel sheathing	Wood structural panel sheathing with a thickness not less than 5/16-inch for 16-inch stud spacing and not less than 3/8 inch for 24-inch stud spacing in accordance with Table 3.2-1
4	Fiberboard sheathing	4-foot by 8-foot panels not less than 1/2 inch thick applied vertically on studs spaced not over 16 inches on center when installed in accordance with Table 3.2-1
5	Gypsum board sheathing	1/2-inch thick by 4 feet wide, wallboard of veneer base, on studs spaced not over 24 inches on center and nailed at 7 inches on center with nails as required by Table 3.2-1
6	Particleboard wall sheathing	Sheathing panels where installed in accordance with Table 3.2-1
7	Portland cement plaster	Portland cement plaster on studs spaced 16 inches on center, installed in accordance with Table 3.2-1
8	Hardboard panel siding	Hardboard siding installed in accordance with Table 3.2-1

Table 8.5-4 Maximum Length of Braced Wall Panels (Based on 1997 UBC Sec. 2320)

Construction Method	Minimum Length (feet)	Description
2, 3, 4, 6, 7, 8	4	NA
5	8	Applied to one face
	4	Applied to both faces

8.5.2 1997 UBC Engineered Seismic Design Provisions

Existing ground story bracing walls being checked for compliance to the 1997 UBC engineered seismic design provisions shall have an engineered vulnerability-based assessment or general engineered assessment.

8.5.3 2000 or later IRC Seismic Wall Bracing Provisions

Existing ground story bracing walls being checked for conformance to the 2000 or later IRC seismic wall bracing provisions shall have the type and extent of sheathing or bracing assessed by a registered design professional or licensed contractor.

8.5.4 2000 or later IBC Engineered Seismic Design Provisions

Existing ground story bracing walls being checked for conformance to the 2000 or later IBC engineered seismic design provisions shall have an engineered vulnerability-based assessment or general engineered assessment.

Commentary

This commentary is intended for use by persons implementing the prestandard provisions. Further information detailing development of the prestandard provisions is available in the companion Volume 3, *Background Documentation*.

The intended primary users of this prestandard are persons involved in seismic retrofit design, construction, plan review, and inspection of wood light-frame dwellings. The user is expected to be generally familiar with residential construction and related terminology. Simplified and detailed vulnerability-based assessments and prescriptive design methodologies are intended to be available for use by any person having a general knowledge of residential construction. Engineered assessment and retrofit methodologies are intended to be used by registered engineers or licensed architects with knowledge of seismic retrofit design. State or local laws may govern which persons are qualified to use engineered design methods.

C.1 Scope and Administration

C.1.1 Prestandard Scope

This prestandard addresses seismic assessment and retrofit of specified seismic vulnerabilities common to one- and two-family wood light-frame dwellings. The provisions have been primarily developed around single-family dwellings. The provisions are, however, equally applicable to other wood light-frame buildings that are of similar construction and scale. For this reason, assessment and retrofit provisions may also be applicable to *townhouses* and to dwellings originally constructed as single-family dwellings that have since been split into-multi-family dwellings. Extending the use of this prestandard to single-family dwellings converted to other uses should be at the discretion of the *building official*.

The seismic vulnerabilities addressed in this prestandard were selected based on their prevalence in the existing building stock in regions of high seismic hazard and on informed judgment that vulnerability-based retrofit can provide good benefit-to-cost ratios for individual property owners and improved resilience for communities.

Damage to *crawlspace dwellings* has been observed repeatedly in moderate to major earthquakes. Typical damage includes dwellings sliding off foundations due to inadequate anchorage and collapse of inadequately braced *cripple walls*. Assessment and retrofit of these conditions have been identified as high priority for many years. Existing retrofit guidance includes Appendix Chapter A3 of the *International Existing Building Code* (IEBC), a number of local and regional retrofit plan sets, and the plan set provided in FEMA P-1024, *Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake* (FEMA, 2015).

Damage to *living-space-over-garage dwellings* is similar in nature to the “soft story” failures seen in multi-family wood residential buildings in recent moderate to major earthquakes (EERI, 1996). Prescriptive or vulnerability-based guidance addressing retrofit of one- and two-family dwellings for this vulnerability have not been previously available.

Damage to *hillside dwellings* caused dramatic failures in the 1994 Northridge Earthquake (EERI, 1996). The behavior observed indicates that the strength and stiffness of crawlspace wall bracing systems below the lowest occupied floor are often inadequate. The resulting failure mode involves brittle failure of the dwelling connection to the *uphill foundation*, allowing the dwelling to pull away and potentially collapse. Seismic retrofit guidance was developed by the City of Los Angeles following the Northridge Earthquake, and adopted locally for voluntary retrofit as Division 94 of the Los Angeles Building Code (LADBS, 1994). This guidance has not, however, been incorporated into a model code or standard. The provisions of this prestandard make significant progress for mitigating this vulnerability, in that extensive numerical studies were used to confirm seismic response, identify the needed levels of strength and stiffness for effective retrofit, and identify the dwelling configurations for which use of this retrofit approach is appropriate.

Chimney damage has long been commonly observed following moderate to major earthquakes. The existing building stock has widespread pre-1970 brick *masonry chimneys* that are unreinforced and inadequately anchored to the dwelling structure. Because masonry chimneys are significantly stiffer than the dwellings to which they are attached, it is not practical to protect them from damage. The retrofit provisions of this prestandard for chimneys take a practical approach of presenting best practices for seismic risk reduction. The retrofit guidance has been drawn in part from chimney repair guidance provided by FEMA P-1024, City of Los Angeles, City of Napa, and other jurisdictions following recent earthquakes.

Failure of masonry fireplace surrounds have not received as much attention as chimneys but are understood to have been contributors to injuries following the 2000 Yountville and 2014 South Napa earthquakes (McDonald, 2018). Often, the masonry veneer on the interior wall surrounding the fireplace is of full brick or stone but is not anchored to the wall behind, leaving the veneer vulnerable to collapse.

The vulnerabilities included in this prestandard were identified to be of highest priority (ATC, 2014). The following vulnerabilities are also of concern and represent possible damage to dwellings but are not specifically addressed in this prestandard: *split level* dwellings, dwellings with inadequately braced walls in occupied stories, and inadequate anchorage of *slab-on-ground* dwellings. In addition, parts and portions of dwellings were identified as earthquake-vulnerable, including: water heaters, masonry veneer, decks, porch roofs, patio covers, and similar attached components.

Resources available to provide systematic assessment of seismic performance include the simplified assessment of FEMA P-50, *Simplified Seismic Assessment of Detached, Single-Family, Wood-Framed Dwellings* (FEMA, 2012), which provides a practical, simplified assessment method that identifies the additional vulnerabilities listed above, and the multi-tiered provisions of ASCE/SEI 41, which may be used when a complete systematic assessment is found appropriate.

The methods of assessment and retrofit are listed in Section 1.1. The differentiation between vulnerability-based and general engineered methodologies is important. A vulnerability-based approach addresses only the seismic force-resisting elements at the vulnerable location and their connection into the dwelling. This approach has been used because it is believed to provide substantial improvement to seismic performance at a reasonable benefit-to-cost ratio. An alternative would be to conduct a systematic full-structure assessment and retrofit. The retrofit would likely be invasive, expensive, and provide only marginally improved performance for typical wood light-frame dwellings without vulnerable configurations. It therefore makes sense to focus on recognized vulnerabilities.

This prestandard presents the following assessment methodologies:

- **Simplified vulnerability-based assessment.** This method provides a rapid assessment of existing original construction or an existing retrofit to determine conformance to the provisions of the prestandard for the vulnerability being considered. Existing construction is compared to requirements from previous prescriptive retrofit provisions or recent building or residential code provisions.

- **Detailed vulnerability-based assessment.** This method provides a more detailed assessment of existing construction for the vulnerability being considered. Existing construction is compared to requirements from previous prescriptive retrofit provisions or recent building or residential code provisions.
- **Engineered vulnerability-based assessment.** This method uses engineered calculation of demand and capacity to assess existing construction for the vulnerability being considered. Existing construction is compared to requirements from engineered seismic design provisions.
- **General engineered assessment.** This is a generalized engineered assessment that includes the seismic force-resisting system of the entire dwelling, rather than being vulnerability based. This method requires use of standards other than this prestandard.

In the simplified and detailed vulnerability-based assessment approaches, it is noted that existing construction is compared to requirements from previous prescriptive retrofit provisions or recent building or residential code provisions. These previous provisions are less stringent than those used for prescriptive retrofit in this prestandard. Based on extensive background studies, this prestandard is putting forward a higher level of retrofit with the intent that this higher level become the standard moving forward.

This prestandard presents the following retrofit methodologies:

- **Prescriptive retrofit.** This method provides pre-engineered retrofit designs, intended to be implemented by the contractor without requiring engineered design.
- **Prescriptive retrofit supplemented by engineering calculations and details.** Where existing conditions fall outside of the prescriptive details, engineered design is permitted to develop alternate details with capacity equivalent to the prestandard details.
- **Simplified engineered vulnerability-based retrofit.** This method provides engineered design limited to the vulnerability and the load path into and out of each retrofit element.
- **General engineered retrofit.** This is a generalized engineered retrofit method that includes the seismic force-resisting system of the entire dwelling, rather than being vulnerability based. This method requires use of standards other than this prestandard, supplemented by additional retrofit requirements.

C.1.2 Prestandard Purpose

The primary purpose of the prestandard is reduction of earthquake-induced damage and collapse in wood light-frame dwellings. This statement of purpose is consistent with the appendix chapters to the IEBC. Although there is general alignment of performance objectives between the retrofits in this prestandard and the concepts of IEBC and ASCE/SEI 41, there is no explicit correlation due to the prestandard's use of probability of collapse at risk targeted maximum considered earthquake (MCE_R) as a primary performance measure, as discussed below.

It is considered impractical to provide seismic retrofit of wood dwellings to a level that would prevent all damage in anticipated moderate to major earthquakes. In most of the finish materials used in dwellings, damage is initiated at very low story drift ratios. It is believed that reduction of building drift to the level required for finish material damage control would require significant changes in dwelling construction from the ground up, and is not practical to accomplish through retrofit of existing buildings; however, providing strength above minimum required, can reduce damage.

Seismic retrofit criteria provided in this prestandard were developed through consideration of seismic performance targets for each specified vulnerability. The intent of this approach was to develop simplified retrofit design methods that would incorporate performance-based design objectives. The methodology and intent are discussed in detail in the companion Volume 3, *Background Documentation*. Following is a brief overview.

Extensive numerical studies of representative dwelling models were used to quantify seismic performance improvement with retrofit. The studies were primarily based on the methodology described in FEMA P-695 (FEMA, 2009). The primary performance criteria were probability of collapse in the MCE_R . The probabilities of collapse predicted by others using this methodology are higher than those observed in past earthquakes (NIST, 2012). Therefore, probabilities of collapse reported by numerical studies that form the basis of this prestandard are believed to be somewhat high. This understanding is included in judgments made regarding acceptable retrofit performance, and the results of numerical studies are emphasized more as a relative, rather than absolute, measure of performance.

Two secondary criteria informed, but did not necessarily determine, the prestandard retrofit criteria. A transient drift ratio of 0.75% at a seismic demand of $0.4MCE_R$ was taken as an indicator of the level of anticipated post-earthquake repair. A transient drift ratio of 1.5 % at a seismic demand

of $0.67MCE_R$ was taken as an indicator of post-earthquake suitability for continuous safe occupancy.

The prestandard provides simplified engineered retrofit design methodologies based on the seismic design provisions of the *International Building Code* (IBC) and ASCE/SEI 7 using equivalent lateral force or alternative simplified seismic design methods. ASCE/SEI 7 based simplified methodologies are incorporated in order to keep the cost and complication of retrofit design from becoming too burdensome. Response modification, R , factors developed for the retrofit of each vulnerability differ between vulnerabilities due to significant differences in dwelling seismic response. In general, the values of R are lower than those prescribed in current building codes for new construction. Load path connections for retrofit elements were developed using a capacity method, with the intent that the peak capacity of elements and load path connections are balanced.

While quite damaging economically, cripple wall collapses in crawlspace dwellings were judged to pose limited safety risk to occupants, as the living space generally remains reasonably intact. In the course of developing this prestandard, a notable portion of the retrofit designs targeting 20 percent probability of collapse in the MCE_R were found to be unwieldy to construct. For these reasons, retrofit criteria were chosen based on damage reduction concepts, with the intent of encouraging more widespread use. This results in the probability of collapse in the MCE_R identified by numerical studies of representative buildings being higher than 20 percent. However, use of prescriptive provisions are generally conservative and the studies are believed to over-report collapse, so actual probability of collapse of retrofit buildings are likely lower than predicted. Because previous retrofit criteria are less stringent than those in this prestandard, buildings assessed and determined not to require retrofit are expected to have higher probability of collapse than those retrofit using the prestandard, with the values varying based on geometry and other factors.

In living-space-over-garage ground stories, and in hillside dwellings with vulnerable anchorage and *cripple walls*, collapse could pose a safety risk to occupants. Therefore, the probability of collapse at the MCE_R (identified by the project team as a desirable target), for retrofit of these vulnerabilities was studied. Numerical studies of representative buildings found the probability of collapse at the MCE_R to be in the range of 10 to 20 percent. This is qualified by the fact that the studies are believed to over-report collapse, and by the wide variation in the existing building stock. With this qualification considered, this range of probability of collapse is in the general range of

expectations for Life Safety performance in other current seismic retrofit standards.

Chimney and fireplace surround retrofits were developed with the intent of providing best practices for risk reduction, without numerical quantification of performance.

The retrofits in this prestandard only address specific vulnerabilities, thus the performance of the overall dwelling will vary based on the seismic resistance of portions of the dwelling not addressed. Fundamental to the numerical studies was the consideration of the performance of the superstructure, that is, the portion of the dwelling above the targeted vulnerability. The numerical studies verified that the retrofits would in general not shift significant damage to the upper occupied stories. The extent to which this can be accomplished is affected by the variability of the existing building stock. There will be greater improvement in seismic performance for dwellings that have medium to high seismic resistance in the occupied stories, and lesser improvement for dwellings with low resistance in the occupied stories.

C.1.3 Alternative Methods

This section is taken from and consistent with the IBC and *International Residential Code* (IRC). It is intended that any material or methods of construction deemed acceptable by the building official be permitted in construction of seismic retrofits.

C.1.4 Use of This Prestandard

Section 1.4 identifies the portions of the prestandard applicable to each vulnerability. Intended use of the prestandard is further illustrated in the Figure C.1.4-1 flowchart.

It is anticipated that local governments, insurers, and others might require use of this prestandard in their own policies or programs. In addition, individual homeowners or *design professionals* might use this prestandard on a voluntary basis. All such users should understand that despite the foregoing discussion of retrofit objectives and probabilities of collapse, the specific level of retrofit being achieved should be communicated only as compliance with a specific chapter of this prestandard.

Use of ASCE/SEI 7 or other standards for retrofit design is allowed as discussed in Section 1.7. Use of ASCE/SEI 7 seismic design parameters is not allowed when using the simplified vulnerability-based retrofit design methods of this prestandard. The extensive performance-based numerical

studies used to develop the prestandard’s retrofit provisions have identified seismic response modification, *R*, factors lower than would be assigned by ASCE/SEI 7, even though the performance objective used in the studies was the same or less stringent than that targeted by ASCE/SEI 7. It was concluded from this that *R*-factors lower than those in ASCE/SEI 7 are needed to obtain desired performance for the specific portions of the structure being retrofit.

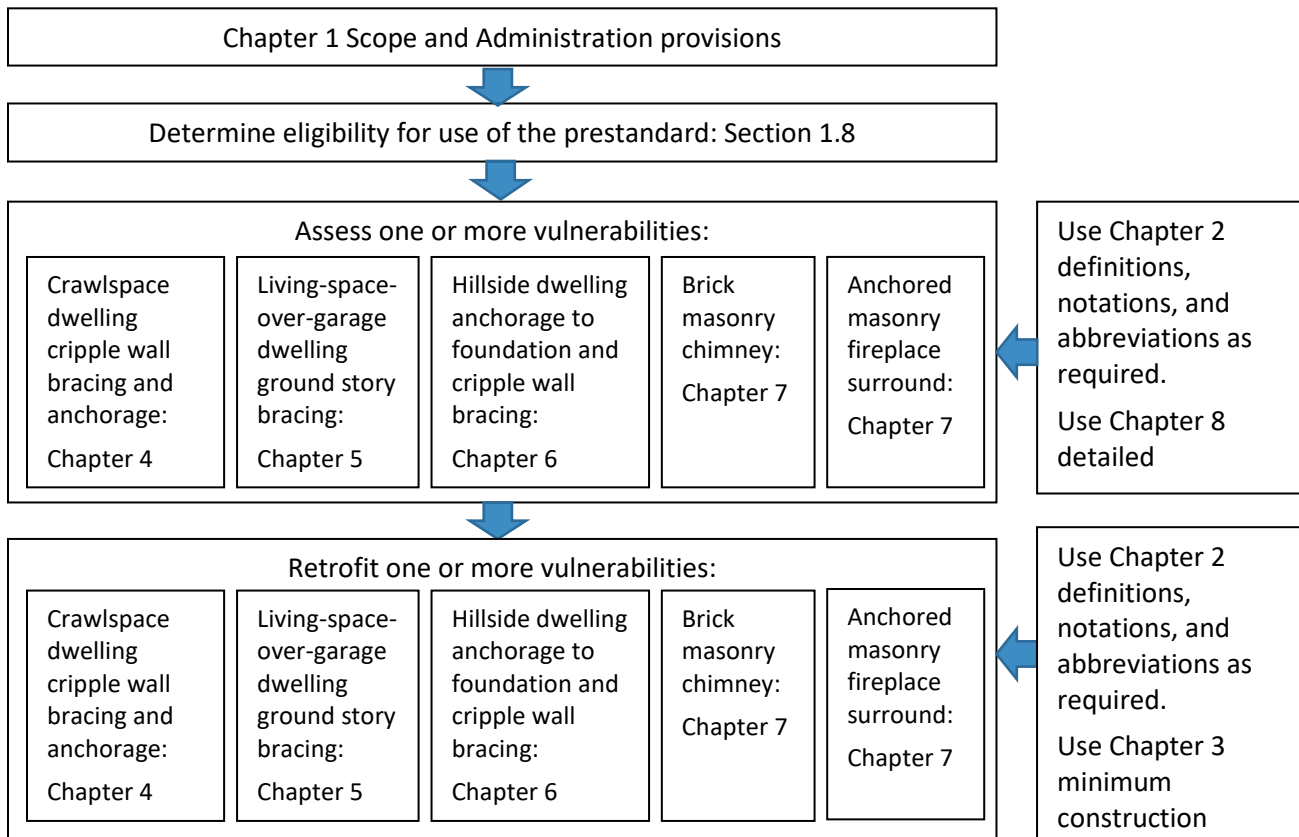


Figure C.1.4-1 Flowchart of intended use of prestandard provisions.

As with any prestandard, compliance requires that all applicable provisions are followed for all relevant conditions within the dwelling.

Earthquake Retrofit Schedules and illustrations related to the prescriptive retrofit methods for crawlspace and living-space-over-garage dwellings of Sections 4.4 and 5.4 are provided at the end of each related prestandard chapter. Figures in Sections 4.4 and 5.4, are similar to construction documents, such that details are presented in “sheets” as identified in figure call-outs.

C.1.5 Combinations of Seismic Vulnerabilities

It is common for more than one of the prestandard's seismic vulnerabilities to be present in a dwelling. This section discusses a few commonly found combinations of vulnerabilities and how the provisions of this prestandard apply.

Vulnerable chimneys and fireplace surrounds occur regularly in dwellings that have one or more of the other vulnerabilities addressed in this prestandard. Use of the chimney or fireplace surround provisions of this prestandard is always allowed, regardless of the occurrence of other vulnerabilities.

It is common for dwellings on low slope sites to have a combination of crawlspace and slab-on-ground conditions. Often a slab-on-ground garage occurs in combination with a dwelling built over a crawlspace (two-story dwellings with garages should be treated as living-space-over-garage dwellings), but common configurations also include dwellings with a good portion of the occupied space built on a slab-on-ground. In such cases, the retrofit of the crawlspace portion of the dwelling is always permitted. The perimeter of the crawlspace portion is to be treated as the perimeter of the dwelling for purposes of applying the provisions of this prestandard. In the event that the slab-on-ground portion is not anchored, better overall performance can be achieved by anchoring the slab-on-ground portion as well as retrofit the crawlspace portion. It is unusual, however, to find dwellings with monolithic slab-on-ground foundations that do not have existing anchor bolts.

Hillside dwellings can occur with a combination of crawlspace and slab-on-ground conditions. Where the dwelling is supported on slab-on-ground occurring at the same level as the lowest framed floor (base-level diaphragm), there is concern that the slab-on-ground will change the dwelling seismic response, possibly making the hillside retrofit less effective. For this reason, this configuration is scoped out of Chapter 6 by Table 6.1-1, and, a general engineered retrofit design is appropriate.

One of the most common split-level dwelling configurations involves an approximately four-foot offset between the main house floor and the floor of the room over garage (Figure C.1.5-1 and Figure C.1.5-2). This can occur in combination with either a crawlspace or slab-on-ground condition. Although it is recommended that all vulnerabilities be retrofitted, the prestandard accommodates projects that address individual vulnerabilities. Not specifically addressed by this prestandard is the additional split-level vulnerability of separation between the one-story and two-story wings of the dwelling.



Figure C.1.5-1 Split level configuration in a living-space-over-garage dwelling.



Figure C.1.5-2 Split level configuration in a living-space-over-garage dwelling.

Compliance should allow one or more of the following statements to be made following completion of assessment or retrofit:

- The crawlspace dwelling cripple walls have been determined to be in compliance with Chapter 4 based on assessment.
- The crawlspace dwelling cripple walls have been retrofit to comply with Chapter 4.
- The living-space-over-garage dwelling ground story *bracing walls* have been determined to be in compliance with Chapter 5 based on assessment.
- The living-space-over-garage dwelling ground story bracing walls have been retrofit to comply with Chapter 5.
- The hillside dwelling anchorage to foundation and *crawlspace walls* have been determined to be in compliance with Chapter 6 based on assessment.
- The hillside dwelling anchorage to foundation and crawlspace walls have been retrofit to comply with Chapter 6.

- Masonry chimneys have been determined to be in compliance with Chapter 7 based on assessment.
- Masonry chimneys have been retrofit to comply with Chapter 7.
- Masonry fireplace surrounds have been determined to be in compliance with Chapter 7 based on assessment.
- Masonry fireplace surrounds have been retrofit to comply with Chapter 7.

In order for the above statements to be made, all provisions of the applicable chapter shall have been implemented at all locations where they are applicable.

C.1.6 Site Seismicity

Use of this prestandard is intended for dwellings assigned to Seismic Design Categories (SDC) B through E. The primary use is intended to be SDC C through E, as this is where retrofit is considered to provide the most benefit. It is noted, however, that, in areas where dwellings are assigned to SDC B, damage from lack of dwelling anchorage to the foundation can occur. This suggests that, as a minimum, anchorage of dwellings to the foundation is appropriate across all SDCs.

Seismicity for use in engineered retrofit is identified in terms of short-period design spectral response acceleration, S_{DS} , determined in accordance with IBC or ASCE/SEI 7. This is used in the engineered retrofit design provisions that are detailed in Chapter 4 to Chapter 7.

Seismicity for use in prescriptive retrofit is identified in terms of short-period design spectral response acceleration, S_{DS} , determined based on the SDC assigned in accordance with one of the methods described in Section 1.6. Retrofit solutions have been pre-calculated using S_{DS} values of 1.0, 1.2, and 1.5. These are used in the prescriptive retrofit provisions of Chapter 4 and Chapter 5.

C.1.7 Assessment and Retrofit Methodologies

Important for both assessment and retrofit is the distinction between vulnerability-based methods and general engineering methods. When using a vulnerability-based method, the extent of assessment is specifically limited to the existing components critical to that vulnerability, and the extent of retrofit is specifically limited to the retrofit element and the load path connections to get load into and out of the retrofit element. This limited

scope based on numerical studies presumes that mitigation of one or more specific vulnerabilities will improve the building's overall performance.

When general assessment or retrofit is required, the engineer is intended to look beyond the vulnerability and to consider the seismic performance of the dwelling as a whole. In these cases, retrofit of more than individual vulnerabilities may be appropriate or necessary to improve dwelling performance.

General engineering assessment and retrofit provisions are outside of the scope of this prestandard. Use of methodologies such as ASCE/SEI 7 or ASCE/SEI 41 is intended. When general engineering retrofit methodologies are being used, supplemental provisions are given for retrofit design to reflect insights gained in the development of this prestandard.

For crawlspace and living-space-over-garage dwellings, the numerical studies identified that retrofit design using the *R*-factors of ASCE/SEI 7 did not provide the seismic performance intended by this prestandard. This is thought to be related in part to the effect of the finish materials causing the lowest (cripple wall or garage) story to be soft and weak, with concentrated drift and damage. If general engineering retrofits are to be designed with ASCE/SEI 7, additional strength and stiffness at this level must be provided.

For hillside dwellings, the primary seismic response was found to be torsional rotation about the uphill foundation. ASCE/SEI 7 would permit the diaphragm in such a dwelling to be idealized as flexible for purposes of distributing forces. Where a flexible diaphragm is used, the torsional response and critical behavior of pulling away from the uphill foundation is not captured. An additional requirement is provided to trigger analysis requirements that will capture this critical behavior.

C.1.8 Limitations of Use

Table 1.8-1 presents eligibility criteria for use of the prestandard as a whole.

Item 1 addresses buildings constructed as a dwelling. The vulnerabilities included in the prestandard are common for one- and two-family dwellings of wood *light-frame construction*. The assumptions inherent in the prestandard will not apply to many larger residential buildings or to non-residential occupancies.

Item 2 is related to the construction of the structural system, specifically the de facto seismic force-resisting system. Dwellings constructed of other materials, including cold-formed steel, might not satisfy the assumptions inherent in the prestandard.

Item 3 ensures that the dwelling matches the range of assumptions made for the numerical studies. Exterior wall weight is limited primarily to disqualify dwellings with masonry veneer extending more than four feet above the foundation, which significantly affects the seismic weight and seismic response of the dwelling.

C.1.9 Conditions Beyond the Scope of this Prestandard

This prestandard addresses assessment and retrofit of seismic vulnerabilities in wood light-frame dwellings traditionally considered high priorities for mitigation. Additional seismic vulnerabilities might be predicted by a complete assessment and retrofit of the entire seismic force resisting system. Criteria for full-building assessment and retrofit include engineered methods such as ASCE/SEI 41 and simplified methods such as FEMA P-50.

Although site soil hazards can affect dwelling seismic performance, assessment and retrofit of these hazards are not required by this prestandard. Non-mandatory Appendix S briefly introduces the most common of these site soil hazards. The intent is to inform users of the potential dwelling performance where seismic risks exist, and to inform users of available tools to determine the potential for and level of risk at a dwelling site. Where site soil hazards exist and the hazard is high, very significant damage can occur to dwellings in an earthquake. At the same time, the cost of mitigating site soil hazards can be significantly higher than the cost of retrofits provided in this prestandard. The prestandard is developed on the basis that significant improvements in seismic performance and safety can occur when retrofits in this prestandard are implemented with or without site soil hazards also being addressed. This is to ease the concern that requiring assessment and retrofit of site-soil hazards would deter owners from implementing retrofit, thereby leaving vulnerable dwellings unaddressed.

C.1.10 Administrative Provisions

It is the intent of this prestandard to defer to the extent possible, to the administrative provisions already being used by the local building department. The following are items specific to retrofit work.

Documentation of existing dwellings is necessary in order to develop a retrofit design. As a minimum, it is necessary to develop a plan at the level of retrofit work, to reflect overall dimensions (in enough accuracy to allow development of retrofit design) and configuration, and identify locations where retrofit can be installed. It is also necessary to determine the details of framing configurations in order to select appropriate retrofit details.

Materials of construction (roofing, interior and exterior finishes) need to be

identified in order to make a detailed weight takeoff for engineered design, or categorize the dwelling weight of construction for prescriptive designs.

Construction documents acceptable to the local building department must be developed to document the intended retrofit work. Requirements for construction documents may vary between building departments. Volume 2, *Prescriptive Plan Set* provided in association with this prestandard illustrates a suggested minimum level of retrofit design documentation. Supplemental information may be required by some building departments.

In addition to the testing requirements already addressed by the administrative provisions of the local building department, the supplemental provisions in Chapters 4 and 5 are needed to address installation of *tie-downs* in existing foundations of unknown dimensions and strengths.

C.2 Definitions, Notation, and Abbreviations

C.2.1 Definitions

The following provides background information regarding selected defined terms.

Base-level diaphragm. The term base-level diaphragm was first introduced in hillside retrofit provisions developed by the City of Los Angeles in order to specifically identify the diaphragm that was intended to be anchored to the uphill foundation. It is generally the lowest occupied floor, and it generally extends to all edges of the building footprint. Where there are multiple diaphragms that might be considered a base-level diaphragm, the lowest diaphragm that extends to the uphill foundation should be selected.

Braced wall line and braced wall panel. These terms are as used in the 1994 and 1997 Uniform Building Code (UBC), and are provided for use in Section 8.5.1 assessment of existing ground story bracing only.

Bracing wall. This term is used generically for framed walls, new or existing, prescriptive or engineered, pre- or post-retrofit that provide bracing to cripple wall stories or garage stories.

Chimney, exterior. An exterior chimney is differentiated for purposes of this prestandard, because the type of seismic hazard and resulting assessment and retrofit methods differ based on whether the chimney is exterior or interior. Where the chimney is exterior such that at least one wall of the chimney can be seen on the dwelling exterior over at least one story height, this adds modes of failure where the chimney can fall away from the dwelling, and at the same time increases access for retrofit.

Chimney, interior. Interior chimneys are those that do not qualify as *exterior chimneys*.

Crawlspace dwelling. The primary attribute of a crawlspace dwelling, as addressed by this prestandard, is a dwelling with a wood-framed floor at the lowest occupied story and a crawlspace beneath. See Figure C.2.1-1.



Figure C.2.1-1 Crawlspace dwelling.

Crawlspace wall. The term crawlspace wall includes the varying materials that can occur at the crawlspace perimeter, including concrete, masonry, and wood light-frame walls. Framed crawlspace wall is generally used by this prestandard in conjunction with hillside dwellings, however the term may be used interchangeably with cripple walls.

Cripple wall. Although not stated in the definition, for purposes of this prestandard, cripple walls are wood light-frame walls. This prestandard generally uses the term cripple wall in conjunction with crawlspace dwellings and stud wall heights up to 7'-0". The term may, however, be used interchangeably with crawlspace wall.

Cripple wall clear height. See Figure C.2.1-2 for illustration of cripple wall clear height.

Cross-slope loading. Cross-slope loading is identified as being perpendicular to the out-of-hill loading. This means that it is parallel to the uphill foundation. Because the base shear of this dwelling type is primarily resisted at the uphill foundation, cross-slope loading causes torsion or

rotation of the dwelling, with the base-level diaphragm cantilevering horizontally from the uphill foundation.

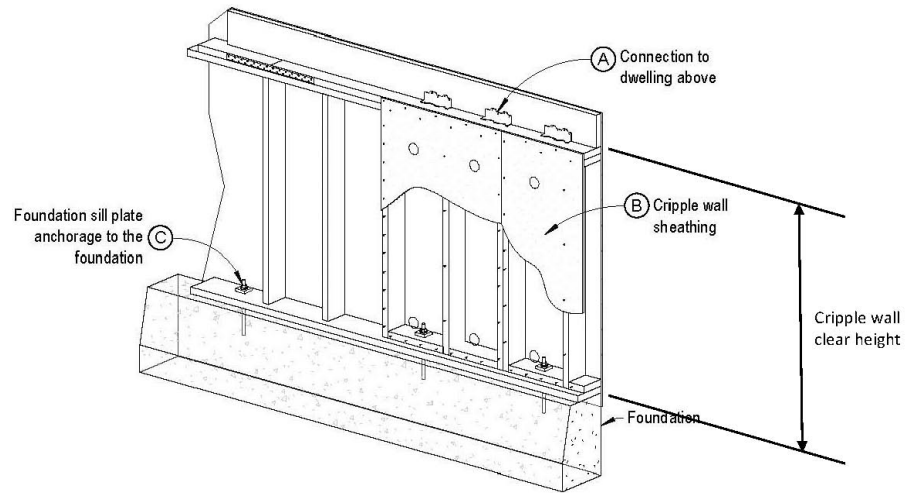


Figure C.2.1-2 Illustration of cripple wall clear height.

Ground-story residential unit. This term is used to differentiate types of living-space-over-garage dwellings. In order to qualify as a ground-story residential unit for purposes of this prestandard, a ground story occupied space must have finishes on the interior face of exterior walls and interior walls that were constructed substantially in conformance with the code at the time of installation. The residential space can be from original construction or from an alteration. The strength and stiffness provided by these interior walls and finish materials and their anchorage to the foundation are relied on for seismic bracing of these dwelling types. Where there is question as to the general adequacy of installation, removal and replacement of the alteration work should be considered.

Hillside dwelling. A hillside dwelling, as addressed by this prestandard, is best described as a dwelling built over (as opposed to into) a moderate to steep hillside. This is most commonly a dwelling in which the main occupied floor (base-level diaphragm) is directly connected to the uphill foundation along one side, then cantilevers out over a descending grade toward the opposite side (Figure C.2.1-3). The area below the base-level diaphragm is unoccupied and can be enclosed by cripple walls or be open (with gravity support using a post and beam system). How the unoccupied area is enclosed and supported is key to understanding hillside vulnerability. The unoccupied space often has little or no bracing wall, but there is usually ample access to install retrofit elements.



Figure C.2.1-3 Hillside dwelling.

The other primary configuration built on moderate to steep hillsides is the dwelling built into the hillside. This configuration often has either a garage or an occupiable space at the lowest level. This dwelling will generally not have the hillside vulnerability addressed by this prestandard. A dwelling of this second type could have other vulnerabilities, including some addressed by this prestandard.

In addition to the base-level diaphragm, a hillside dwelling can have additional partial diaphragms at lower levels, splitting the unoccupied crawlspace into several different areas. With this configuration, the retrofit provisions of this prestandard would be applied to anchorage of the base-level diaphragm. Supplemental anchorage of lower partial diaphragms to their foundations might also be prudent.

Living-space-over-garage. This term includes several types of dwellings in which living space occurs over a garage or a portion of the dwelling

originally constructed as a garage. This term captures the dwellings in which all of the living space occurs at an upper level over a garage story, as shown in Figure C.2.1-4. In this dwelling type, the garage story may be unfinished and still used as a garage and utility area, or may have been partially or fully converted to a ground story residential unit. This term also captures dwellings where a portion of the upper level living space occurs over the garage, as seen in Figure C.2.1-5.



Figure C.2.1-4 Living-space-over-garage dwelling.



Figure C.2.1-5 Living-space-over-garage dwelling.

Load-path connection. For each new or existing retrofit element, load-path connections attach the element to the dwelling, and transfer seismic forces into and out of the element. Without adequate load path connections, retrofit

elements are not able to effectively improve the performance of the dwelling. Load path elements include anchorage to the foundation and *connectors* (shear clips) to the framing above.

Out-of-hill loading. This term addresses loading in the direction that would push the dwelling into the uphill foundation or pull the dwelling away from the uphill foundation. In spite of the “out-of-hill” terminology, the load must be considered to act in both towards and away from the hill.

Primary anchor. Primary and secondary anchors are used in combination to anchor hillside dwelling base-level diaphragms to uphill foundations.

Anchors with smaller seismic forces may be threaded rods connected to the foundation and the base-level diaphragm. Anchors with larger load may use structural steel elements or new concrete grade beam elements, also connected to the foundation and the base-level diaphragm as required to resist design loads. The scope of retrofit for primary anchors, as specified in Section 6.5.4.1, includes *load path connections* between the base-level diaphragm and the primary anchor chord/collector element, the design of the chord/collector element, and the anchorage of the chord/collector element to the uphill foundation

On a simple rectangular base-level diaphragm, one primary anchor is located at each end of the uphill foundation. Where more complex base-level diaphragm configurations add offsets or transitions at the uphill foundation, additional primary anchors are added at each offset or transition. The term primary anchor comes from the City of Los Angeles hillside building retrofit provisions (LADBS, 1994).

Retrofit elements. Each of the major elements of the seismic force-resisting system is termed a retrofit element. Load path connections are required to transfer seismic forces into and out of each retrofit element.

Secondary anchor. Primary and secondary anchors are used in combination in anchorage of hillside dwellings to uphill foundations. Secondary anchors are installed between primary anchors at regularly spaced intervals. The term secondary anchor comes from the City of Los Angeles hillside building retrofit provisions. The scope of retrofit for secondary anchors, as specified in Section 6.5.4.2, includes load path connections between the base-level diaphragm and the secondary anchor chord/collector element, the design of the collector element, and the anchorage of the collector element to the uphill foundation.

Uphill foundation. Primary and secondary anchors are used in combination in anchorage of hillside dwellings to uphill foundations. The uphill

foundation is viewed as the primary seismic force load path for the hillside dwelling. This is based on the existing foundation being the stiffest load path, and generally of substantial construction adequate to resist forces. The vulnerability-based assessment and retrofit provisions of this prestandard do not require retrofit of the uphill foundation. This is in part because the vulnerability being addressed is the separation of the dwelling from the uphill foundation rather than the strength of the foundation itself.

Weight classification. Weight classifications are assigned for use in the prescriptive retrofit design provisions of Chapters 4 and 5 of this prestandard. The classifications have been developed as a function of the type and therefore, weight of roofing material, exterior wall finish, and interior wall finish. Dwelling weight classification is one of the primary parameters determining applicable prescriptive retrofit designs. See Chapters 4 and 5 for further details.

C.2.2 Notation

This notation is used in the retrofit provisions of Chapters 4 through 7.

C.2.3 Sources of Definitions

Portions of the text in this prestandard have been excerpted from other sources, either with or without modification. Excerpted text is noted with the source in brackets. A notation is provided where the text has been modified. This information is provided as an aid to users, and to facilitate future updates of the prestandard.

C.2.4 Abbreviations

Figures in this prestandard include abbreviations commonly used in construction documents.

C.3 Minimum Construction Requirements

This chapter is intended to serve as a resource for retrofits designed in accordance with Chapters 4 through 7. Minimum construction requirements are primarily taken from the IRC. Some requirements have been added or modified as required to serve the purposes of this prestandard.

The provisions of this section are provided as a convenience with the objective of having all provisions contained in this prestandard. Where it is preferred, it is acceptable to use the provisions of the locally adopted building or residential code. No edition of the building or residential code is noted, as it is more important to defer to local adoption.

The provisions of Chapter 3 are not intended to be used in conjunction with assessment of existing construction. Assessment provisions are contained in Chapters 4 through 8.

C.3.1 General

Existing Construction. Where retrofit work will be installed, it is important for existing damaged or deteriorated materials in the vicinity of the retrofit work to be corrected, because such elements will no longer be accessible for repair following the retrofit. Although it is desirable for other damaged or deteriorated materials found in the course of assessment and retrofit to be repaired or replaced, this requirement narrowly focuses on materials that will be fastened to or enclosed by retrofit work.

C.3.2 Materials

This section provides minimum standards, strengths, and dimensions of materials of construction, substantially consistent with the IRC and IBC.

Sawn lumber. It is anticipated that the majority of retrofit work performed using this prestandard will use sawn lumber incorporated into existing wood framing. Douglas fir-Larch is noted as acceptable, as it is commonly used in the western states. Because fastener capacity is based on framing specific gravity, any framing species with a specific gravity the same or higher is acceptable.

Preservative treated lumber. AWPA U1 Use Category 4B is the lowest treatment category that is provided for structural members that will be in moist environments.

Commonly used preservative treatments are known to be highly corrosive in moist environments. For this reason, any fastener or connector in contact with preservative treated wood is required to be hot-dipped galvanized, or of equivalent durability. Even with this precaution, fasteners and connectors in contact with preservative treated wood can have a limited life span and should be checked periodically for corrosion.

Pressure preservative treatment of some species including Douglas fir-Larch has limited penetration into the framing member, creating a shell at the member exterior of approximately 1/4-inch thick. Any cuts, notches, or bored holes will penetrate through this treated shell, exposing untreated wood. AWPA M4 provides direction for field treatment of cuts, notches, and bores in order to restore some level of decay resistance.

Wood structural panel sheathing. Both plywood and oriented strand board (OSB) are permitted to be used for retrofits in accordance with this prestandard, provided exposure ratings are met. Composite panels are not permitted. Deterioration of both sheathing and the supporting framing can occur in damp crawlspaces. Susceptibility to deterioration is not considered to be significantly different between plywood and OSB when oriented vertically so that water can drain off. Where the dampness of the crawlspace is a potential concern, a *registered design professional* should be consulted.

Cold-formed steel. This section is provided for use with Chapter 7 construction of new *flue* chases. Cold-formed steel studs should not be included in wood light-frame walls for purposes of retrofit in accordance with this prestandard.

Minimum fastening. Minimum fastening of retrofit installation is incorporated into prestandard figures. Where fastening for associated work is not provided, fastening should be not less than the minimum fastening table provided in Figure 3.2-1, reprinted from the IRC.

Connectors. Connectors are most commonly proprietary cold-formed steel devices, widely available through a number of manufacturers. This prestandard provides minimum required capacities for the connectors in Chapters 4 through 6, allowing a user to choose an appropriate connector from a catalog. As part of choosing a connector, it is important that it is rated for the load direction intended by this prestandard.

Structural steel. This section is provided for use with Chapters 5 and 6. For Chapter 5 steel retrofit columns, use of ASTM A36 steel is not permitted. Steel must conform to ASTM A572 or ASTM A992.

Post-installed anchors. Post-installed anchors for use with this prestandard are limited to adhesive anchors and concrete screw anchors. Expansion anchors are not permitted, as expanding the anchors can damage or spall the foundation into which they are being installed. Use of concrete screws can be problematic in weaker existing concrete. Where weak concrete is suspected, the provisions of this prestandard require a torque test to verify adequacy. Adhesive anchors are required for tie-downs, where used.

Proprietary shear walls. This section is provided for use with Chapter 5. Proprietary shear walls are one of the permitted methods of bracing and are most likely to be used at the front and back of garages. The criteria noted are used by the manufacturer to develop load and deflection information, used for selection of an appropriate shear wall type for either prescriptive or engineered retrofit design. Proprietary elements used are limited to wood or

cold-formed steel shear panels, as these are consistent with the studies used to develop the retrofit criteria, and the detailing developed.

C.3.3 Installation

This section provides minimum standards for installation of materials of construction.

Notching and boring. These criteria are provided to limit notching and boring of either new framing members being added as part of the retrofit, or existing framing members in the immediate vicinity of the retrofit. Existing utility lines, such as electrical and water, sometimes require relocation during retrofit installation. The notching and boring limitations will help limit damage to framing.

Anchor bolt installation. In *crawlspace dwelling* and *hillside dwelling* cripple wall retrofits, it is intended that anchor bolts (or retrofit anchors) be provided over the full length of each perimeter cripple wall. In *living-space-over-garage* dwellings, it is anticipated that required anchor bolts will be distributed across the extent of each bracing wall.

Fasteners. Splitting of framing members during installation of nails can be a significant problem in older framing members. The issue is particularly acute where nails are very closely spaced (2 and 3 inches on center sheathing edge nailing), and where nailing into a short framing member (short studs or blocking). The wood design standards require predrilling of nail holes where splitting of framing is found to be an issue. It is often not possible to know if this will be an issue prior to start of retrofit construction. Further, when nailing is associated with installation of retrofit sheathing, it can be difficult to observe members after nailing is completed. For this reason, caution is warranted during installation. The need to predrill applies equally to sheathing nailing and nailing for connectors (especially if connector nailing coincides with edge nailing).

Special inspections. This section addresses work intended both to require special inspection and to not require special inspection.

Welding of structural steel, whether in a fabrication shop or in the field, will always require special inspection.

Special inspection in accordance with the adopted building code is required for retrofit of hillside dwellings. This is because the seismic demands on these elements are higher and more critical than other retrofit types, and the hillside configuration makes detailing and execution of work more difficult and more varied.

Concrete foundations for which the design does not rely on a strength greater than 2,500 psi are generally exempted from special inspection. This does not prohibit providing stronger concrete; it only limits the design basis. This limit on design strength has been incorporated into the prescriptive designs of this prestandard, and it is anticipated that concrete will be exempt from special inspection, including: inspection of rebar, inspection of concrete placement, and concrete strength testing.

Installation of adhesive anchors and concrete screws for anchor bolts are not intended to require special inspection. Installation of adhesive anchors for tie-down bolts are not intended to require special inspection provided anchors pass a specified torque test. Torque tests should be done with caution. Torque loads in Table 4.4-1 and Table 5.4-1 should not be exceeded, and they should only be applied after the appropriate cure time has occurred per manufacturer's instructions.

Wood structural panel shear walls are not intended to require special inspection, even though nails are spaced between 2 and 4 inches on center. This is because the work can reasonably be included in a building department inspection. Where the building department is not able to provide this inspection, triggering of a special inspection is recommended.

C.4 Vulnerability-Based Assessment and Retrofit of Crawlspace Dwellings

C.4.1 General

This chapter addresses assessment and retrofit of the lateral force-resisting system within the crawlspace that includes the existing foundation system, attachment of the foundation sill to the foundation, bracing of the cripple wall (Configuration A), and the attachment of the first occupied floor framing to either the top of a cripple wall (Configuration A) or the foundation sill (Configuration B).

The term vulnerability-based is used here to reinforce the concept that only the seismic force-resisting components within the crawlspace are assessed and potentially retrofitted. It is recognized that other deficiencies and vulnerabilities may exist in the structure above or adjacent to the crawlspace or in the foundation and soils beneath the crawlspace. Experience in historic North American earthquakes as well as analytical studies have demonstrated the high vulnerability of unbraced cripple walls and inadequately anchored mudsills. Retrofit of this single vulnerability will significantly improve the overall performance of the single-family building stock in future earthquakes.

The intent of the prestandard is to provide the user with three assessment methods as described in Section 4.3, as well as vulnerability-based prescriptive retrofit solutions where certain conditions are met, and a vulnerability-based simplified engineered retrofit procedure to be used for situations where the prescriptive solutions are not appropriate. The user of this prestandard may choose to omit the assessment stage and proceed directly to the retrofit stage.

Based upon extensive numerical studies as well as research on typical superstructure archetypes that both considered median and a reasonable lower bound superstructure strengths, it is considered unlikely that a particular crawlspace could be over-strengthened using these provisions and thus force serious damage into the superstructure. A more complete discussion of these numerical studies and research into superstructure archetypes can be found in the companion Volume 3, *Background Documentation*.

Figure C.4.1-1 presents a flowchart depicting the intended use of the prestandard for assessment and retrofit of cripple walls and anchorage in crawlspace dwellings. This flowchart is a companion to Figure C.1-4, which illustrates how this chapter is used within the context of the entire prestandard. The initial step in the flowchart points the user to Section 1.8 in which three eligibility criteria must be verified for a dwelling to qualify for use with this prestandard. These eligibility criteria are repeated within Tables 4.1-1 and 4.1-2. The first table provides eligibility criteria that must all be verified or compliant to use this Chapter. Table 4.1-2 provides additional eligibility criteria that also must be verified to be compliant to use the prescriptive provisions within this chapter. The Table 4.1-2 eligibility criteria define the assumptions that were made during the development of the prescriptive solutions and therefore must be followed in order for the solutions to be valid.

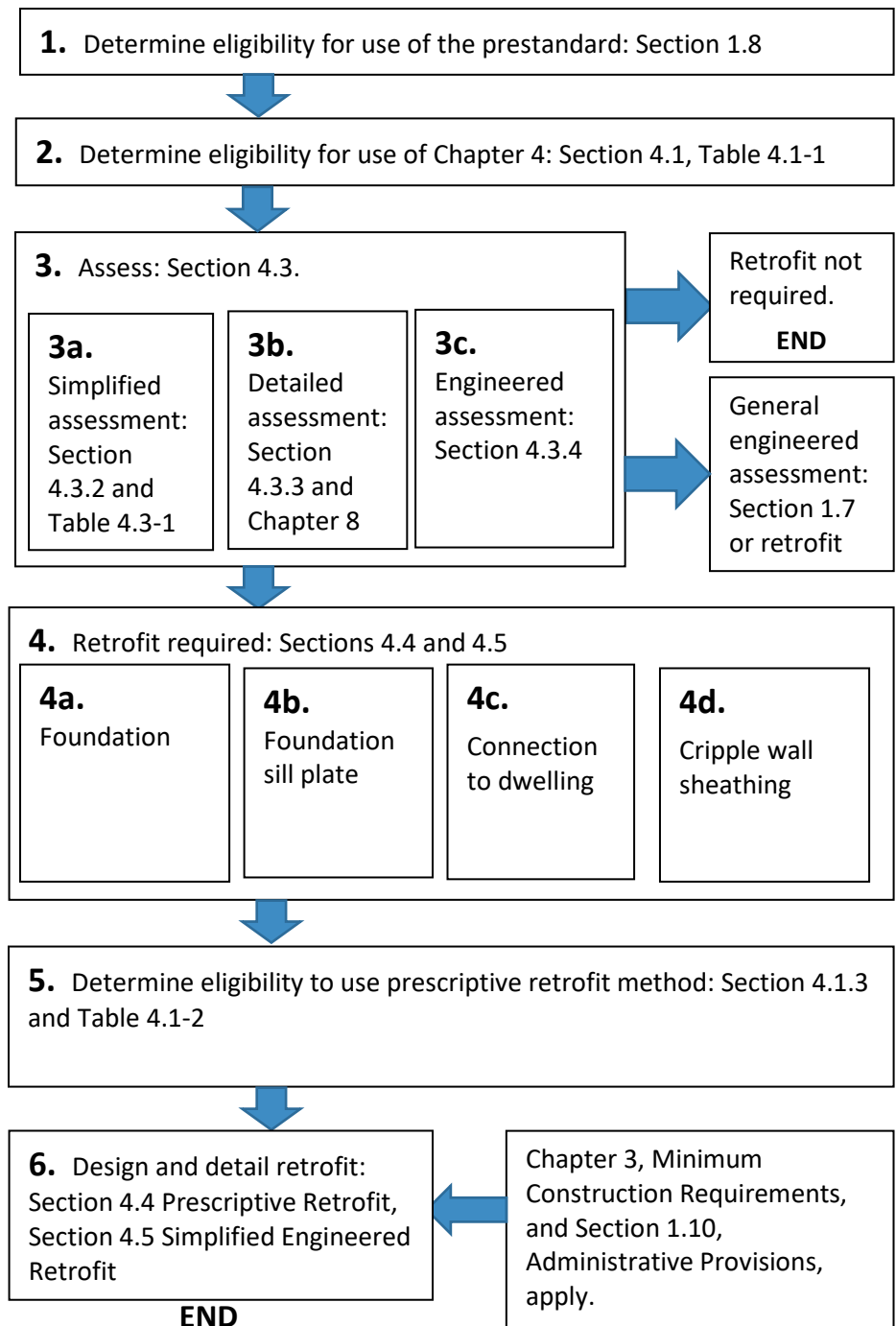


Figure C.4.1-1 Flowchart for use of Chapter 4 provisions.

C.4.2 Definitions and Minimum Requirements

See Chapter 2 and Chapter 3 commentary for further information.

C.4.3 Vulnerability-Based Assessment

C.4.3.1 Scope

A simplified prescriptive assessment procedure and a detailed prescriptive assessment procedure are available for the user. The simplified prescriptive assessment procedure by nature is more conservative and intended as an expedited check to determine whether existing conditions are acceptable, specific components require retrofitting, or whether a detailed assessment should be done. The detailed assessment procedure is still prescriptive by nature, but may require a registered design professional to complete.

No calculations are anticipated to be completed as part of the detailed assessment procedure. The general intent of the detailed assessment procedure is to grandfather in those original construction conditions such as the IEBC Appendix Chapter A3 or retrofits that include certain detailing that have been deemed to provide adequate safeguards although possibly less substantial than a retrofit provided in accordance with this prestandard, against these vulnerabilities.

Compliance with the vulnerability-based objective of this prestandard may also be verified by a registered design professional where it can be demonstrated through assessment including calculations that the existing foundations, foundation sill anchorage, cripple wall bracing (if present), and the connection of the existing first floor to the top of cripple wall or foundation sill are in compliance with this prestandard. Compliance will include demonstrated equivalence to the engineered retrofit procedure included within Section 4.5 and not the assumed lesser standards that may have been grandfathered in under the simplified or detailed assessment methods.

Although not covered within this prestandard, a homeowner may always opt to have a general engineered assessment, as discussed in Section 1.7.

C.4.3.2 Simplified Assessment

The simplified assessment method looks at six items contained in four specific configuration areas including the foundation system, the cripple wall sheathing and construction (where occurs), the anchorage of the foundation sill to the foundation, and the connection of the first-floor framing to the top of the cripple wall or foundation sill.

The flowchart presented in Figure C.4.3-1 provides an overview of the simplified structural assessment method that is intended to systematically address each one of these critical components and includes four steps that

must all be completed. At each step, the user will answer “Yes,” “No,” or “Don’t Know.” “Yes” generally signifies the particular component is acceptable, while “No” or “Don’t Know” require a detailed assessment per Chapter 8 or the particular condition to be retrofit. Presumably, there may be some components that are deemed acceptable, while others which may not. Each component deemed unacceptable must be retrofit, while those which are deemed acceptable need not be retrofitted. The only exception to this is that if a cripple wall requires new or additional wood structural panel sheathing, all other components must also be retrofitted in accordance with Sections 4.4 or 4.5.

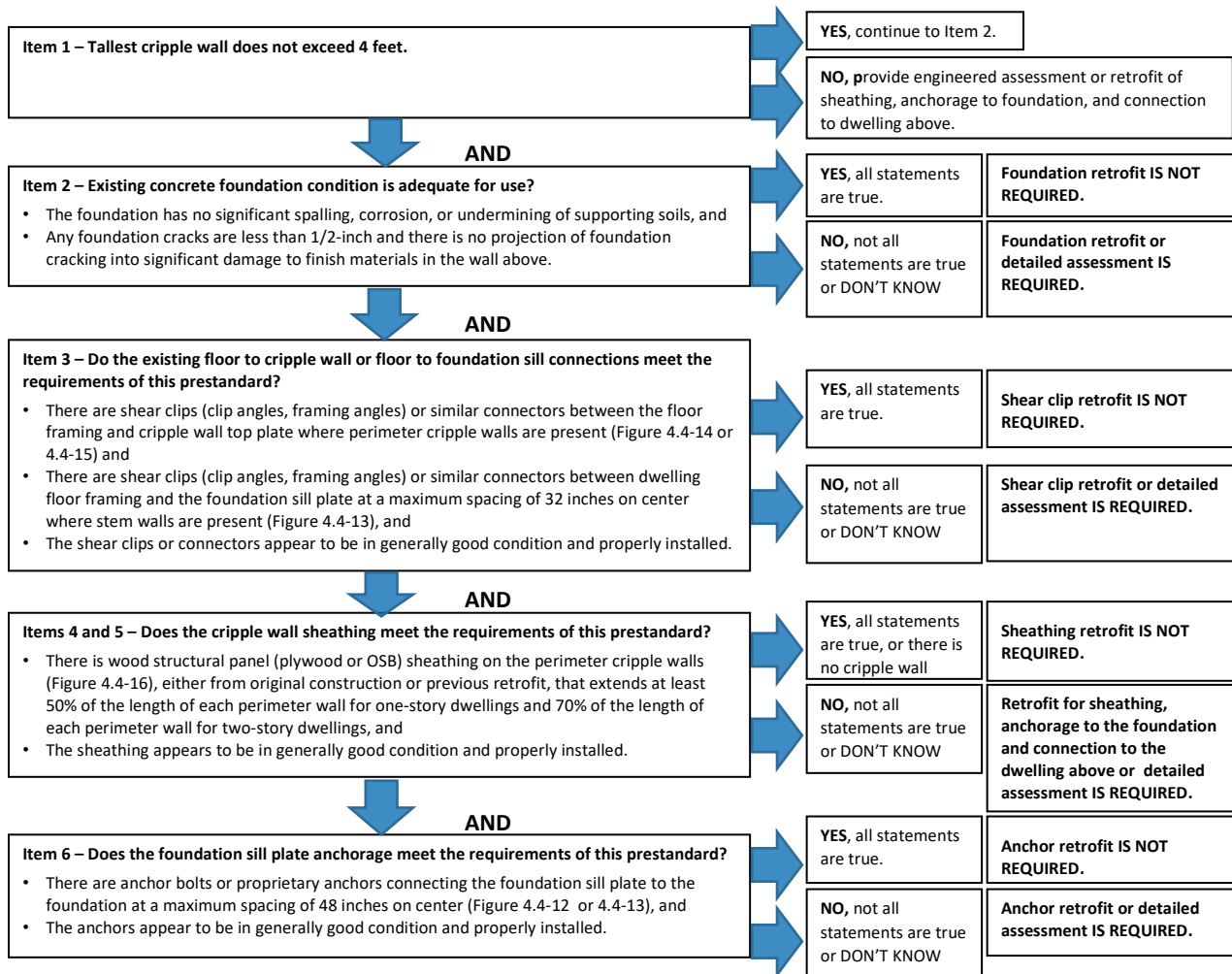


Figure C.4.3-1 Overview of the simplified assessment procedure.

With respect to foundations, the key concern is whether the existing foundation is stable and whether retrofit anchors for the mudsill can be reliably connected to the foundation. Virtually all foundations will have cracks, some spalling of concrete, corrosion of embedded steel, and possibly areas of eroded soil. If the concrete surface is visibly deteriorated, a detailed

assessment should be performed to determine if the underlying concrete can hold retrofit anchors. Cracks or localized soil erosion should generally not trigger a foundation retrofit or preclude a cripple wall retrofit as long as reliable attachment of the mudsill to the foundation can be achieved. Cracks, localized soil erosion, and differential settlement of a dwelling may indicate ongoing soil instability that should prudently be evaluated prior to initiating a cripple wall retrofit.

C.4.3.3 Detailed Assessment

See Chapter 8 commentary for further information.

C.4.3.4 Engineered Assessment

An assessment by a registered design professional (Architect or Engineer) may be used in lieu of the simplified or detailed assessment where the eligibility criteria within Section 1.8 and Table 4.1-1 are met. Compliance will include demonstrated equivalence to the engineered retrofit procedure included within Section 4.5 and not those standards that may have been grandfathered under the simplified or detailed assessment methods.

The findings of any assessment, whether it be the simplified, detailed or one by a registered design professional must be *approved* by the building official.

C.4.4 Prescriptive Vulnerability-Based Retrofit

C.4.4.1 Scope

This section includes four items: (1) the foundation; (2) *foundation sill plate* anchorage to the foundation; (3) cripple wall sheathing; and (4) the connection of first floor to the top of cripple wall or foundation sill below. Where retrofit of cripple wall sheathing is required, the improvement of anchorage to the foundation and connection to the dwelling above are also made mandatory, whether or not they were triggered by assessment. This additional retrofit scope is mandated in order to make the capacity of the load path generally equivalent to the capacity of the retrofitted cripple wall. Without this measure, the retrofitted cripple wall might not reach the intended performance.

C.4.4.2 Determination of Seismic Design Category

The vulnerability-based prescriptive retrofit procedures within this prestandard have been developed for three unique levels of seismicity. These include S_{DS} values of 1.0, 1.2, and 1.5 as described in Section 1.6. As indicated within the Earthquake Retrofit Schedules in Figures 4.4-6 through 4.4-11, the requirements for cripple wall sheathing and anchorage generally become greater with increasing levels of seismicity but may also vary

slightly for some elements based upon a dwelling weight classification of the dwelling. One such condition may be overturning where for some home sizes and cripple wall heights, the weight of exterior finishes may offset computed uplift forces. Where actual S_{DS} values for a particular dwelling are greater than that indicated in the selected Earthquake Retrofit Schedule, the Earthquake Retrofit Schedule of increased seismicity must be used.

C.4.4.3 Determination of Weight Classification

Three unique weight classifications, heavy, medium, and light construction, have been developed for use with the prescriptive procedures of this prestandard. These are shown in Figure 4.4-1 and include items that are assumed to be easily identifiable. The determination of a particular dwelling's weight classification begins with the identification of the exterior finishes with choices of either stucco and plaster or lighter materials such as horizontal wood siding or shingles. Notes within the figure address other finish types that may be found. After this determination, the roofing material and the interior finishes are identified. It should be noted that the type of the interior finishes has a significant influence on the overall seismic weight or mass of a particular dwelling, which in turn significantly influences seismic forces and the required retrofit.

For the purposes of the prescriptive design presented, interior finishes are assumed to be the same for interior wall and ceiling systems. It is anticipated that many dwellings may include a mix of both exterior and especially interior finishes, particularly where some remodeling has occurred and plaster over wood lath or gypsum board has been replaced by gypsum. Where 25% of the exterior finishes are comprised of a heavier type of finish such as stucco or plaster, these finishes should be used in Figure 4.4-1 to determine the overall weight classification.

C.4.4.4 Foundations

Vulnerability-based prescriptive retrofit procedures have been developed for existing continuous foundations constructed with either concrete or reinforced masonry. Unreinforced brick masonry (URM) or unreinforced concrete block masonry and unreinforced stone foundation systems must be evaluated by a registered design professional through the simplified engineered retrofit procedure of Section 4.5.

In many cases, an existing foundation of unreinforced brick and possibly unreinforced stone may be deemed acceptable without replacement, especially where only shear anchors are installed. Registered design professionals should generally look for signs of significant defects or

deterioration in existing foundations that would preclude installation of adequate retrofit anchor bolts between the sill and foundation.

C.4.4.5 Foundation Sill Plate Anchorage to the Foundation

No commentary provided.

C.4.4.6 Cripple Wall Sheathing

No commentary provided.

C.4.4.7 Additional Requirements for Cripple Walls with Tie-Downs

Cripple wall retrofits that utilize new tie-down anchors must meet additional verification and testing requirements outlined in Section 4.4.7. These additional visual verification and testing requirements begin with footing size. After the check on geometry is performed, additional testing verification is required to also ensure that the concrete is in reasonably good shape and to finally verify that tie-down anchors can develop bonding capacity of the adhesive. Self-certification is required either by the home owner of the general contractor within Table 4.4-1. In order to keep costs affordable, the visual and testing verification contained within this chapter are not intended to be exhaustive, and are deemed justifiable partially due to the low capacities assumed for tie-down resistance used within this prescriptive design procedure. The owner or general contractor are always encouraged to utilize greater length of sheathing where possible to avoid use of tie-downs but this is not always possible.

C.4.4.8 Connection to Dwelling Above

Figures 4.4-14 through 4.4-15 provide many common retrofit details used to create a direct and visible connection between the first occupied floor framing and the top of existing cripple wall or the foundation sill where no cripple wall is present. Although not specially engineered, it is likely that some connection already exists at these locations within existing dwellings based upon earlier construction practices; however, these connections vary widely based upon area and age, and are very difficult to verify. For that reason, these details have been provided to ensure that a complete load path is provided.

C.4.4.9 Additional Requirements for Non-Rectangular Dwellings with Plan "T" or "L" Configurations

Most dwellings are not rectangular and include plan re-entrant corners or notches. For the purposes of this prestandard, cripple walls are generally assumed to occur only along the exterior of the dwelling perimeter and

calculated seismic forces are assumed to be distributed equally to each or the two perimeter walls in each direction even where offsets occur. An exception to this rule is made where the offset is greater than 33% of the perimeter wall length as indicated in Figure C.4.4-1. The exception is made to provide a greater safeguard where diaphragms may be somewhat more flexible in plane relative to the newly sheathed perimeter cripple walls and where additional strengthening is deemed appropriate.

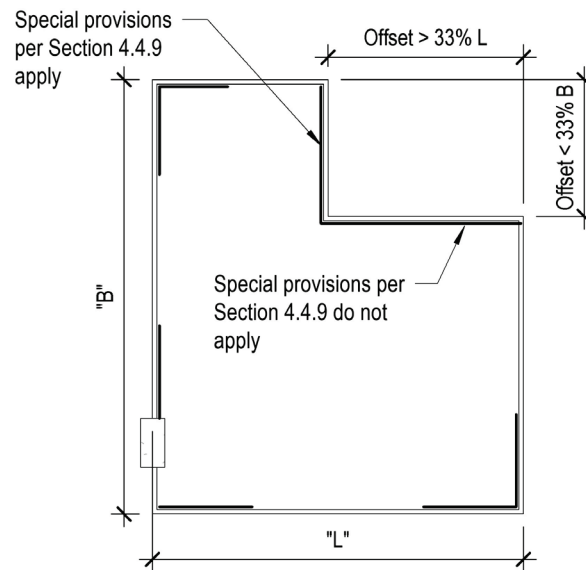


Figure C.4.4-1 Plan with offset walls.

C.4.4.10 Special Provisions for One-Story Homes with Clay Tile Roofing

Dwellings with heavier clay tile roofing occur commonly. However, older clay tile roofing can weigh 18-20 psf and as such, have been scoped out of previous retrofit provisions due to this weight. Numerical studies used to develop this prestandard, while extensive, did not specifically address these heavier roof systems. However, this prestandard did address a sufficient amount of one- and two-story heavy type dwelling configurations which effectively induce similar horizontal seismic demands onto the cripple walls and as such, these very common dwellings have been included for the single-story conditions into both the prescriptive and engineered design procedures within this prestandard. This has conservatively been done by requiring the same level of strengthening or retrofitting that would be required for a two-story dwelling of twice the ground floor area with a heavy weight classification.

C.4.4.11 Commentary for Prescriptive Vulnerability-Based Retrofit Assumptions Made in Section C.4.4

The following section lists all significant assumptions used for the development of the prescriptive retrofit approach developed within this prestandard. This includes all provisions and figures within Section 4.4, as well commentary in Section C.4.4. The intent of listing the assumptions here is so that a registered design professional can assess whether modification of these assumptions could benefit any particular home that may require engineering work. The assumptions are as follows:

- The roof slope was taken as 6:12 for weight calculations. If the roof of the particular building has a lesser slope, the building may be lighter than the building used in the prescriptive calculations.
- Gable walls are assumed to exist on the shorter side of the building.
- The interior partition length was taken as 80% of the exterior wall length for weight calculations for all floor levels. If the particular building has fewer partitions, it may be lighter than the building used in the prescriptive calculations.
- Unit weights in non-mandatory Appendix L were used for weight calculations. If different building materials are used in the particular building, it may be lighter or heavier than the building used in the prescriptive calculations. For heavy and light second floor construction 2 psf and 1 psf, respectively, were included for tile (this represents 33% and 17% coverage with 6 psf for tile). For all first floor construction, 2 psf was used. If no floor tile or 100% floor tile exists in the particular building, the floor weights for the particular building will be lighter or heavier than the building used in the prescriptive calculations.
- The overturning moment used to determine tie-down forces for cripple walls was calculated using 30% of the global overturning moment associated with the mass of the building above the first floor. This assumption is based on data from Fischer et al. (2001). The global overturning moment for two-story buildings was calculated as the sum of individual story weights times story heights, without vertical distribution as required by the building code. The total overturning moment used for tie-down forces was calculated using the combined global overturning moment above plus the total base shear times the cripple wall height.
- The floor-to-floor height was taken as 9 feet for weight calculations. If the roof of the particular building has taller floor heights, the building may be heavier than the building used in the prescriptive calculations.

Additionally, taller floor-to-floor heights will increase the overturning moment.

- The building was taken as rectangular with an aspect ratio (plan width to length) of 3/4 for weight calculations. Use of the actual plan shape and/or aspect ratio of the particular building will likely result in a different weight and wall panel lengths than the building used in the prescriptive calculations.
- The area of second floor was taken as equal to the area of first floor. If the second floor of the particular building has a smaller plan area than the first floor, the building may have a different weight than the building used in the prescriptive calculations. Additionally, the overturning moment used in the prescriptive calculations will be larger than the overturning moment for the particular building.
- Exterior walls have openings for windows and doors that generally will reduce their weight. The reduction in weight is smaller for the lighter walls because the window and door weights approach those of the walls with the lighter finishes. Percent openings in exterior walls was taken as equal to 20%, 15%, and 0% for heavy, medium, and light exterior walls, respectively. If actual percent openings and weights of windows and doors are calculated for a particular building, the weight determined for exterior walls may be different from the weight used in the prescriptive calculations.
- Interior partition walls have openings for windows and doors that generally will reduce their weight. The reduction in weight is smaller for the lighter partition walls because the door weights approach those of the walls with the lighter finishes. Percent openings in interior partition walls was taken as equal to 20%, 10%, and 0% for heavy, medium, and light interior walls, respectively. If actual percent openings and weights of doors are calculated for a particular building, the weight determined for interior partition walls may be different from the weight used in the prescriptive calculations.

C.4.5 Simplified Engineered Vulnerability-Based Retrofit

C.4.5.1 General

Item 1. This section permits a retrofit to address only the cripple wall and anchorage vulnerability (foundation sill anchorage and connection of the first floor to the top of cripple wall or to the foundation sill) without identifying or addressing other aspects of the dwelling construction or load path that might not conform to current building or retrofit codes. This is permitted because

the elimination of a cripple wall vulnerability is recognized to greatly improve the seismic performance of a significant portion of the existing building stock. Assessment and retrofit of other aspects of the dwelling is always permitted, just not required.

Items 2 and 3. It is intended that retrofit design use ASCE/SEI 7 Section 12.14, Simplified Alternative Structural Design Criteria for Simple Bearing Wall or Building Frame Systems, in combination with the seismic design parameters (R and Ω_0) of this section. The R -factor of 4.0 given in Item 3 is different than that assigned by ASCE/SEI 7 for new construction. This is because the R -factor of Item 3 has been developed based on performance-based numerical studies of the specific performance of cripple walls in wood light-frame dwellings. These studies identified lower R -factors and therefore higher seismic design forces to be needed for this use. As such, retrofit designs developed using other criteria, including the ASCE/SEI 7 seismic design parameters, shall not be identified as conforming with this prestandard. Volume 3, *Background Documentation* provides further detail of retrofit design derivation.

Item 4. It is required that adequate cripple wall sheathing be provided to resist the entire calculated cripple wall demand using the simplified procedure and the seismic design parameters (R and Ω_0) of this section. The beneficial effects of existing finish materials have already been considered in the numerical modeling from which the R -factor was determined.

Item 5. The prestandard has incorporated the use of overstrength factors into the vulnerability-based prescriptive and simplified engineering design procedures of Chapters 4 and Chapter 5. The overstrength factor is used for design of the load path into and out of the retrofit elements (i.e., connections). This is intended to help ensure that the peak capacity of the retrofit elements can be developed without the load path acting as a weak link. In some cases, elements, such as the cripple wall sheathing, have been increased to reduce anticipated uplift forces. For these cases, the design for connectors such as anchor bolts or floor to framing clips will have an effective Ω_0 factor of less than 1.5. This is deemed acceptable based on numerical studies described in the background documents of the prestandard.

For a retrofit to achieve the targeted performance, it is important that load path connections for the cripple walls (i.e., anchor bolts and shear clips) have capacities balanced with the cripple wall capacity. This will make it unlikely that the load path connections will be a weak link and fail prior to the cripple walls reaching peak capacity. The use of an overstrength, Ω_0 , factor provides balance between the load path connections and cripple wall capacity. It is

intended that design for the load path connections uses forces based on ASCE/SEI 7 Section 12.14.3.2.2 seismic load effects including overstrength, in combination with the strength design load combinations of ASCE/SEI 7 Section 2.3.6 or allowable stress design load combinations of ASCE/SEI 7 Section 2.4.5. The resulting strength or ASD demands are intended to be compared to strength or ASD capacities in accordance with ANSI/AWC NDS and ANSI/AWC SDPWS, consistent with current design practice.

Although the overstrength factor is intended to be used in exactly the same way as in ASCE/SEI 7, the derivation of the factor for this prestandard is different, and based on numerical studies. The overstrength factor has been back-calculated to achieve the balance capacity condition discussed above. This has been done using peak capacities of the cripple walls, anchor bolts, and shear clips available from testing. The companion Volume 3, *Background Documentation* provides further detail.

Item 6. As discussed in Section C.4.4.7, where tie-downs are used within a cripple wall retrofit, additional visual verification and testing must be completed to provide additional safeguards that the existing foundation systems can develop these local anticipated uplift forces. In practice, the length of sheathing along cripple walls are often artificially increased to offset calculated uplifts at the ends of the sheathed segments. This procedure while deemed appropriate often led to calculated lengths of sheathing that did not fit within the available lengths along a particular wall line. This was particularly the case for rectangular floor plans where the raised cripple wall portion had an aspect ratio greater than 4:3.

Item 6 is intentionally left somewhat vague in order to give the registered design professional some degree of latitude in assessing an existing foundation and for developing appropriate capacities for resistance. The requirements contained within Section 4.4.7 that were developed for the prescriptive procedures, can be reviewed for guidance.

C.4.5.2 Additional Simplifying Assumptions

The assumptions of this section are intended to ensure that the engineering design remains simple in effort both to quantify demands and to distribute forces and retrofit elements. These simplifying assumptions are believed adequate for the great majority of existing dwellings. In circumstances where the dwelling incorporates unusual materials, or an unusual configuration, more detailed quantification and modeling may be required.

Item 1. To provide an engineered retrofit design, it is necessary to perform a weight take-off for the dwelling. Representative unit weights are provided in

non-mandatory Appendix L to give guidance on commonly occurring assembly weights and to provide consistency with the application for engineered retrofits.

Items 2 and 3. Two different simplifying assumptions are permitted to be used for distribution of wood structural panels on cripple walls. Where offsets are not greater than 33% of the maximum wall length, these items permit seismic demands to be proportioned to the wall lines with offsets, based upon relative wall lengths.

Where offsets are greater than 33% of the maximum plan dimensions, this simplification may not be appropriate, and the registered design professional should consider diaphragm in-plane flexibility, as interior offset walls might attract and benefit from greater lengths of wood structural wall panel sheathing or connection strengthening than would be proportioned simply upon relative lengths.

Even where cripple walls or connections between the floor and foundations are strengthened, floor diaphragms particularly with traditional floor coverings are generally considered to act as rigid in plane compared to the cripple walls, so deformation demand on the cripple walls will be close to uniform even where offsets exist. Although there might be some separation between center of mass and center of stiffness, resulting in torsion, this condition is considered negligible and should not adversely influence the seismic performance of the dwelling. This method of distribution is considered to be most constructible and most easily implemented. Where offsets are greater than 33% of the maximum plan dimensions, the registered design professional must consider diaphragm flexibility and exercise reasonable judgment regarding the relative distribution of calculated seismic demands.

It is recognized that some offset wall lines greater than 33% of the maximum plan dimensions may be relatively short and where diaphragms are considered to act closer to flexible, may not have ample length for required wood structural panel bracing or required connections. For these cases, the design professional is encouraged to sheath as much length as possible and to also add new anchor bolts or clips to develop the capacity of this sheathing. These assumptions are considered appropriate for the vulnerability-based approach of this prestandard.

Item 4. While this prestandard utilizes a vulnerability-based approach that only addresses the strengthening of the cripple wall level, it is reasonable to assume that some degree of uplift demands could be imparted on the cripple

wall level from the superstructure above. This phenomenon is very complex to evaluate, as most existing dwellings were not originally engineered to have direct floor-to-floor ties as well as a full height designated seismic force-resisting system. In practice, uplift forces that might be developed on the cripple wall from the structure above from simplified engineering assumptions varied extensively, and were often either ignored or addressed by reducing the dead load resistance above.

As this prestandard is vulnerability-based, it was also not deemed practical or necessary for a design professional to accurately survey the walls within the occupied levels for each particular superstructure in order to demonstrate the presence of an existing and dedicated vertical load path for these non-engineered dwelling. Rather, it was deemed appropriate to develop a reasonable and simplified engineering approach where prescriptive designs could be implemented and if necessary, where a registered design professional could generally account for some reasonable level of overturning forces from the superstructure into the cripple wall level.

The method presented within Item 4 has been developed based upon large-scale shake table building tests conducted at University of California, San Diego (Fischer et al., 2001) where wall lines and anchors (anchor bolts and tie-downs) were directly instrumented. These tests concluded that the actual force distribution imparted to the structure's base from the superstructure above was conservatively based upon the typical engineering assumption where all direct shear and overturning demands are applied only to the in-plane walls in the same orthogonal direction. Instead, a box-type phenomenon was observed where the majority of the tension and compression forces were resisted by the wall lines perpendicular to the direction of loading. This box-type distribution was estimated to generally have a ratio of about 70% applied to the perpendicular walls and 30% to the walls parallel to and at the top of the cripple wall. This leads to the use of 15% per wall line as there is assumed to be two equal and exterior walls lines within the same direction as shown in Figure C.4.5-1. Additional information is available within Volume 3, *Background Documentation*.

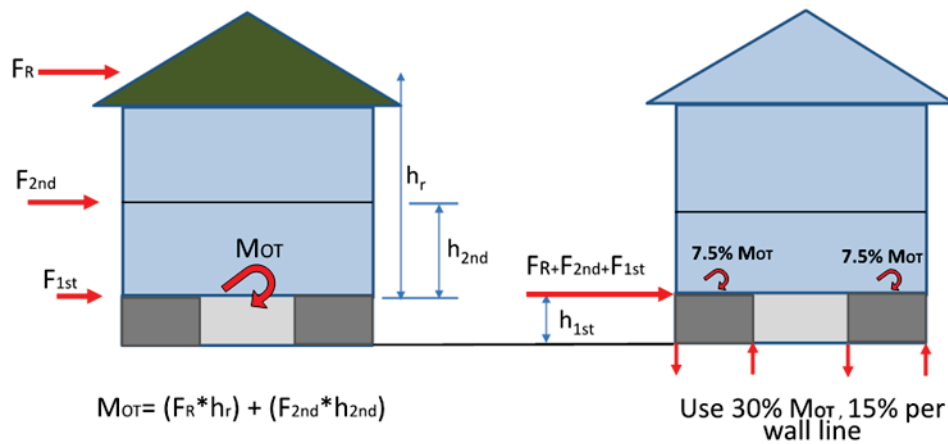


Figure C.4.5-1 Simplified assumptions for overturning.

C.5 Vulnerability-Based Assessment and Retrofit of Living-Space-Over-Garage Dwellings

C.5.1 General

This chapter addresses assessment and retrofit of ground story *bracing walls* in *living-space-over-garage* dwellings. This dwelling type and vulnerability are introduced in the Chapter 1 commentary, and the term *living-space-over-garage* is defined in Chapter 2 and discussed in the Chapter 2 commentary. Figure C.5.1-1 provides a photo of a commonly occurring *living-space-over-garage* dwelling configuration.



Figure C.5.1-1 Example of living-space-over-garage dwellings.

This prestandard provides the user with multiple vulnerability-based assessment methods as described in Section 5.3, and vulnerability-based retrofit methods as provided in Sections 5.4 and 5.5.

The user of this prestandard may choose at any time to omit assessment and proceed directly to retrofit.

The purpose of this prestandard is identified in this section and Section 1.2 to be the reduction of earthquake-induced damage in wood light-frame dwellings. The primary focus of the retrofit provisions is reduction of damage in the ground story and related safety hazards. The term vulnerability-based is used here to reinforce that assessment and retrofit scope is limited to the ground story bracing walls and their load-path connections, even if other vulnerabilities exist.

Commentary to Section 1.2 discusses background studies performed in the process of developing the retrofit provisions of this prestandard. In the case of the living-space-over-garage dwellings, numerical studies supporting the development of this prestandard identified that the retrofit provisions included in the prestandard are anticipated to significantly improve the seismic performance of this dwelling type, and significantly reduce possible risk to life. Based on the numerical studies, it is further considered unlikely that a ground story would be over-strengthened using these provisions to the extent that damage in the occupied upper stories would be significantly increased. A more complete discussion of the numerical studies can be found in the companion Volume 3, *Background Documentation*.

Figure C.5.1-2 provides a flowchart depicting intended use of the prestandard for assessment and retrofit of ground story bracing walls in living-space-over-garage dwellings. This flowchart is a companion to Figure C.1-4, which illustrates how this chapter is used within the context of the prestandard. The initial step in the flowchart points the user to Section 1.8 in which three eligibility criteria must be true for a dwelling to qualify for use of this prestandard. These eligibility criteria are repeated in Tables 5.1-1 and Table 5.1-2. The first table provides eligibility criteria which must all be verified or compliant to use this chapter. Table 5.1-2 provides additional eligibility criteria that also must be true or compliant to use the prescriptive retrofit provisions of Section 5.4. The Table 5.1-2 eligibility criteria define the assumptions that were made during the development of the prescriptive solutions and therefore must be followed in order for the solutions to be valid.

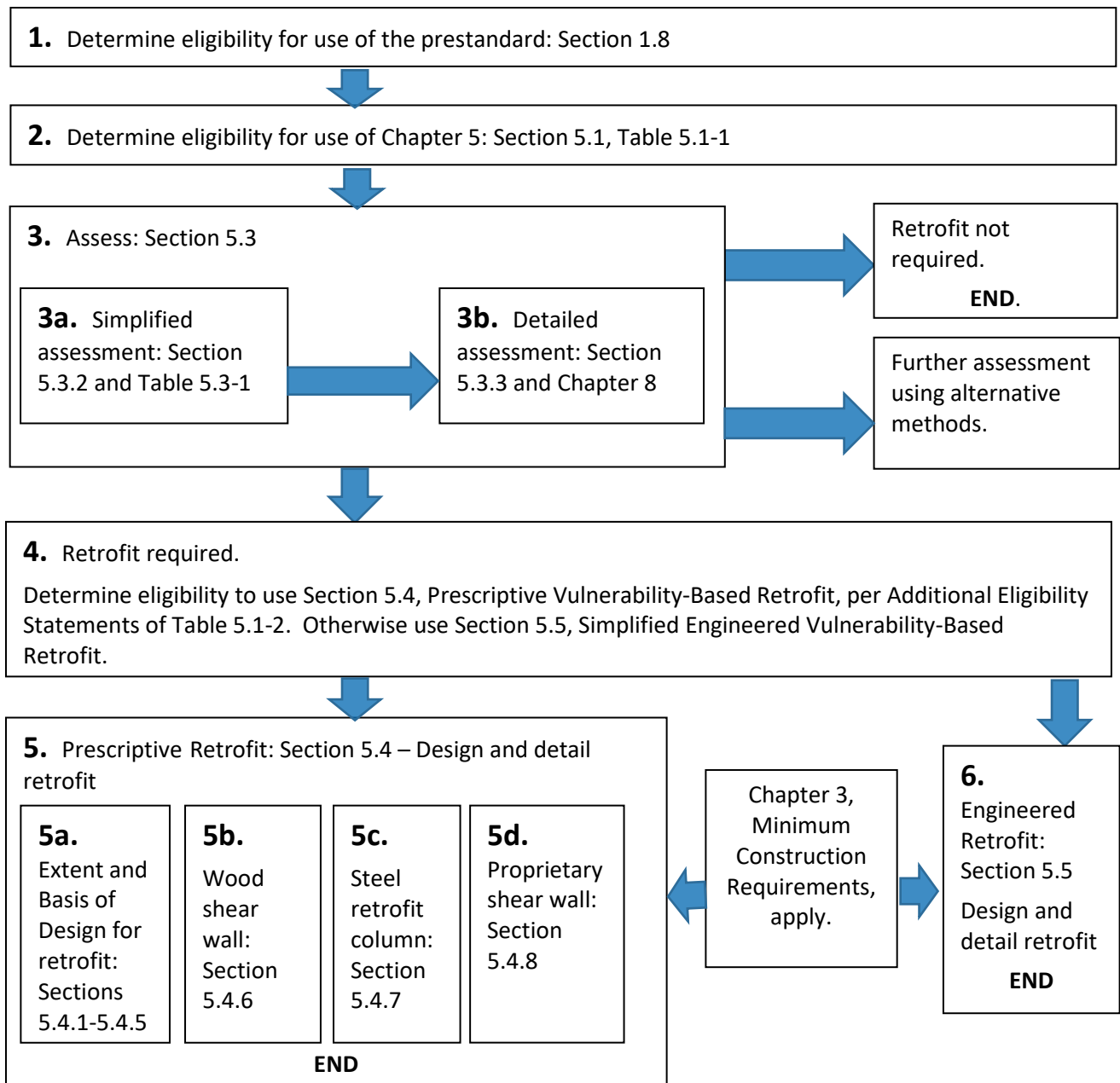


Figure C.5.1-2 Flowchart for use of Chapter 5 provisions.

C.5.2 Definitions and Minimum Requirements

See Chapter 2 and Chapter 3 commentary for further information.

C.5.3 Vulnerability-Based Assessment

C.5.3.1 Scope

Three vulnerability-based assessment methods are available for the user: simplified assessment, detailed assessment, and engineered assessment. The

simplified assessment is intended as an expedited check to determine whether existing conditions are compliant, require retrofit, or whether a detailed assessment should be made. The detailed assessment is still prescriptive in nature, but gives more detailed information by which compliance can be judged. Compliance with the vulnerability-based objective of this prestandard may also be verified by an engineered vulnerability-based assessment in which a registered design professional demonstrates compliance of existing conditions.

The general intent of the vulnerability-based assessment procedures is to grandfather in those original construction conditions and bracing elements that have been deemed to provide adequate ground story bracing though possibly less substantial than a retrofit provided in accordance with this prestandard.

A homeowner may always opt to have a general engineered assessment, as discussed in Section 1.7.

C.5.3.2 Simplified Assessment

The simplified assessment method looks at the ground story bracing walls. The flowchart presented in Figure C.5.3-1 provides an overview of the simplified assessment method. The user will answer “Yes,” “No,” or “Don’t Know.” “Yes” generally signifies the particular component is acceptable, while “No” or “Don’t Know” require a detailed assessment per Chapter 8 or retrofit. If deemed unacceptable, the ground floor must be retrofitted, while if deemed acceptable they need not be. As part of this simplified assessment procedure, a general conditions assessment must be undertaken where the bracing is deemed to be compliant, and no retrofit is needed. The conditions assessment can be limited to elements that are readily visible or easily accessed and does not require removal of existing finishes. This is done to make sure that the existing bracing elements were both properly installed and that this bracing, as well as members that it is attached to, are in good condition and would not compromise the anticipated seismic performance. Where existing members are deteriorated, these members must be repaired for the bracing elements to comply. Where bracing is not compliant and retrofitting is required, it is presumed that any existing elements that are deteriorated or damaged will be repaired as part of the retrofitting process. The assessment of existing conditions need only include the actual bracing members and those members which these bracing members are directly attached to. Prior to assessment, the dwelling perimeter has already been confirmed to be supported on continuous concrete foundations per Table 5.4-1.

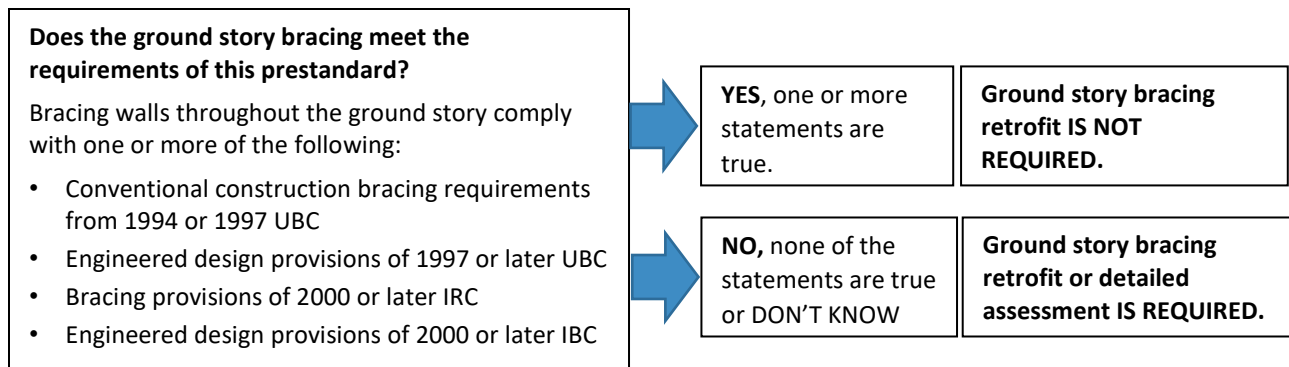


Figure C.5.3-1 Overview of the simplified assessment procedure.

The assessment is intended to quickly identify dwellings with bracing walls known to be in conformance with recent building or residential codes. This will most often be used when construction documents are available, detailing the design code and bracing.

C.5.3.3 Detailed Assessment

See Chapter 8 commentary for further information.

C.5.3.4 Engineered Assessment

An assessment by a registered design professional (Architect or Engineer) may be used in lieu of the simplified or detailed assessment where the eligibility criteria within Section 1.8 and Table 5.1-1 are met. Compliance will include demonstrated equivalence to the engineered retrofit procedure included within Section 5.5 and not those standards that may have been grandfathered under the simplified or detailed assessment methods. Like the simplified and detailed assessments, this vulnerability-based assessment addresses the ground-story bracing walls and their load-path connections.

C.5.4 Prescriptive Vulnerability-Based Retrofit

Section 5.4 applies to dwellings that meet the eligibility statements of both Table 5.1-1 and Table 5.1-2.

Ground story bracing walls are to be retrofit in accordance with Sections 5.4.1 through 5.4.8, as applicable.

C.5.4.1 Scope

Sections 5.4.1 through 5.4.8 provide prescriptive designs for retrofit of bracing walls in living-space-over-garage dwellings. Sections 5.4.2 through 5.4.5 address characteristics of the dwelling that need to be determined in order to design the retrofit. Section 5.4.5 provides descriptions of permissible types of retrofit elements and where they can be placed. Sections

5.4.6 through 5.4.8 provide sizing and details of retrofit elements and their load path connections.

The retrofit elements in this section are considered to provide reasonable and constructible retrofit design. Instances will occur, however, when modification of the detailing is needed. Section 5.4.1 allows for alternate details to be developed by a registered design professional.

C.5.4.2 Determination of Earthquake Retrofit Schedule

The vulnerability-based prescriptive retrofit procedures in this prestandard have been developed for three unique Levels of Seismicity. These include S_{DS} values of 1.0, 1.2, and 1.5, as described in Section 1.6. The requirements for ground story bracing generally become greater with increasing levels of seismicity but may also vary slightly based upon a dwelling weight classification for some elements.

As a guide to the user, Figure 5.4-1 provides an illustration of applicable retrofit figures, based on the S_{DS} value for the dwelling site. As shown, some figures apply to all S_{DS} values, while others are specific to a single S_{DS} . Note that the applicable S_{DS} is also stated in each figure in Section 5.4.

C.5.4.3 Determination of Weight Classification

Three unique weight classifications, heavy, medium, and light construction, have been developed for use with the prescriptive procedures of this prestandard. These are shown in Figure 5.4-2, and are assumed to be easily identifiable. The determination of a particular dwelling's weight classification begins with the identification the exterior finish materials with choices of stucco or lighter materials such as horizontal wood siding or shingles. Notes in the figure address other finish types that may be found. After this determination, the roofing material and the interior finishes are identified. It should be noted that the type of the interior finish has a significant influence on the overall seismic weight of a dwelling, which in turn significantly influences seismic forces and the required retrofit.

For the purposes of the prescriptive retrofit designs, interior finishes are assumed to be the same for interior wall and ceiling systems. It is anticipated that many dwellings may include a mix of finish materials, both exterior and especially interior finishes, and particularly where remodeling has occurred and plaster has been replaced with gypsum board. Where 25% or more of the exterior finishes are comprised of a heavier type of finish such as stucco, these finishes should be used in Figure 5.4-2 to determine the overall weight classification.

C.5.4.4 Determination of Building Area

The selection of a prescriptive retrofit design from the Earthquake Retrofit Schedules in Figures 5.4-7 through Figure 5.4-24 is dependent on the building area, which is a direct indicator of building weight and therefore seismic forces. For purposes of this chapter, the building area is taken as the width of the garage times the length of the dwelling perpendicular. These widths and lengths are identified in Figure C.5.4-1 through Figure C.5.4-3. For the configuration without a *ground-story residential unit*, as seen in Figure C.5.4-1, the building area encompasses the full ground story. For the configuration in Figure C.5.4-2, the building area still encompasses the full ground story, even though there is a *dwelling unit*. Credit is given in the design process for the bracing provided for the dwelling unit walls. For the configuration in Figure C.5.4-3, the building area will be less than the full ground-story area. This recognizes the bracing provided by existing walls in the occupied portions of the ground story.

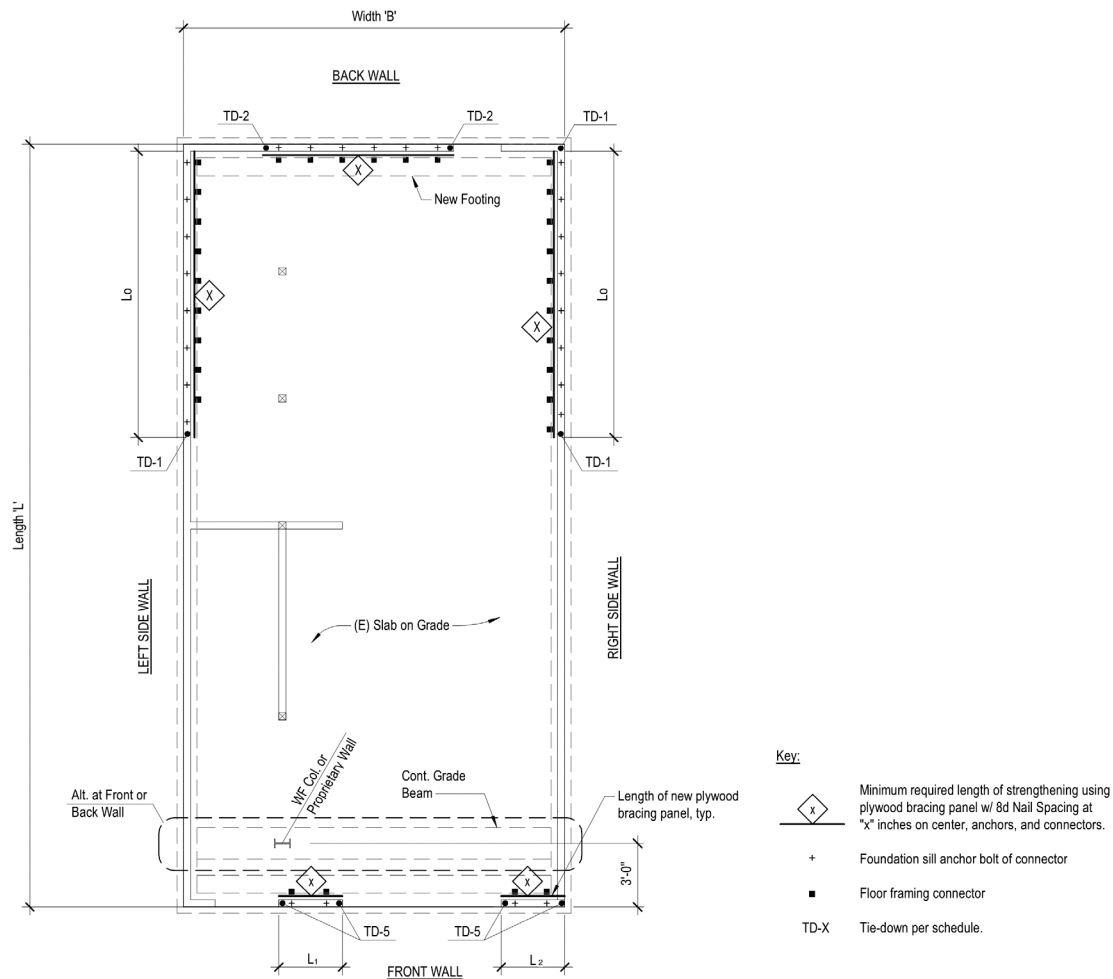


Figure C.5.4-1 Ground floor plan of living-space-over-garage dwelling without *ground story residential unit*. Retrofit encompasses entire ground story.

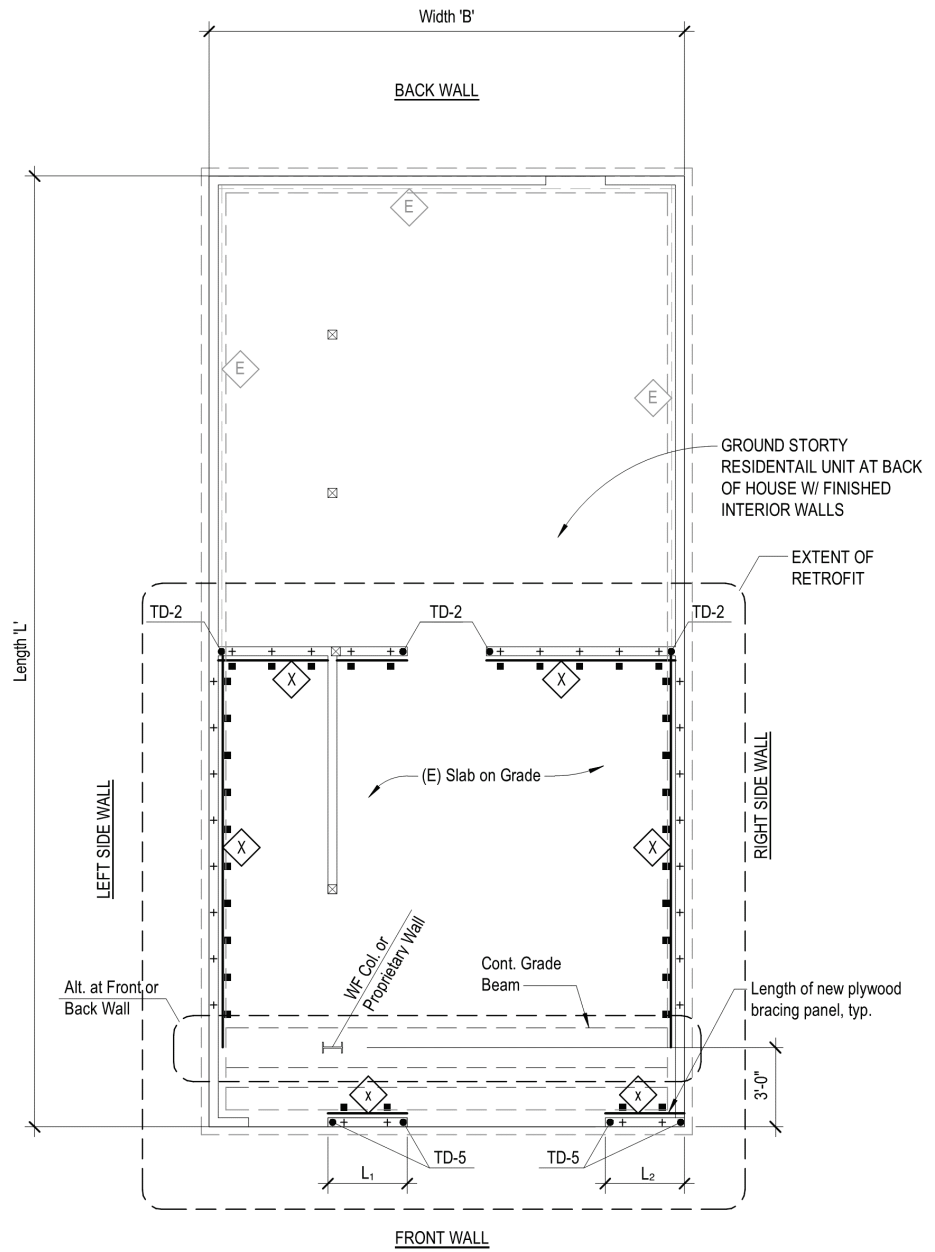


Figure C.5.4-2 Ground floor plan of living-space-over-garage dwelling with ground story residential unit. Retrofit occurs in garage area.

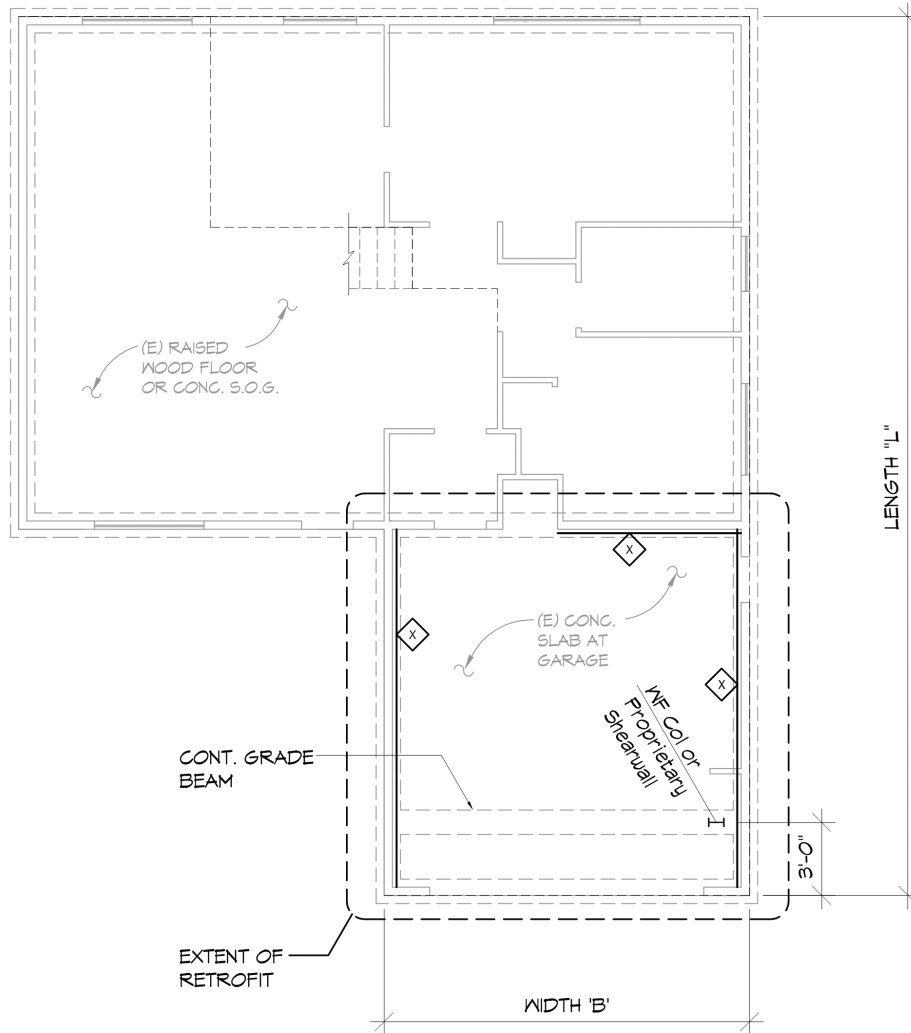


Figure C.5.4-3 Ground floor plan of living-space-over-garage dwelling with ground story residential unit. Retrofit occurs in garage area.

C.5.4.5 Determination of Building Retrofit Type

The determination of the prescriptive retrofit design is dependent on the identification of applicable retrofit type. Two retrofit types are identified based on whether the dwelling has a ground-story residential unit. Where there is no ground-story residential unit, the extent of the retrofit encompasses the entire ground story area. Figure C.5.4-1 shows a ground floor plan illustrating a dwelling with no ground-story residential unit, and also illustrating typical placement of retrofit elements. Transverse retrofit elements are provided at or within four feet of the front and back walls of the dwelling. Longitudinal retrofit elements can be provided anywhere along the length of the two side walls of the dwelling.

Where there is a qualifying ground-story residential unit, the extent of the retrofit is limited to the garage and associated storage and utility areas. Figures C.5.4-2 and C.5.4-3 illustrate two examples of dwellings with qualifying ground-story residential units, and also illustrate typical placement of retrofit elements. Transverse retrofit elements are provided at or within four feet of the front and back walls of the garage. Longitudinal retrofit elements can be provided anywhere along the length of the two side walls of the garage. See also commentary to the definition of ground-story residential unit.

Section 5.4.5 imposes some limits on the type and placement of retrofit elements, and refers the user to Sections 5.4.6 through 5.4.8 for details of the retrofit elements.

C.5.4.6 Wood Structural Panel Shear Wall Retrofit

The first retrofit element type is a *wood structural panel* sheathed shear wall. Depending on the dwelling characteristics and the length of wall available for sheathing, the shear wall can be selected with and without tie-downs and on existing foundations or new foundations.

It is generally anticipated that enough length for shear walls will be available on longitudinal walls to allow the use of existing foundations, whether with or without tie-downs.

It is anticipated that providing an adequate length of shear wall at the front and back of the dwelling is more difficult. It might be possible to use wood structural panel sheathed shear wall at the back of a garage in a dwelling with a ground-story residential unit. Where there is little wall length, it is anticipated that steel retrofit columns or *proprietary shear walls* will need to be used.

Commentary is provided for selected subsections below.

C.5.4.6.1 Tie-Downs to Existing Foundations

Shear wall retrofits that utilize new tie-down anchors in existing foundations must meet additional verification and testing requirements that are outlined in Section 5.4.6.4. These additional visual verification and testing requirements begin with footing size to ensure that the area of concrete and overall weight available are deemed adequate to resist expected uplift demands. After the check on geometry is performed, additional testing is required to help ensure that the concrete is in reasonably good condition and that tie-down anchors can develop the bond capacity of the adhesive. The visual and testing verification contained within this chapter are purposely not

exhaustive in order to keep costs affordable. This is deemed justifiable partially due to the low capacities assumed for tie-down resistance used in this prescriptive design procedure. The owner or general contractor is always encouraged to utilize greater length of sheathing where possible to avoid use of tie-downs.

C.5.4.6.2 Connection to Dwelling Above

Figure 5.4-27 provides common retrofit details used to create a direct and visible connection between the first occupied floor framing and the top of retrofit shear walls. Although not specially engineered, it is likely that some connection already exists at these locations within existing dwellings based upon earlier construction practices. Existing conditions can, however, vary widely based upon area and age, and are very difficult to verify. For that reason, these details are presented in Figure 5.4-27 to ensure that a complete load path is provided.

C.5.4.7 Steel Retrofit Column

This retrofit type is particularly useful at the front of a dwelling or garage, where there is little or no framed wall length. The steel columns included are wide-flange sections, viewed as steel cantilevered columns in accordance with AISC 341. A single column is provided at the dwelling or garage front or back, as noted in Section 5.4.5 and the applicable figures. The column will generally be set in the front or back wall by about three to four feet to allow addition of a new foundation and to prevent interference with existing electrical/gas lines. The column is cast into the foundation, per provided details, to provide a fixed moment connection at the steel retrofit column base. The steel retrofit column is not designed or intended to support gravity loading.

C.5.4.7.1 Foundation for Steel Column

The length of the column foundation is to extend the full width of the dwelling or garage, until it meets an existing perpendicular foundation at each end, to which it will be doweled with adhesive anchors. The size and detailing of the foundation are provided in the figures. The cross-section of the foundation is purposely large in order to limit the amount of steel column drift due to foundation flexure, and to help ensure that the foundation is not the weak link in the resisting element. Where the new foundation approaches existing foundations, attention should be paid to potential undermining of the existing foundation. Most existing foundations can withstand loss of bearing along a length of a couple of feet. If additional undermining is anticipated, a registered design professional should be consulted.

C.5.4.7.2 Collector for Steel Column

A collector is required at the underside of the floor system above. This collector is intended to extend the full length of the dwelling or garage. The connection of the steel retrofit column to the collector and the collector to the framing system above are both important to the performance of the steel column.

C.5.4.8 Proprietary Shear Wall Retrofit

The third retrofit element type is a proprietary shear wall. This is a pre-engineered, pre-manufactured wall of wood light-frame or cold-formed steel. This type of bracing element can provide a significant amount of strength and stiffness in a fairly short wall length. Use will require a new foundation, as well as a collector at the floor framing above.

C.5.5 Simplified Engineered Vulnerability-Based Retrofit

This section provides a simple and focused vulnerability-based method for engineered design of living-space-over-garage dwelling ground story bracing walls. The intent of the section is to minimize the time and complexity of preparing an engineered design. Direction is given to obtain seismic design forces within the context of ASCE/SEI 7 Section 12.14, while ASCE/SEI 7 criteria that are not critical to the design are exempted. In addition, rules are provided for simplifying the calculation and distribution of seismic forces. The simplified engineered provisions of this section were used to develop the prescriptive retrofit design of Section 5.4.

C.5.5.1 General

Item 1. This section permits retrofit scope to be limited to ground-story retrofit elements and their load-path connections. Retrofit elements can include wood structural panel sheathed shear walls, steel retrofit columns, and proprietary shear walls. This scope is permitted because the elimination of a living-space-over-garage vulnerability is recognized to greatly improve the seismic performance of a significant portion of the existing building stock. Assessment and retrofit of other aspects of the dwelling are always permitted, but not required.

Item 2. The building area used for calculation of seismic weight and resulting base shear is specified in the same way as the building area for prescriptive retrofits. The dimensions “B” and “L” are illustrated in Figure C.5.4-1 through Figure C.5.4-3. If a rectangle is drawn “B” wide and “L” long, any weight that falls in that rectangle at any story is considered to contribute to the seismic weight.

Item 3. It is intended that retrofit design use the Simplified Alternative Structural Design Criteria for Simple Bearing Wall or Building Frame Systems method of ASCE/SEI 7 Section 12.14 in combination with the seismic design parameters (R and Ω_0) of this section. Item 3 provides a table indicating whether or not each provision of ASCE/SEI 7 Section 12.14 is applicable, modified, or not applicable. To keep the engineered design simple, as many of the requirements as possible have been identified as not applicable.

Item 4. The R -factor of 5.0 given in this section is different than that assigned by ASCE/SEI 7 for new construction. The R -factor has been developed from performance-based numerical studies of the specific performance of living-space-over-garage dwellings. These studies identified lower R -factors and therefore higher seismic design forces to be needed for this use. Use of this R -factor also provides some flexibility to permit the simplifying assumptions of this section. Because of this difference in R -factors, retrofit designs developed using other criteria, including the ASCE/SEI 7 seismic design parameters, shall not be identified as conforming to this prestandard. The companion Volume 3, *Background Documentation* gives further detail of retrofit design derivation.

Item 5. It is required that retrofit elements be adequate to resist the entire calculated demand, ignoring finish materials. While existing finish materials are known to have a beneficial effect, this effect has already been considered in the numerical modeling from which the retrofit design method was determined.

Item 6. In order for a retrofit to achieve the targeted performance, it is important that load path connections for the retrofit elements (i.e., anchor bolts and shear clips) have capacities balanced with the retrofit element capacity. This will make it unlikely that the load path connections will be a weak link and fail prior to the retrofit elements reaching peak capacity. The use of an overstrength, Ω_0 , factor of 1.5 provides balance between the load path connections and retrofit element capacity. It is intended that design for the load path connections use forces based on the ASCE/SEI 7 Section 12.14.3.2.2 seismic load effects including overstrength, in combination with the strength design load combinations of ASCE/SEI 7 Section 2.3.6 or ASD load combinations of Section 2.4.5. The resulting strength or ASD demands are intended to be compared to strength or ASD capacities in accordance with ANSI/AWC NDS and ANSI/AWC SDPWS, consistent with current design practice. Although the overstrength factor is intended to be used in exactly the same way as current ASCE/SEI 7, the derivation of the factor for this prestandard is different, and again based on numerical studies. The

overstrength factor has been back-calculated to achieve the balance capacity condition just discussed. This has been done using peak capacities of the retrofit elements, anchor bolts, and shear clips available from testing. See companion Volume 3, *Background Documentation*, for more detail.

Item 7. This item allows the registered design professional some degree of latitude in assessing an existing foundation and for developing appropriate capacities for resistance. The requirements contained within Section 5.4.6 and those developed for the prescriptive procedures, can be reviewed for guidance.

Item 8. Many new retrofit elements, particularly those in the transverse direction, will require addition of new foundations. New foundations are to be designed in accordance with the adopted building code, using the seismic force levels specified by this section. It is intended that the retrofit foundations be stiff and strong enough to induce inelastic behavior in the vertical retrofit element rather than the foundation.

C.5.5.2 Additional Simplifying Assumptions

The assumptions of this section are intended to ensure that the engineering design remain simple in effort both to quantify demands and to distribute forces to retrofit elements. These simplifying assumptions are believed adequate for the great majority of existing dwellings. In circumstances where the dwelling incorporates unusual materials or an unusual configuration, more detailed quantification and modeling may be required.

Item 1. In living-space-over-garage dwellings without ground-story residential units, the entire ground story is generally accessible for retrofit. Where this is the case, retrofit elements are to be provided at the front wall, rear wall, and two side walls. Where each of these elements can be located within four feet of the exterior wall, the distribution of seismic forces can be justified to be reasonably equal, so it is permitted to design the retrofit elements at each wall for half of the base shear (the base shear calculated based on seismic weight per Section 5.5.1, Item 2). This division of seismic based shear for design of the retrofit elements is consistent with the project numerical studies and the intended performance target of this prestandard.

Item 2. In living-space-over-garage dwellings with ground-story residential units, the garage is accessible for retrofit. Where this is the case, retrofit elements are to be provided at the front of the garage, rear of garage, and two garage side walls. Where each of these elements can be located within four feet of the existing garage walls, it is permitted to design the retrofit elements at each garage side wall for half of the base shear, the retrofit elements at the

garage front for one quarter of the base shear, and the retrofit elements at the garage rear for one half the base shear (the base shear calculated based on seismic weight per Section 5.5.1, Item 2). This division of seismic based shear for design of the retrofit elements is consistent with the project numerical studies and the intended performance target of this prestandard.

Item 4. Although this prestandard utilizes a vulnerability-based approach that only addresses the strengthening of the cripple wall level, it is reasonable to assume that some degree of uplift demands could be imparted on the cripple wall level from the superstructure above. This phenomenon is very complex to evaluate as most existing dwellings were not originally engineered to have direct floor-to-floor ties as well as a full height designated seismic force-resisting system. In practice, uplift forces which might be developed on the cripple wall from the structure above from simplified engineering assumptions varied extensively and were often either ignored or addressed by reducing the dead load resistance above.

As this prestandard is vulnerability-based, it was also not deemed practical or necessary for a design professional to accurately survey the walls within the occupied levels for each particular superstructure in order to demonstrate the presence of an existing and dedicated vertical load path, that for these non-engineered dwelling. Rather, it was deemed appropriate to develop a reasonable and simplified engineering approach where prescriptive designs could be implemented and if necessary, where a registered design professional could generally account for some reasonable level of overturning forces from the superstructure into the cripple wall level.

The method presented within Item 4 has been developed based upon large-scale shake table building tests conducted at University of California, San Diego (Fischer et al., 2001) where wall lines and anchors (anchor bolts and tie-downs) were directly instrumented. These tests concluded that the actual force distribution imparted to the structure's base from the superstructure above did not follow a typical engineering assumption whereas all loads were applied to each orthogonal direction but rather a box-type phenomenon existed whereas a majority of these tension and compression forces were resisted by the wall lines perpendicular to the direction of loading. This box-type distribution was estimated to generally have a ratio of about 70% applied to the perpendicular walls and 30% to the walls parallel to and at the top of the cripple wall. This leads to the use of 15% per wall line as there is assumed to be two equal and exterior walls lines within the same direction as shown in Figure C.5.5-1. Additional information is available within *Volume 3, Background Documentation*.

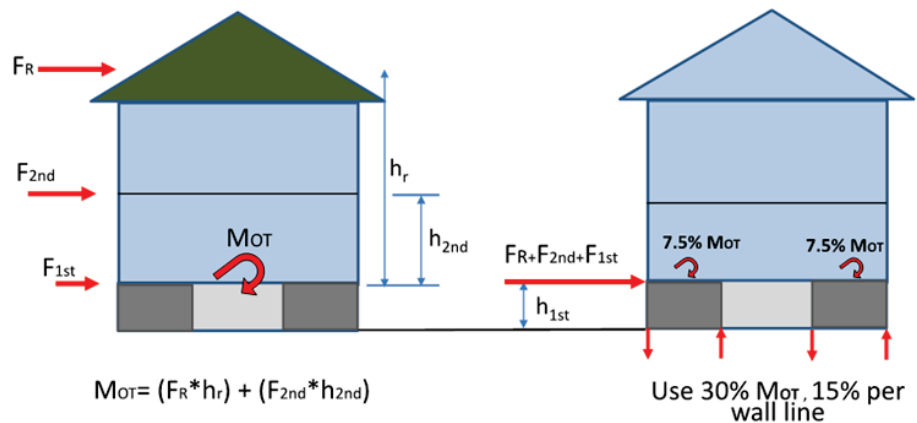


Figure C.5.5-1 Simplified assumptions for overturning.

C.6 Vulnerability-Based Assessment and Retrofit of Hillside Dwellings

C.6.1 General

The *hillside dwelling* is unique both in construction and seismic response, relative to other common wood light-frame dwelling configurations. Either the dwelling recesses into the hillside slope behind it, projects out over the hillside slope below it, as shown in Figure C.6.1-1, or in some cases, is a combination of both. Hillside dwellings that project out over the hillside often include lower partial floor levels as the dwelling steps down the slope. Foundations for dwellings projecting out over the hillside can include stepped, sloped, continuous concrete footings, with or without concrete *stem walls*, isolated spread footings, cast-in-place concrete piers or caissons, or combinations of these. Older hillside dwellings are typically entirely of wood light-frame construction above the foundation, while newer hillside dwelling construction may incorporate structural elements of steel or concrete.

This chapter addresses wood light-frame hillside dwellings where either the entire dwelling or a major portion of the dwelling projects out over the hillside, with unoccupied space below. Dwellings that recess into the hillside do not commonly have the vulnerability addressed by this chapter, but may have the cripple wall vulnerability addressed by Chapter 4 or the living-space-over-garage vulnerability of Chapter 5.

Significant damage occurred at a number of these dwellings in the 1994 Northridge Earthquake, including collapse of 13 hillside dwellings and loss of three lives (Los Angeles Times, 1997). Discussion of the earthquake response of hillside dwellings can also be found in a PEER (2000). Hillside dwellings are believed to be vulnerable due to the combination of brittle

diaphragm anchorage to the uphill foundation and inadequate strength and stiffness of crawlspace walls or other bracing below the *base-level diaphragm* (main floor). The connection of the base-level diaphragm to the uphill foundation is the stiffest load path for seismic loading, and insufficient strength can result in brittle failure of this connection in earthquakes. Failure of the anchorage to the uphill foundation can also often cause loss of gravity support, potentially initiating collapse.



Figure C.6.1-1 Example hillside dwelling.

The related primary vulnerability is the low strength and stiffness of the wood light-frame crawlspace walls (or in some cases diagonal steel bracing) below the base-level diaphragm along the sloping sides and downhill end of the dwelling. This is believed to make them unreliable sources of earthquake bracing.

The low strength of the crawlspace walls is believed to be in great part due to stiffness incompatibility within the crawlspace wall as it slopes or steps down the hillside (Figure C.6.1-2). Based on observations of damaged walls following the Northridge Earthquake (Cochran, 2018), the stepped crawlspace wall starts out as a single wall segment, but as the top of the wall is laterally loaded during the earthquake, it eventually breaks into individual segments, with the number of segments corresponding with the number of wall steps (Figure C.6-1-3). When the single wall breaks into wall segments of different heights, significant loss of strength and stiffness is believed to occur.

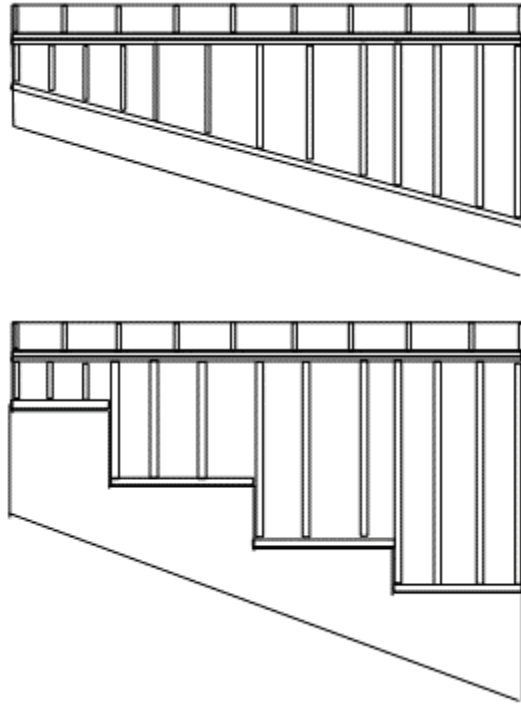


Figure C.6.1-2 Sheathed shear wall with sloped base (top) and stepped base (bottom).

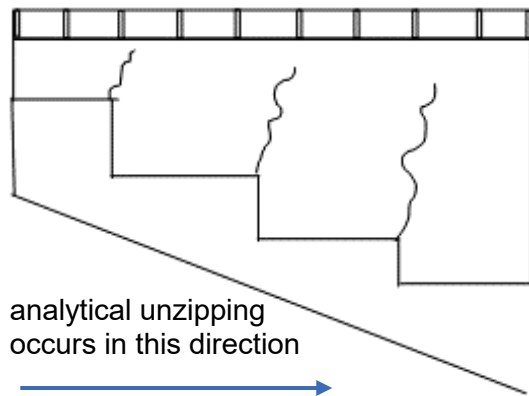


Figure C.6.1-3 Sheathed shear wall with stepped base and deflection cracks.

As part of the numerical studies serving as the basis for this prestandard, detailed analytical models of stepped cripple walls were developed. The analytical models demonstrated a behavior (term by some as “unzipping”), where the stiffest uppermost crawlspace wall segment reaches peak capacity first and then loses capacity as the next tallest step is pushed to peak capacity. This results in reduced overall capacity, and significant degradation of the shorter steps, providing some confirmation of the Northridge Earthquake observations.

Testing conducted as part of the CUREE-Caltech Woodframe Project (CUREE, 2002) did not identify reduced capacity or stiffness of moderately stepped cripple walls relative to level cripple walls. It remains possible, however, that significantly different behavior would be seen in testing of steeply stepped cripple walls, as occur with the hillside dwellings addressed by this chapter.

After the 1994 Northridge Earthquake, the City of Los Angeles Building Department adopted a voluntary retrofit ordinance, Division 94, for hillside dwellings (LADBS, 1994). This ordinance has been mandatory for all new hillside dwellings design since that time. The same ordinance has been adopted by the International Code Council Los Angeles Basin Chapter under their Los Angeles Region Uniform Code Program (LARUCP), which includes approximately 90 Southern California Jurisdictions. The retrofit provisions of this chapter are similar in concept to the Division 94 provisions, but differ in seismic force levels and detailing as a result of the numerical studies conducted as a basis for this prestandard.

Figure C.6.1-4 through Figure C.6.1-6 illustrate the main retrofit elements required by this chapter. Figure C.6.1-4a illustrates an isometric view of a rectangular plan single-story hillside dwelling, with the crawlspace below the first floor unoccupied. Figure C.6.1.4b illustrates the dwelling's crawlspace, and Figure C.1.6-5 illustrates the upper left corner of the crawl space and the seismic retrofit anchorages required by this chapter. Included are: shear anchors; *secondary anchors*; and a *primary anchor*.

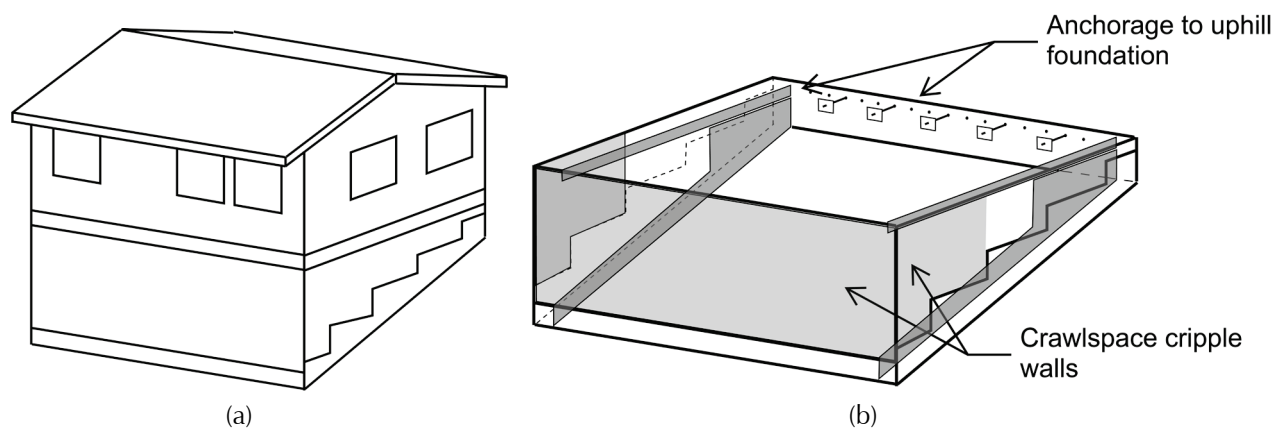


Figure C.6.1-4 Single story hillside dwelling and foundation.

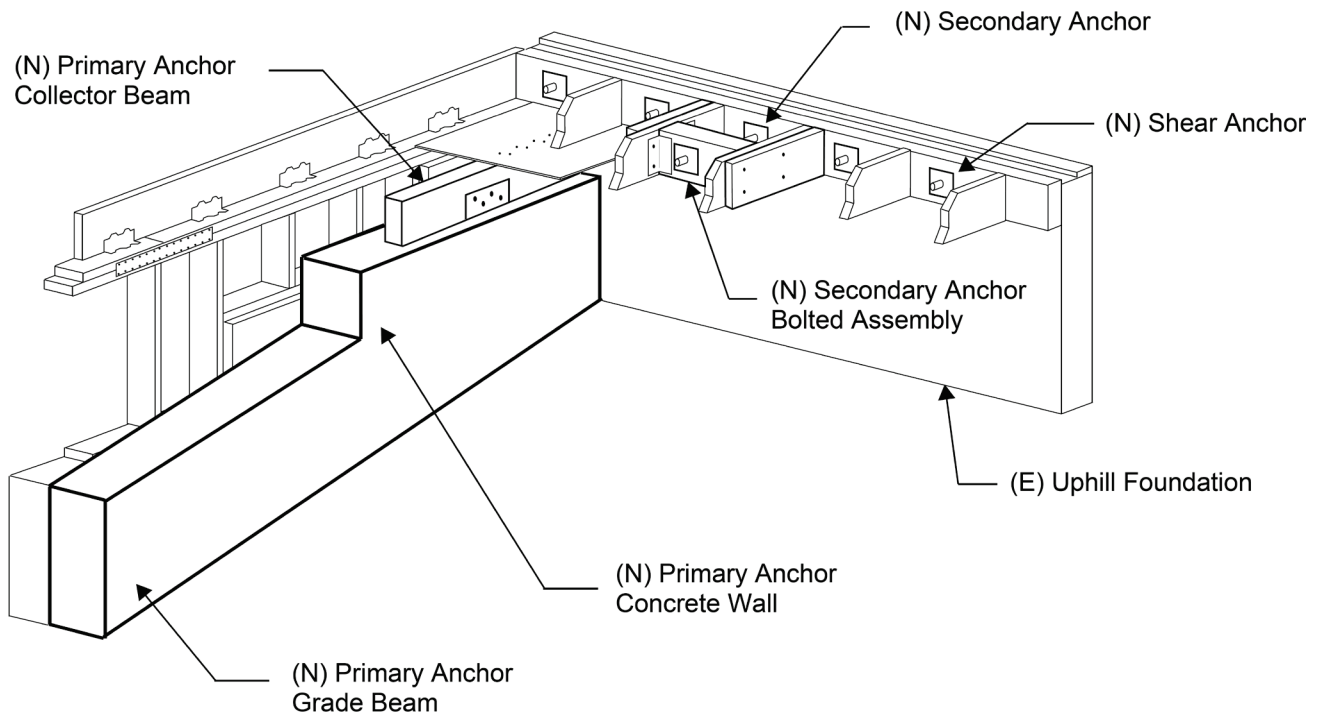


Figure C.6.1-5 Partial crawspace foundation isometric.

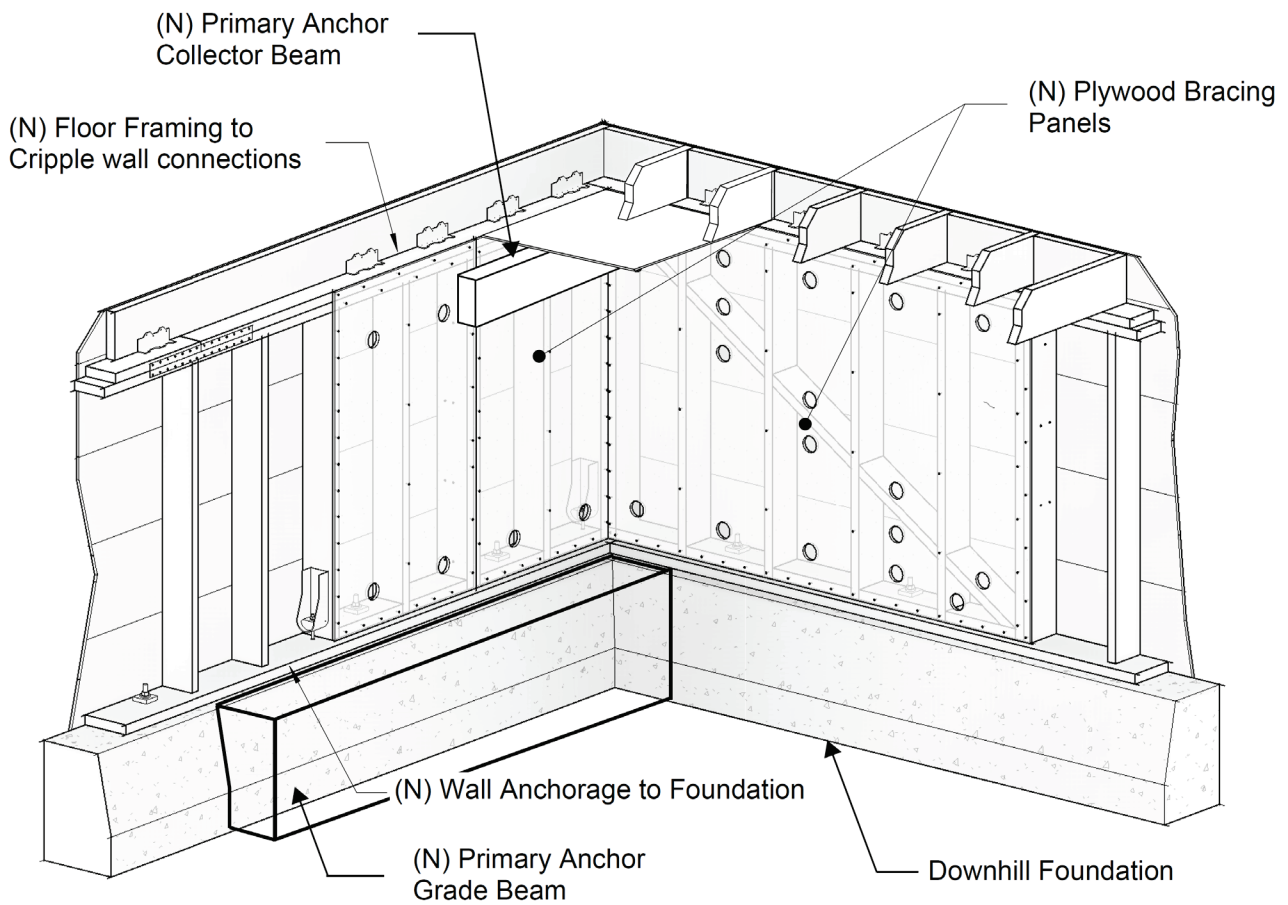


Figure C.6.1-6 Partial crawspace interior view isometric showing a portion of crawspace wall retrofit.

Figure C.6.1-6 illustrates the interior view of the lower right-hand corner of the crawlspace, showing the downhill end of the primary anchor and crawlspace wall retrofit, similar to that required by Chapter 4 of this prestandard. Initial retrofit solutions studied in the development of this prestandard relied only on anchorage to the uphill foundation. Retrofit of crawlspace walls was added because numerical studies showed retrofit of the cripple walls to reduce dwelling torsion, and consequently reduce wall damage in the occupied stories.

Chapter 6 addresses the hillside dwelling configuration in which the entire light-framed wood dwelling projects out over the hillside slope, supported by wood light-frame crawlspace walls on the sloping sides and downhill side. The uphill end of the dwelling is supported either by bearing directly on top of the foundation or on a short light-framed wood crawlspace wall supported on the foundation. Hillside dwellings having steel bracing for the lateral resisting system on one or more sides are beyond the scope of Chapter 6 of this prestandard, unless wood light-frame shear walls are added to replace or supplement the steel bracing.

In addition to the anchorage and crawlspace wall bracing provisions addressed by this chapter, existing hillside dwelling foundations can be of concern because geotechnical requirements, concrete design requirements, and hillside foundation design approaches have changed significantly since hillside homes started becoming popular after 1940s. In areas of unstable soils, shifting of entire hillside dwellings and their foundations has been observed during earthquakes, although failure of the foundation itself has not been observed.

This prestandard solely addresses the vulnerability of the anchorage of the dwelling to the foundation, as retrofit of this vulnerability is believed to significantly improve the seismic performance of the dwelling. While it may be prudent in areas of known instability, this prestandard does not require that a geotechnical assessment be performed as part of the vulnerability assessment. Requirement of a geotechnical assessment was judged by the developers of this prestandard to create an unnecessary barrier to gaining improved performance through retrofit of the highly vulnerable anchorage and crawlspace walls.

Non-mandatory Appendix S is provided to inform the user of potential hazards and resources for further information. When using this prestandard for a property that exhibits indicators of potential soil vulnerability, the user is encouraged to consider further assessment and possible retrofit to address soil vulnerability in addition to diaphragm anchorage and crawlspace wall

retrofit. In some locations, it is possible that the building department or other authority will have identified areas of site soil hazards. In general, older foundations that pre-date 1980 are considered to be of higher concern than those constructed after 1980 due to changes in foundation design and construction requirements.

The assessment approach and minimum requirements of the prestandard retrofit are depicted in the following flowchart in Figure C.6.1-7.

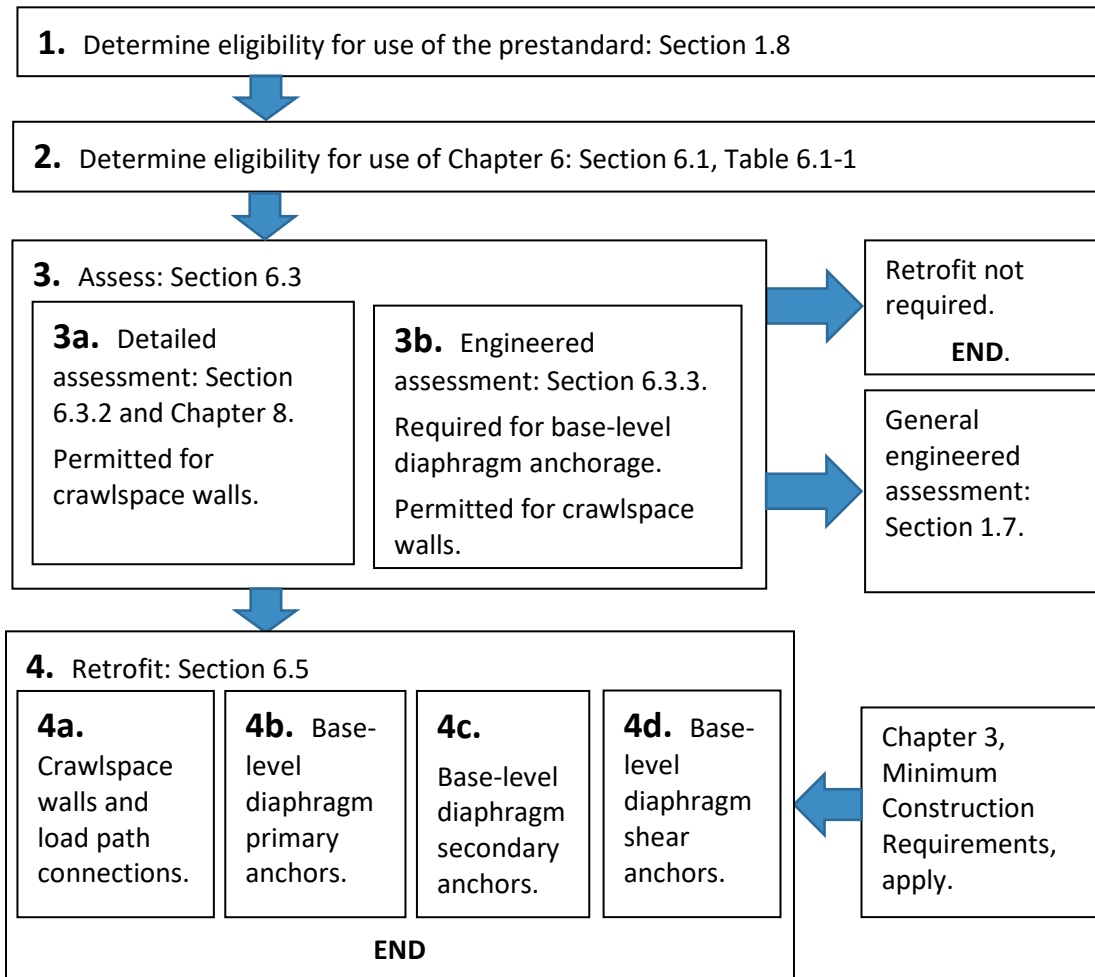


Figure C.6.1-7 Flowchart of assessment and retrofit design for hillside dwellings.

C.6.1.1 Use of this Chapter

The following addresses specific eligibility statements of Table 6.1-1. The dwelling is assessed to be compliant or non-compliant with each statement. Compliance with all statements is required in order for the dwelling to qualify for use of the vulnerability-based assessment and retrofit of Chapter 6. Where any statement is not compliant, the dwelling will need to be assessed and retrofit in accordance with general engineered provisions of Section 1.7.

Items 1 and 2. See commentary to Chapter 1 and to Chapter 2 definitions.

Item 3. The retrofit provisions presented in the chapter are applicable to dwellings with one or two stories above the crawlspace. While the retrofit concepts presented are still applicable to dwellings with more stories, the increased number of stories could potentially introduce other seismic vulnerabilities not currently addressed by the chapter. There is no limit placed on the square footage of dwellings to be retrofit in accordance with this chapter.

Item 4. The focus of this prestandard and the supporting numerical studies is only on wood light-frame construction. Other construction materials and systems may have other vulnerabilities and require other retrofit methods.

Item 5. The computer modeling used in the numerical studies assumes wood light-frame crawlspace walls below the base-level diaphragm for a substantial portion of the dwelling perimeter. Where the dwelling perimeter is instead substantially supported on concrete or masonry stem walls or other construction types, this can lead to a different response of the hillside dwelling structure during an earthquake, and is beyond the scope of this chapter.

Item 6. The perimeter walls of the dwelling are assumed to have a continuous foundation, allowing the wood light-frame crawlspace walls to extend down to and be anchored to the foundation. Continuous foundations adequate for the purposes of this assessment statement include concrete spread footings with or without stem walls, and grade beams and tie-beams extending between pier and caisson foundations with or without continuous concrete piers. Some hillside dwellings use posts below the base-level diaphragm around the perimeter of the building. In some dwellings, sheathing has also been installed across the face of the posts for fire protection of the underside of the dwelling, but does not extend all the way down to the ground or foundation. Dwellings without crawlspace walls can be retrofit to add crawlspace walls. Dwellings without continuous foundations can be retrofit to add foundations.

Item 7. The wall height restriction of 16 feet is because that is the tallest wall studied in the numerical modeling used to develop the retrofit provisions of this chapter. As walls become taller than 16 feet, it is not known whether the crawlspace wall stiffness is adequate to provide the improved seismic performance targeted by this chapter.

Item 8. A dwelling sited on a slope of 1 vertical to 5 horizontal or steeper was identified by analysis as the slope angle where the overall seismic

response became notably different from the type addressed by the crawlspace wall retrofits of Chapter 4. The primary concern in choosing this criterion was the magnitude of displacement of the base-level diaphragm away from the uphill foundation; the uphill anchorage is believed to become vulnerable to failure at very small displacements.

Item 9. Hillside dwellings often have vertical offsets (step-downs or split levels) within a floor level. Due to the more complex seismic response of dwellings with this type of offset, it was determined that dwellings of this type were beyond the scope of this prestandard.

Item 10. When the garage is located in the portion of the building projecting out over the hillside, substantial heavy floor framing is installed to support the vehicle loads. Where the dwelling floor framing is typically 2x members, the garage floor joist may be 4x or 6x members with a concrete slab to provide durability from the wear and tear of a car driving in and out of the garage. This represents a significant amount of building mass relative to the rest of the dwelling structure. Although hillside dwellings can have either an attached garage or a detached garage structure, the decision was made to not include the garage mass as part of the building structure in the numerical models. Therefore, garages are required to be detached from the dwelling when using this prestandard. Many of the hillside dwellings have a portion of the structure supported by a concrete slab-on-ground (e.g., a garage or a bedroom), and the remainder projects out over the hillside. While hillside dwellings with attached garages are beyond the assessment and retrofit scope of Chapter 6, the retrofit concepts presented in this chapter are still important to consider.

Item 11. The anchorage of the base-level diaphragm to the uphill foundation is essential to maintain during an earthquake to help prevent collapse of the dwelling. Typically, the dwelling perimeter wall stacks directly above the uphill foundation allowing direct shear transfer to the foundation. In some cases, however, the dwelling's entry porch may occur at this location, causing the dwelling perimeter wall to be set back from alignment with the uphill foundation. This puts more demand on the diaphragm to transfer forces to the uphill foundation. To help minimize the force transfer through the diaphragm, it was determined that at least 75% of perimeter wall length must occur over the uphill foundation.

Item 12. Masonry chimneys often represent a significant portion of a dwelling's mass. The decision was made to exclude dwellings with chimneys from the scope of this chapter due to their significant added mass, high frequency of collapse during earthquakes, and impact on the dwelling's

response during an earthquake, depending on where it is located along the perimeter or within the dwelling.

C.6.1.2 Vulnerability-Based Assessment and Retrofit Methods

This section serves as a road map to assessment and retrofit methods. Assessment methods are discussed in Section 6.3. Where retrofit is required by Section 6.3, retrofit is permitted by the simplified engineered vulnerability-based retrofit provisions of Section 6.5 or the general engineered retrofit method of Section 1.7. The prescriptive vulnerability-based retrofit methods that are available for crawlspace dwellings and living space-over-garage dwellings in Chapters 4 and 5 are not available in Chapter 6 for hillside dwellings.

C.6.2 Definitions and Minimum Requirements

Unique to hillside structures are the terms: “primary anchor,” “secondary anchor,” and “base-level diaphragm,” along with the hillside loading directions “*out-of-hill loading*,” and “*cross-slope loading*.” Definitions of these terms are provided in Chapter 2, and related discussion in the commentary to Chapter 2.

C.6.3 Vulnerability-Based Assessment

Section 6.3 provides several methods of vulnerability-based assessment. Where these are not applicable, a general engineering assessment is required. Important in the vulnerability-based assessment is the concept that the assessment and the subsequent retrofit, if required, can narrowly focus on the potential vulnerability, rather than requiring assessment and possible retrofit of the entire seismic force-resisting system. This concept is at the heart of this prestandard. It has been identified by the prestandard developers that the seismic performance of dwellings can be notably improved by specifically addressing known vulnerabilities in isolation. It is anticipated that this limited scope vulnerability-based approach will significantly lower the cost and increase the number of dwellings retrofit. See Section 1.5 for discussion of combinations of vulnerabilities and Section 1.9 for discussion of conditions beyond the scope of the prestandard.

C.6.3.1 Scope

This section serves as a road map to the available methods for assessment. The simplified vulnerability-based assessment method is not permitted for hillside dwellings due to the large variations in different types of hillside structures and the complexity involved with retrofitting these types of dwellings. Since there is no prescriptive vulnerability-based retrofit

approach, it was determined that a simplified assessment approach was not appropriate to implement either.

C.6.3.2 Detailed Assessment

The detailed vulnerability-based assessment of the hillside dwelling is to be in accordance with the noted sections in Chapter 8. This assessment method is applicable to foundations and crawlspace walls and their load-path connections. The intent of these provisions is to identify existing construction that reasonably mitigates the vulnerability being assessed.

Detailed vulnerability-based assessment of base-level diaphragm anchorage to the uphill foundation is not provided, as adequacy cannot be determined by visual observation alone. Base-level diaphragm anchorage is required to be assessed in accordance with the engineered vulnerability-based assessment methods.

Some of the Chapter 8 detailed assessments are common to other vulnerable structure types found in this prestandard, so all detailed assessments have been located in a common chapter for ease of use of the document.

C.6.3.3 Engineered Assessment

When the dwelling is found to be non-compliant using the detailed assessment, it is permissible to hire a design professional to determine if the existing crawlspace and base-level diaphragm structural system are actually compliant with the prestandard, or to determine what additional retrofit is required to make the dwelling compliant.

Where vulnerability-based assessment is made of existing anchorage to the uphill foundation, it will always be made in accordance with this section. Such assessment requires use of the seismic forces provided in Section 6.5. Because these forces are significantly greater than those used in other codes and standards, it is unlikely that existing anchorages will meet this requirement.

Engineered vulnerability-based assessment of foundations and crawlspace walls is permitted as an alternative to the detailed vulnerability-based assessment. This will be beneficial to use when existing non-typical engineered construction is found at the foundation or crawlspace wall.

C.6.4 Prescriptive Vulnerability-Based Retrofit

The development and use of prescriptive retrofit measures to improve hillside dwelling performance during an earthquake were investigated for hillside dwellings, but not implemented. Due to the variability inherent in

the hillside dwelling building stock, and the significant complexities of installing seismic retrofits on hillside sites, it was decided to limit available retrofit methods to those involving a registered design professional.

A notable source of concern that kept prescriptive designs from being pursued was the load path from the primary anchors into the foundation. The design forces are large and beyond the capacity of off-the-shelf hardware for light-frame construction. In many cases, it is expected that the anchorage forces acting on the foundation will require local reinforcement of the existing foundation elements. Design of such reinforcement will be highly dependent upon existing conditions, anchorage forces, site access, and constructability consideration. Construction of new foundation elements, such as drilled piers upslope of the existing foundation designed to resist primary anchor forces may be a more practical solution than reinforcing the existing foundation but will require guidance from geotechnical engineers.

C.6.5 Simplified Engineered Vulnerability-Based Retrofit

Section 6.5 provides a simplified engineered method for vulnerability-based retrofit. Where these are not applicable, a general engineering retrofit is required. Important in the vulnerability-based retrofit is the concept that the retrofit can narrowly focus on the potential vulnerability, rather than requiring assessment and possible retrofit of the entire seismic force-resisting system. See Section C.6.3 for further discussion.

This section is intended to be implemented by a registered design professional knowledgeable in seismic retrofit.

C.6.5.1 Scope

This section acts as a road map to sections addressing applicable retrofit provisions. Section 6.5.2 specifies seismic design force equations and is applicable to all retrofits. The requirement for retrofit of each of the following items is based on Section 6.3 requiring retrofit on an item-by-item basis:

- Foundation
- Anchorage of the base-level diaphragm to the uphill foundation
- Crawlspace wall bracing, anchorage to the foundation, and connection to floor framing above

The simplified engineered vulnerability-base methodology of Section 6.5 uses anchorage to the uphill foundation and crawlspace walls as primary retrofit elements working together to provide improved seismic performance.

An envelope solution is provided for seismic resistance in that the anchorage to the uphill foundation is designed for the full seismic base shear, V , acting at the base-level diaphragm, as well as each perimeter crawlspace wall being designed for a tributary portion of the base shear. Initial development of the retrofit method intended that the load path use only the anchorage to the uphill foundation; however, numerical studies found that the addition of sheathing to the crawlspace walls greatly reduced torsion in the occupied stories, improving overall seismic performance of the dwelling. In addition, the primary and secondary anchors provide an envelope solution in that the primary anchors alone and the secondary anchors alone are each designed to resist the seismic base shear. Where the uphill foundation is more flexible, it is anticipated that the foundation will flex under load and the base shear will be primarily carried by the primary anchors. Where the uphill foundation is stiff, it is anticipated that the base shear will be carried by the distributed secondary anchors. The combination of the two anchor types provides a high level of confidence that the base-level diaphragm will not be able to break away from the uphill foundation.

C.6.5.2 General

The seismic retrofit design procedure, including seismic forces and material capacities and detailing, have been developed consistent with the methodology of ASCE/SEI 7 and the adopted building code. Because of the limited scope of seismic design forces used for retrofit design, seismic forces are provided in Sections 6.5.2.1 and 6.5.2.2. Where other loads or load combinations are required for design, it is intended that the building code be used. Where material capacities and detailing requirements are required for design, it is intended that the adopted building code and material standards adopted therein be used.

C.6.5.3 Retrofit of Foundations

Where existing foundations are not continuous, or are not adequate to use based on the Chapter 8 assessment, either retrofit of the existing foundation or a new continuous foundation will be required at the dwelling perimeter. The foundation is required to be designed for the applicable loads and load combinations specified by the building code. Included in the foundation design are the required strength and stiffness of the foundation itself, and the design of seismic force transfer to the supporting soils. For these portions of the foundation design, inclusion of seismic forces generated by primary anchors, shear anchors and crawlspace walls is required. Use of an R -factor of 4 is permitted for these portions of the design (rather than 1 or 2) due to the higher ductility anticipated for the new or retrofit foundations, and

because design of the foundation for lower R -factors is likely to be unwieldy and may discourage use of the chapter. Design of the foundation for secondary anchor forces is not required, because the intent of these anchors is to avoid separation of the diaphragm from the foundation.

Design of the primary anchors, secondary anchors, shear anchors, and their anchorage to the foundation is to be in accordance with Section 6.5.4, using the R -factors specified in that section.

It may be necessary in some instances to make a determination as to whether a concrete retrofit element being added as part of the diaphragm anchorage or part of the foundation, and as a result, which R -factor should be used for element design. Where element design loads are primarily seismic diaphragm anchorage forces plus element self-weight, the element should be considered part of the diaphragm anchorage system and designed accordingly. Where an element load also includes more than nominal dwelling dead and live loads, the element may be considered part of the foundation system and the seismic forces reduced to those corresponding to $R = 4$.

C.6.5.4 Retrofit of Base-Level Diaphragm Anchorage

Base-level diaphragm anchorage is comprised of primary anchors, secondary anchors, and shear anchors, as previously described.

C.6.5.4.1 Design of Primary Anchors

Figure C.6.5-1 is an elevation view of the primary anchor installed along the hillside slope incorporating a concrete pier and grade beam (detail shown in Figure C.6.5-2), wood collector member, anchorage of the wood member to concrete pier, and anchorage of the new grade beam to existing uphill and sloping foundations (detail shown in Figure C.6.5-3). The new concrete pier is located at the top of the slope to minimize its height. In the primary anchor design illustrated, the collector beam, grade beam, and their connectors collectively serve as the primary anchor. In some instances, it may be possible for the primary anchor to be more discreetly anchored to the uphill foundation, similar to the secondary anchor designs illustrated in Section C.6.5.4.2.

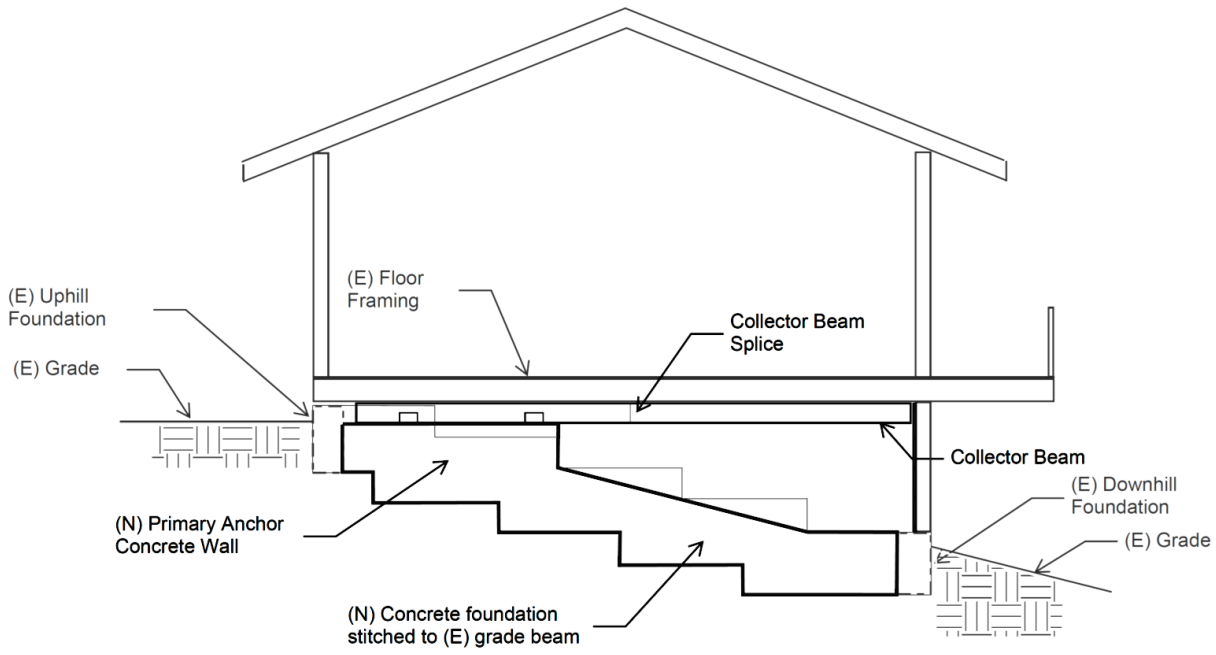


Figure C.6.5-1 New primary anchor elevation.

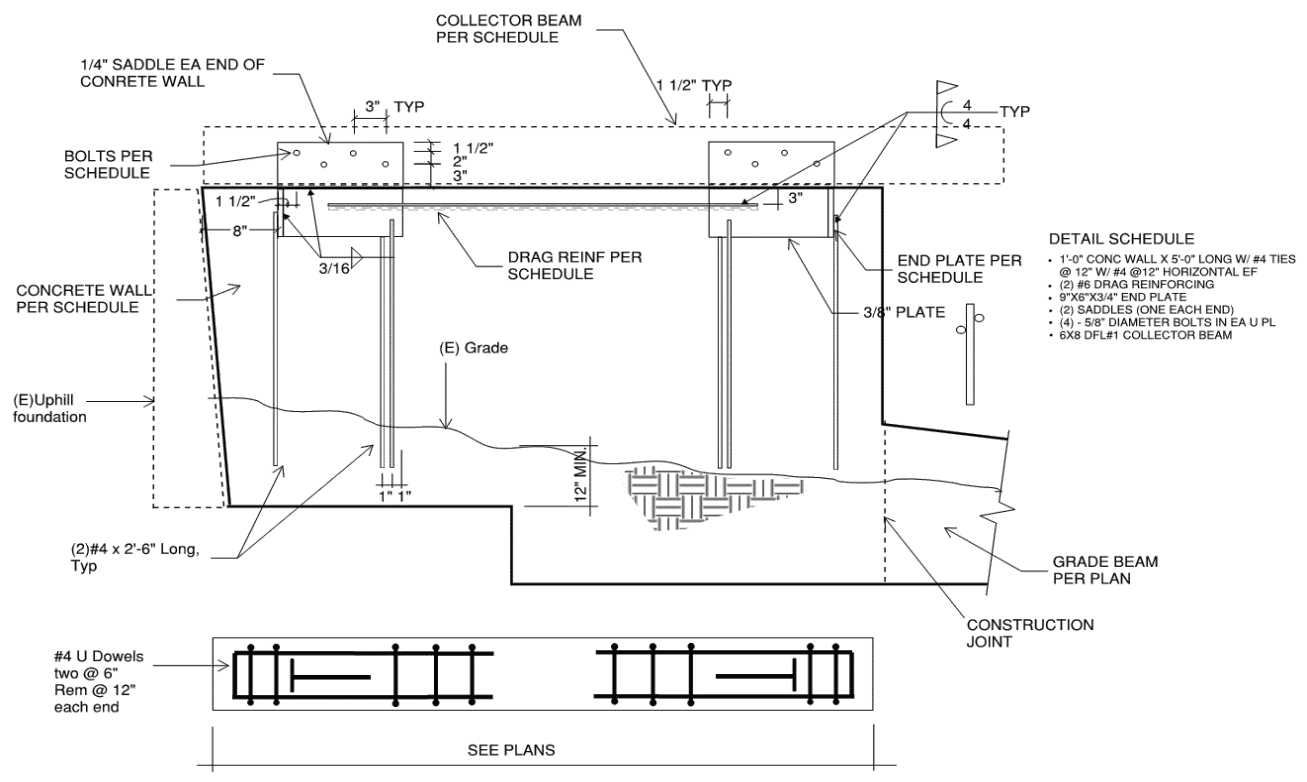


Figure C.6.5-2 New concrete pier and grade beam.

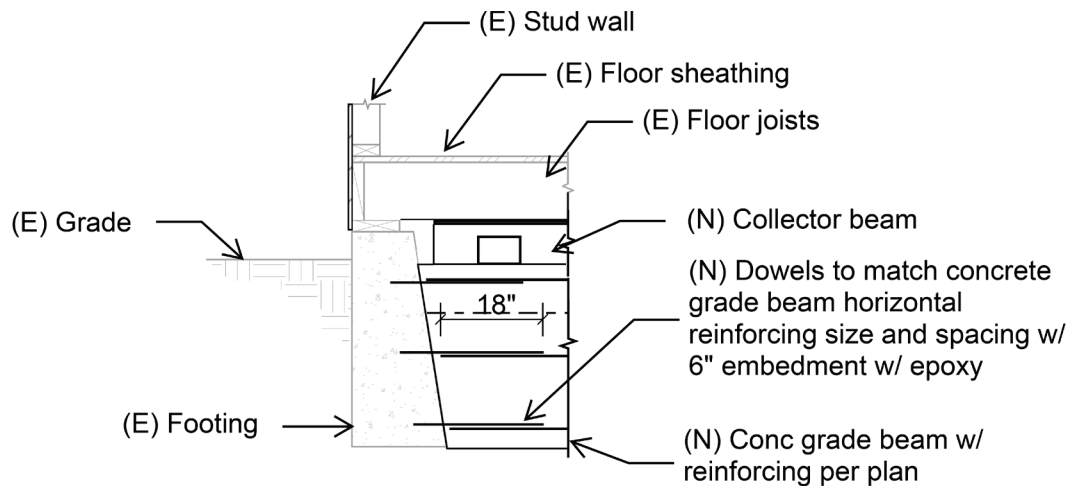


Figure C.6.5-3 New grade beam anchorage to existing foundation.

The primary anchors are designed to collectively resist the entire dwelling base shear using $R = 2.0$. The numerical studies used for development of this retrofit methodology identified this force level to be necessary to achieve the targeted performance. The companion Volume 3, *Background Documentation*, provides further information.

The in-plane stiffness of the downhill foundation crawlspace walls (for seismic forces acting in the cross-slope direction) are significantly more flexible than the uphill foundation system stiffness in the hillside cross-slope direction. As the downhill shear wall deflects in-plane, more shear force is transferred to the uphill foundation than would be assumed by a flexible diaphragm tributary area design approach. The greater stiffness of the uphill foundation relative to the downhill shear wall also influences the force distribution between parallel shear walls in the dwelling structure above the base-level diaphragm, attracting more load to the uphill shear wall above the uphill foundation and very little to the downhill shear wall above the base-level diaphragm.

Although the R value of 2.0 appears severe for primary anchor design, it is the result of low ductility and high stiffness of the uphill diaphragm to foundation connection relative to the flexible and ductile downhill crawlspace wall. A stiffer downhill crawlspace wall is required to attract more of the seismic force to the downhill wall. However, this can only be accomplished by incorporating seismic force-resisting elements that are considerably stiffer than conventionally nailed wood panel shear walls, such as steel braced frames, concrete or masonry shear walls, or other innovative systems. As a retrofit method, these options would require detailed engineering design and may be expensive to implement. In new building

design, this would be more feasible, and would allow for a higher R value associated with reinforced concrete or masonry wall design.

The hillside dwelling earthquake performance is significantly improved by designing the primary anchors for $R = 2$ and adding wood structural panel sheathing to the interior face of the downhill crawlspace wall, as opposed to adding no sheathing. The added wall sheathing attracts more seismic force to the downhill foundation, which then provides more protection for the uphill foundation shear anchors by somewhat reducing their actual shear demand.

Additional primary anchors to the uphill foundation are required when there is more than a 48" inch offset in the uphill foundation. The added primary anchor provides added strength at this location of increased foundation stiffness to protect from brittle failure. Where long interior shear walls occur parallel to the downhill slope direction, and resist a significant amount of the dwelling story shear from the floor or roof above, consideration should be given to providing an added primary anchor underneath or as close as possible to these shear walls.

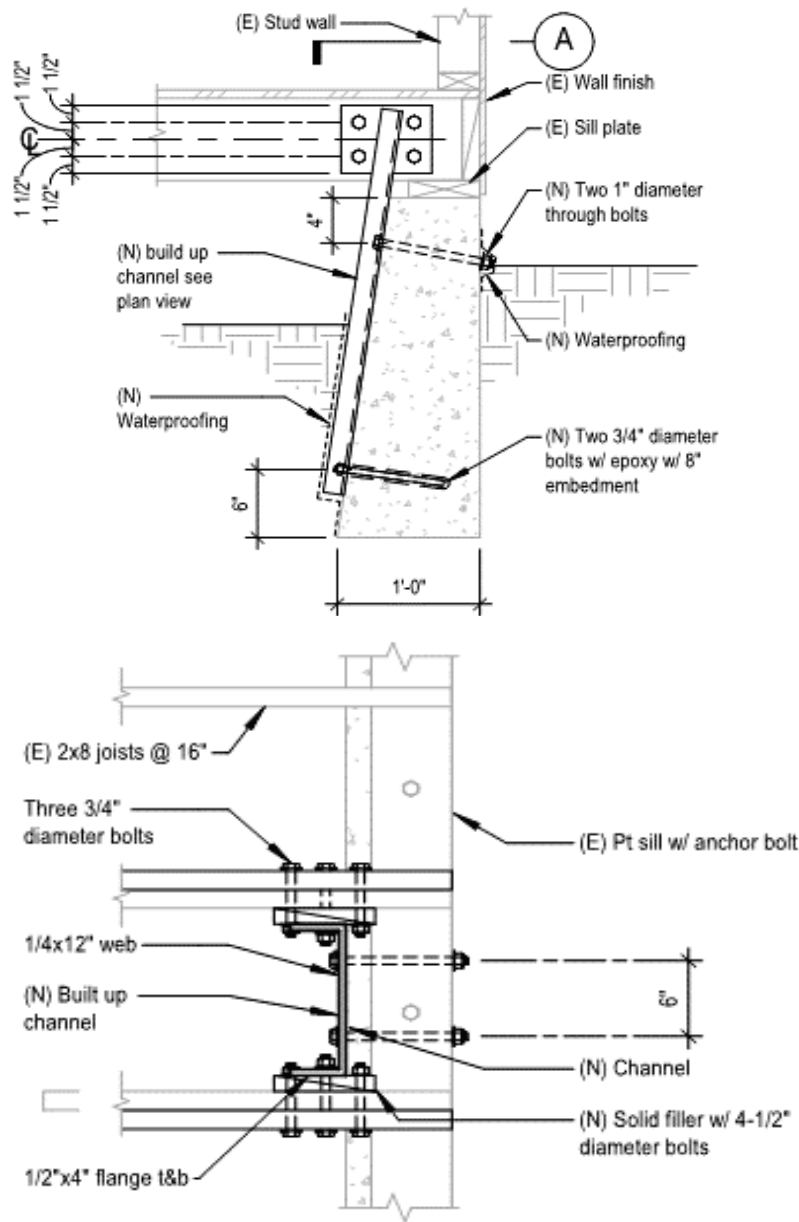
C.6.5.4.2 Design of Secondary Anchors

Figures C.6.5-4 and C.6.5-5 show detailing concepts that might be used for secondary anchors.

The spacing limitation of 48 inches for the secondary anchor is based on expected limited shear transfer capacity of the existing sheathing nailing to the floor joist. Where the existing floor sheathing crosses over the floor joist, the existing nail spacing will likely alternate between field nailing for a given distance (assumed 12 inches on center) and edge nailing for a given distance. There can be variation in the type of nails and diameter of the nails used.

If additional nailing is provided to strengthen the existing floor sheathing to joist shear transfer, the secondary anchor spacing could possibly be increased. Increasing the secondary anchor spacing is not recommended, however, due to required increases in size of other secondary anchor components that tie into existing floor framing and foundation members. In some retrofit cases, the secondary anchor bolt attachment to the floor joist may be the limiting factor. In some cases, the secondary retrofit anchors may need to be spaced closer together to transfer forces to the uphill foundation.

The secondary anchors are designed for $R = 1.0$ and the effective seismic weight tributary to the individual secondary anchors. The tributary area is intended to be the on-center spacing of the secondary anchors times the full width of the diaphragm at the secondary anchor location.



A Plan view

Figure C.6.5-4 Joist on top of concrete stem wall.

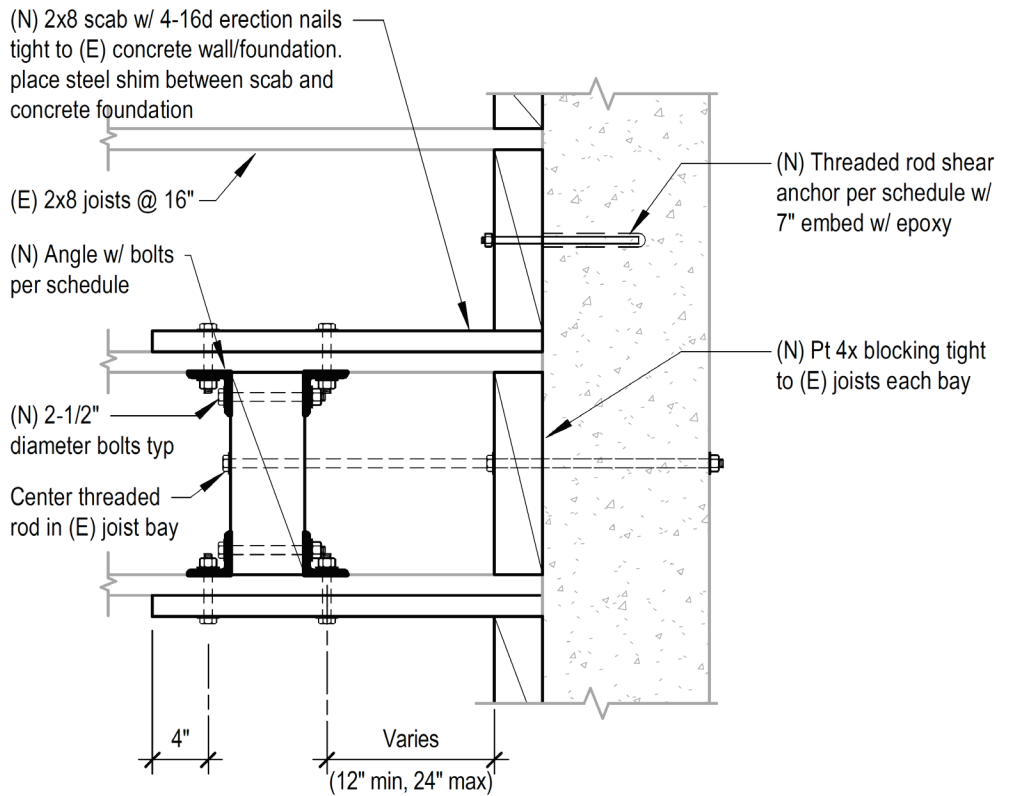
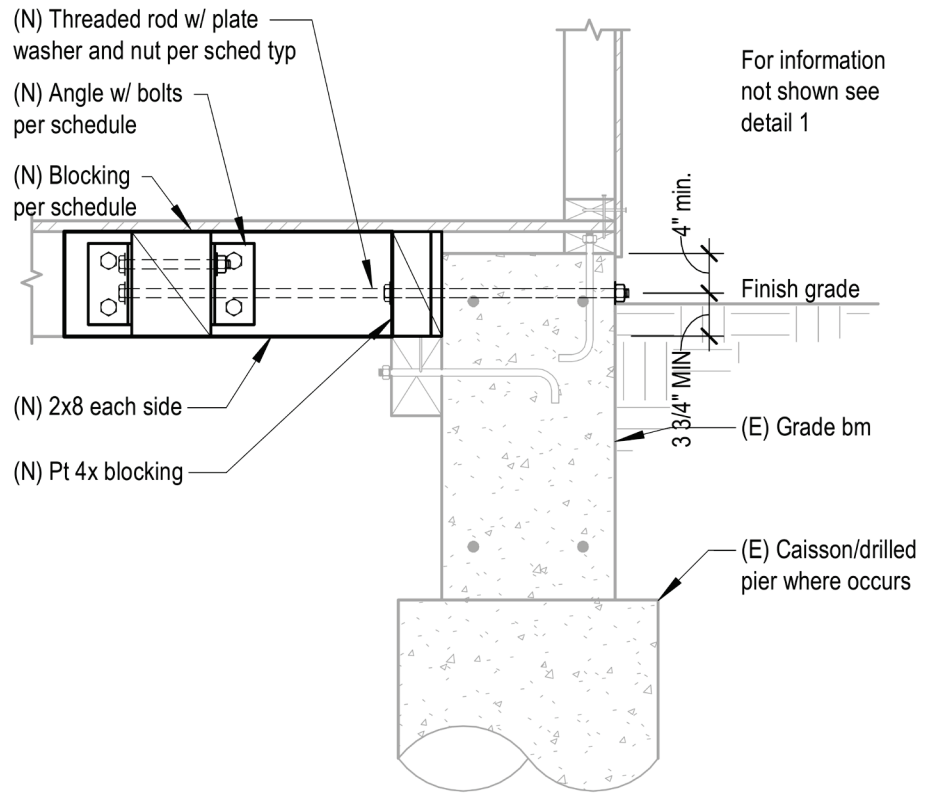


Figure C.6.5-5 Joist to side of concrete stem wall.

The secondary anchors are required to:

- Prevent the floor base-level diaphragm from pulling away from the dwelling's uphill foundation
- Redirect the diaphragm forces away from the stepped or sloped crawlspace walls attached to the tops of the downslope foundations

Attachment of the floor joist to the uphill foundation sill plates in existing dwellings is anticipated to be very limited. Typically, this consists of a few toenails per joist and does not provide much axial load resistance to the joist pulling away as the diaphragm attempts to move downhill during an earthquake. If the joist pulls away from the uphill foundation, then diaphragm shear transfer in the in-plane direction of the uphill foundation will no longer function. Thus, there is a need to ensure the retrofit design will not let the floor joist pull away from the uphill foundation.

It is difficult to provide sufficient shear transfer in the out-of-plane direction of the uphill foundation by just adding sheet metal connectors between the floor joist and foundation sill plate. A significantly stiff and strong secondary anchor is required to anchor the existing floor joist to the uphill foundation and keep the existing shear transfer intact, as well as adding new sheet metal connectors between the rim joist or blocking sitting on top of the uphill foundation. This secondary anchor design is generally easy to achieve as long as the tributary area and associated seismic design force are relatively low, thus the limit of their maximum spacing.

C.6.5.4.3 Design of Shear Anchors

Shear anchors are designed with the intent of being able to transfer the entire *cross-slope direction* base shear from the base-level diaphragm to the uphill foundation. As previously described, this is part of an envelope solution to give a high certainty of good seismic performance. It is acknowledged that some portion of the cross-slope base shear is going to the downhill crawlspace wall, but also that this could be minimal due to the downhill wall's flexibility.

Figure C.6.5-6 illustrates what is anticipated to be one common configuration of a shear anchor, where the uphill foundation stem wall extends to the top of the floor framing and the floor diaphragm ledger can be directly bolted to the face of the foundation stem wall. A crawlspace wall of up to two feet high is permitted to occur between the uphill foundation and the base-level diaphragm. Where this occurs, the crawlspace wall is designed for the base shear level specified in Section 6.5.5 for crawlspace walls, but again the entire base shear, V , must be transferred through the short crawlspace wall to the uphill foundation.

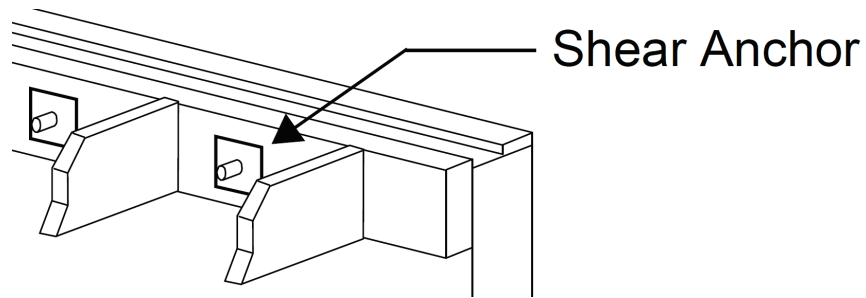


Figure C.6.5-6 New shear anchor between floor joists.

C.6.5.5 Retrofit of Perimeter-Framed Crawlspace Walls

The background studies for this prestandard indicate that providing wood structural panel sheathing on the interior face of the downhill and sloping side crawlspace walls (as shown in Figure C.6.1-6) will improve the earthquake performance of the dwelling. The shear design strength of the crawlspace wall sheathing must be developed into both the supporting foundation (anchor bolts) and to the underside of the base-level diaphragm (framing anchors).

The downhill crawlspace wall is to be designed using a value of $R = 4$, and 50% of the effective seismic weight, W , of the structure. This is an attempt to increase the downhill shear wall strength and stiffness to help divert more of the seismic forces to the downslope side of the dwelling. The 50% of V design force represents a minimum envelope solution, recognizing the use of flexible diaphragm assumption for the base-level diaphragm and assumption that there are only perimeter shear walls below the base-level diaphragm so half the design force goes to the uphill foundation and half goes to the downhill shear wall. The design value of $R = 4$ was selected as a reasonably attainable level of crawlspace wall bracing, consistent with the force level used in design of Chapter 4 crawlspace wall retrofits.

The sheathed crawlspace wall at the downhill foundation also wraps around to the side crawlspace walls. The recommendation is to sheathe as much of these downhill and side crawlspace walls as can practically be done. Wrapping the wood structural panel sheathing around onto the cross-slope crawlspace wall helps to provide a flange effect, further stiffening the downhill wall. The new sheathing nailing and resulting sheathing shear capacity may be limited based on the nominal size of the existing wood studs, unless new thicker sister studs are added for sheathing nailing.

The drift limit of $0.02h_{sx}$ was selected to limit the flexibility of the downhill wall and to help ensure more of the hillside dwelling base shear is transferred to the downhill shear wall and foundation.

See Chapter 4 commentary discussion of the use of Ω_0 equal to 1.5 for crawlspace wall load path connections.

C.7 Vulnerability-Based Assessment and Retrofit of Masonry Chimneys and Fireplace Surrounds

C.7.1 General

A large proportion of the existing stock of single-family dwellings in western states have been built with unreinforced or lightly reinforced masonry chimneys. Along with brittle wall finishes and large masonry fireplace surrounds, masonry chimneys are arguably the most vulnerable elements of conventionally-constructed, wood light-frame houses. While retrofit provisions in other chapters of this prestandard have been calibrated to target quantitative seismic performance levels, the provisions of this chapter are based on experience and engineering judgment regarding best practices for reducing the falling hazards associated with masonry chimneys and masonry fireplace surrounds.

These provisions are not intended to eliminate chimney damage. Retrofit provisions of this chapter are tied to aspects of typical masonry chimneys and fireplaces that make them more vulnerable to strong ground shaking. Such aspects include both construction features (cantilever extension above the roof surface; chimneys unbraced by framing or finishes; multi-story chimneys) and vintage (chimneys that either predate or had been improperly constructed to prescriptive code prescriptions; chimneys with degraded mortar or masonry). The retrofits prescribed in this chapter are a function of which of those poor-performing aspects are present. If none are present (i.e., one story *interior chimneys* with little extension above the roof), no retrofit is required to comply with this chapter. If multiple features are present, demolition of the masonry down to the top of the *smoke chamber* would be required.

Masonry chimneys retrofitted to the requirements of this chapter might not achieve the low collapse performance targeted in other chapters of this document. Masonry chimneys, including those constructed where prescriptive seismic bracing was required by the building code, have performed poorly in past earthquakes. It is unclear whether conventionally-constructed chimneys can achieve the reliably good seismic performance that forms the bases of modern building code provisions. As such, prescriptive provisions include the option of simply removing the masonry chimney and fireplace down to the foundation and replacing with lightweight factory components in a cold-formed steel or wood-frame chase.

The intent of this chapter is to provide minimum standards for retrofitting masonry chimneys and masonry fireplace surrounds. Although it has not been written for purposes of repair, the provisions are useful for repair of masonry chimneys damaged by earthquake shaking.

The prescriptive retrofits of this chapter target the most common types of masonry chimneys found in California and western states. The assessment of this section is intended to determine whether chimney construction is within the types contemplated by the prescriptive approach. The prescriptive measures may not be sufficient for unusually large chimneys or those constructed of masonry units other than solid brick. Also, chimneys located on exterior corners of houses have additional bracing requirements outside the scope of the prescriptive provisions. Chimneys outside the criteria of this section require additional engineering and are to be retrofit per Section 7.4.

A major objective of this chapter is to provide simple prescriptive provisions applicable to large portion of masonry chimneys of the type common to California and western states: solid clay brick masonry chimneys of nominal size constructed with Portland cement mortar/grout that are either lightly reinforced or not reinforced. Unusually large chimneys, corner chimneys, or chimneys of a material other than brick masonry are outside the scope of prescriptive retrofits and should be evaluated by an engineer.

C.7.2 Definitions and Minimum Requirements

See Chapter 2 and Chapter 3 commentary for further information.

C.7.3 Vulnerability-Based Assessment

C.7.3.1 Scope

This section provides assessment criteria by which one can determine whether a chimney or masonry fireplace surround is compliant or noncompliant with this chapter. Compliant chimneys and masonry fireplace surrounds require no further retrofit. Noncompliant chimneys are either eligible or ineligible for prescriptive retrofit. Noncompliant, eligible chimneys can be retrofit per Section 7.4. Noncompliant, ineligible chimneys must be removed or retrofit per the engineering requirements of Section 7.6. Masonry fireplace surrounds are only assessed to determine whether they are compliant as-built. There is no need to determine eligibility of noncompliant surrounds for prescriptive retrofit because the retrofit is the same in all cases – remove the surround and rebuild according to current code. It should be noted that the anchorage or adhesion of interior veneer is empirically based, and surrounds constructed in compliance with current code may still present a falling hazard in strong shaking.

C.7.3.2 Simplified Assessment of Chimneys

Provisions of Section 7.3.2 are simplified methods that can be applied by a homeowner. Noncompliant chimneys are eligible for prescriptive retrofit if they meet the criteria of Section 7.1.3, otherwise complete removal or engineered retrofit is required.

The following is a discussion for a chimney meeting eligibility criteria of Table 7.3-1 to be in compliance with the provisions:

- The assessment of this section considers the potential for bracing or buttressing afforded by the dwelling. Interior brick chimneys of single-story dwelling have performed better than other chimney types, and pose considerably less falling hazard because they benefit from wall support in more than one direction. Based on engineering judgment, these chimneys meeting Table 7.3-1 Item 1 are in compliance with this chapter. Exceptions include tall attics where long sections of chimney are often unbraced (common in older Victorian homes), and chimneys that cantilever well above the roof. Figure C.7.3-1 shows how the dimensions H , A , and B used in this criterion are determined. The extension above the roof, H , cannot be more than twice the least plan dimension, B . The greatest plan dimension, A , must not exceed 40 inches.

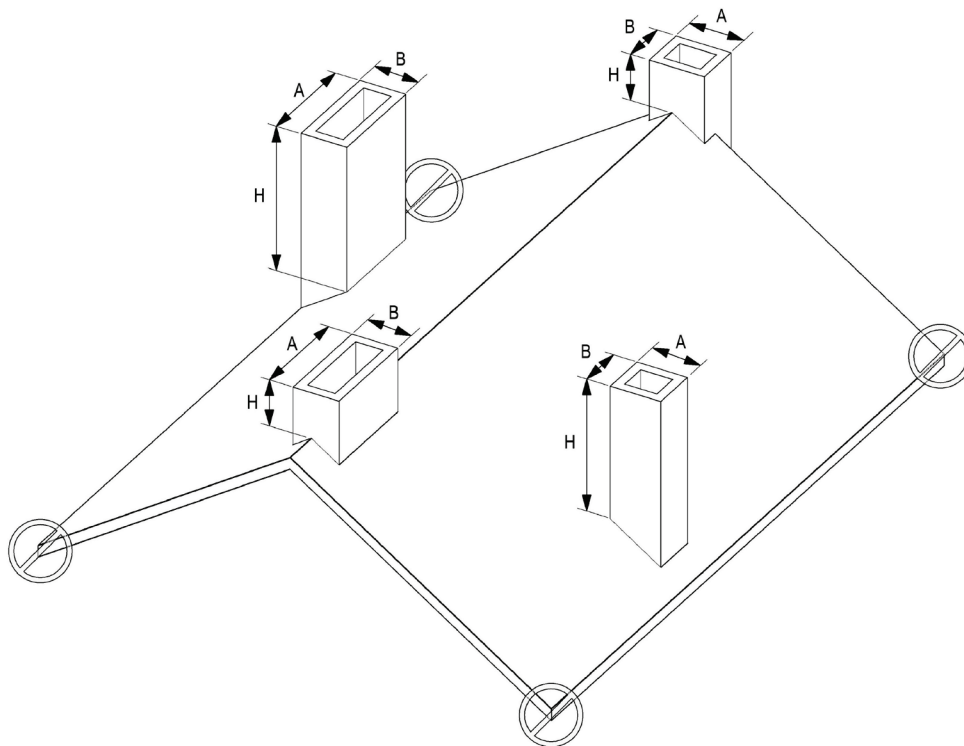


Figure C.7.3-1 Definition of dimensions for assessment.

- Chimneys properly constructed to prescriptive code requirements have performed better than chimneys not constructed per code. In addition, chimneys constructed subsequent to the widely publicized poor performance in the 1994 Northridge Earthquake have likely received more attention from designers and scrutiny by inspectors, and thus higher construction quality is generally expected. As such, per Table 7.3-1 Item 2, chimneys built after 1995 are in compliance with the provisions of this chapter.

C.7.3.3 Detailed Assessment of Chimneys

Provisions of Section 7.3.3 are technical and detailed, and must be performed by a registered design professional or licensed contractor.

Prescriptive bracing requirements for chimneys have not changed significantly for decades. The poor performance of chimneys older than 1995 yet built at a time when modern prescriptive bracing requirements were in place is often attributed to poor quality construction. Well-constructed, code compliant chimneys of pre-1995 vintage are expected to demonstrate seismic performance consistent with the intent of this chapter, and such chimneys are in compliance. It is however very difficult to demonstrate code compliance because important structural components and details are concealed. Per the assessment of Section 7.3.3, compliance can be demonstrated by a contractor or engineer by showing the following:

- Except for very old chimneys, Portland cement mortar should be expected. An experienced contractor or engineer can make this determination by scratch testing the mortar joint. When evaluating whether the physical condition of the chimney meets the requirements for prescriptive retrofit, the mortar and masonry “Fair Condition” is taken from ASCE/SEI 41, which is admittedly a subjective measure. The source cited in ASCE/SEI 41 is less than moderate damage as defined in FEMA 307 (FEMA, 1998). As such, random, isolated cracks less than 1/16-inch wide would qualify as less than minor cracking. If cracking of the mortar joints is judged to be worse than minor, the chimney could still be made to comply with this chapter if the damaged joints are repointed.
- Minor cracking of the masonry units is intended to be treated the same as described above for mortar. Likewise, replacement of isolated cracked or otherwise damaged brick could restore the remaining masonry to a condition that it complies with this chapter.
- Current code requires that the chimney reinforcing steel be anchored to the foundation. However, rebar anchorage is difficult to determine

without extensive destructive exposure, and there appears to be little or no documented earthquake damage attributed to poor reinforcing anchorage. Therefore, confirmation that vertical reinforcing extends into the foundation is not required. Assessment of whether the vertical rebar is properly enclosed by ties or other reinforcing, also a code requirement, is required. An engineer or contractor can determine compliance based on exposing the condition, or perhaps by review of drawings (and indication of general adherence to those drawings) for dwellings of engineered construction. Note that if an engineered retrofit is being implemented (Section 7.6) and the calculations utilize base moment or existing ties, then proper anchorage must be verified.

- Assessment of the *anchor strap* condition requires more than simply checking the code prescribed strap strength and number of connectors, and is a function of whether the diaphragm framing is parallel or perpendicular to the anchor straps. Examples of proper strap framing for those conditions can be found in Figure 7-5 and Figure 7-6 of FEMA 232 (FEMA, 2006), reproduced herein as Figure C.7.3-2 and Figure C.7.3-3, respectively.
- The dimensional limits exclude unusually large chimneys, including those with long cantilever extension above the roof (H in Figure C.7.3-1). The prescriptive requirements of the 1970 UBC had limited this extension, H , to 8 feet, but a more conservative length of 6 feet was chosen for these provisions based on judgement. The 40-inch limit is based on the historic size limitation in prescriptive code requirements when reinforcing with four bars. The 40-inch dimension should be measured along either face of the chimney (not diagonal) just above the shoulder (or lowest smoke chamber, if there is no shoulder). Judgment will be required for nonstandard cross sections.

Chimneys meeting requirements of Section 7.3.3 are in compliance without retrofit. In lieu of complete removal per Section 7.4.4, noncompliant chimneys can be retrofit using engineering provisions (Section 7.6) or, if found eligible in Section 7.3.3, can be retrofit using prescriptive provisions of Section 7.4.

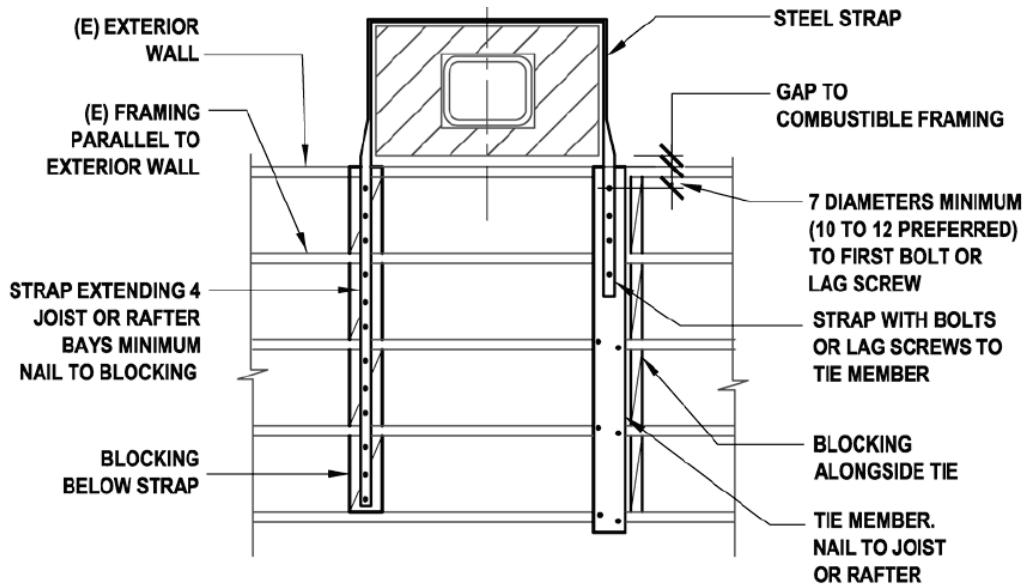


Figure C.7.3-2 Anchor strap installed with framing perpendicular (FEMA 232 Figure 7-5).

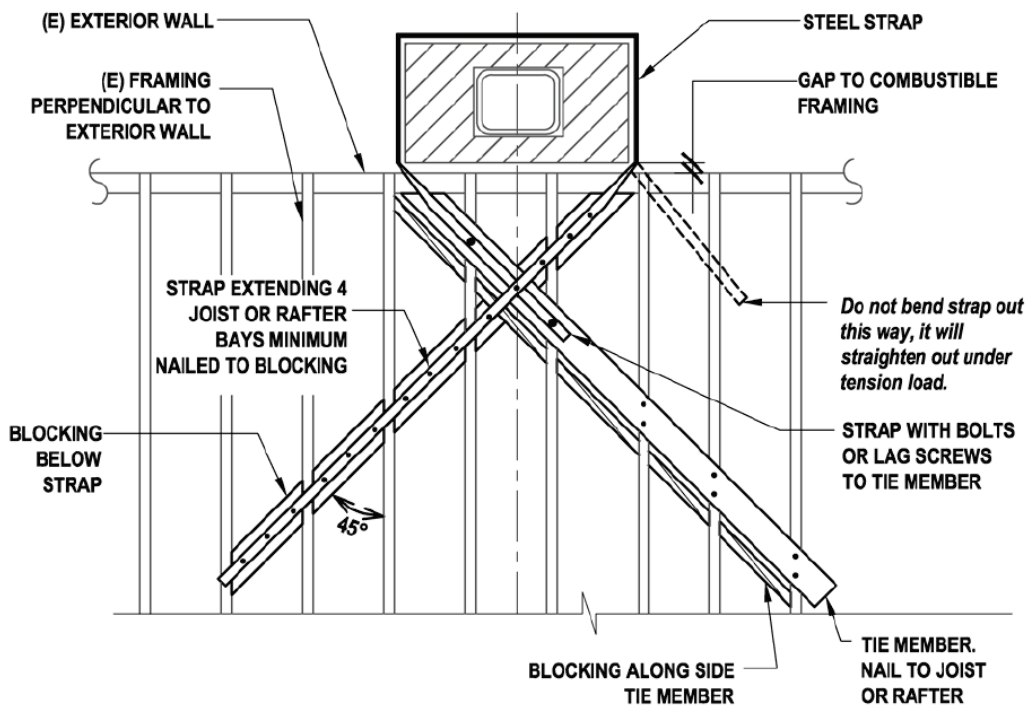


Figure C.7.3-3 Anchor strap installed with framing parallel (FEMA 232 Figure 7-6).

C.7.3.4 Simplified Assessment of Masonry Veneer Fireplace Surrounds

Section 7.3.4 provides simplified methods that can be applied by a homeowner.

The assessment of masonry fireplace surrounds in this section is intended to identify surrounds that are already compliant with the provisions of this chapter without retrofit. The assessment mirrors that for chimneys in Section 7.3.2 in that newer vintage surrounds, or surrounds that can be demonstrated compliant with current prescriptive requirements of the building code, are deemed to comply. In addition, anchored surrounds of limited size (by judgment not more than 3 feet from the *firebox* or more than 4 feet from the floor) are considered to present minimal falling hazard and are likewise in compliance with the provisions.

Surrounds are typically constructed of either anchored full-depth masonry veneer or adhered thin brick veneer. Some surrounds are composed of thin masonry veneer directly applied to the wallboard. Well-adhered thin veneer is not considered a life-safety threat, and it is not the intent of this chapter to mandate removal of light, well-attached veneer, regardless of its extent.

C.7.3.5 Detailed Assessment of Masonry Fireplace Surrounds

Provisions of Section 7.3.5 are technical and detailed, and must be performed by a professional contractor or engineer.

Compliance with this chapter can also be demonstrated if a professional contractor or registered engineer verifies proper anchorage. This will require destruction of finishes to expose the wall cavity, framing, and ties. Opening the wall by removing finishes from the backside might be least intrusive.

Even walls of well-anchored or well-adhered veneer can fail if the wall, and particularly the stud-to-plate connection, is not sufficiently strong to resist out-of-plane loads. The connection to the plate is explicitly required in Section 7.3.5 Item 1e for checking anchored veneer compliance, whereas for adhered veneer there is a restriction on weight (Item 2d). Section 7.5 requires the stud-to-plate connection to be checked and strengthened as required, if the veneer is retrofit.

TMS 402 has prescriptive measures for adhered veneer, but they are partially based on installation means and methods that are not possible to assess post-construction. The shear strength requirement of the attachment is required in lieu of the TMS 402 Section 12.3.2.4 reference to prescriptive requirement of observing the mortar mixing and application at time of construction.

C.7.4 Chimney Prescriptive Retrofit

C.7.4.1 Scope

This section determines the minimum scope of demolition required for chimneys eligible for the prescriptive retrofit of this chapter. Chimneys

demolished to the roofline are always simply capped. Chimneys demolished to the shoulder or to the foundation can be rebuilt according the provisions of this chapter.

The minimum scope of demolition and options for rebuilding can be determined using Table C.7.4-1.

Table C.7.4-1 Determination of Retrofit Scope

Chimney Location	Chimney Height	Unbraced Portion	Required Retrofit	Prestandard Section
Exterior	Any		Demolish to top of firebox	7.4.3 or 7.4.4
Interior	Two or Three Stories		Demolish to top of firebox	7.4.3 or 7.4.4
	One Story	Some portion of the chimney is freestanding (not in contact with a wall on any of the four sides) for a length of more than six feet.	Demolish to floor or ceiling directly below unbraced portion.	7.4.2, 7.4.3, or 7.4.4
		No portion of the chimney is freestanding (not enclosed by full-height, finished walls on at least three faces) for a length of more than six feet, and the chimney extends a height (dimension <i>H</i>) more than two times dimension <i>B</i> ($2 \times B$) above the roof. (See Figure C.7.3-1 for definition of dimensions.)	Demolish to floor or ceiling directly below unbraced portion.	7.4.2, 7.4.3, or 7.4.4

C.7.4.2 Capping of Chimney at Roof, Floor, or Ceiling Level

Flashing and other waterproofing elements around the chimney-to-roof juncture is a common location for water leakage and subsequent wood deterioration. Although it is important not to disturb well-performing waterproofing at the chimney, retrofit work on the chimney presents an opportunity to improve the flashing or other waterproofing elements. The requirement to leave the upper masonry course undisturbed is meant to protect properly functioning flashing and weatherproofing, and is not meant to preclude improvements to the flashing or waterproofing. Note that the highest existing flashing includes a cricket, if present. The provisions include a requirement to close the roof opening using framing that matches the existing construction, which is meant to preclude using unsupported plywood or OSB to span a potentially large opening.

C.7.4.3 Reconstruction from the Chimney Base

In Figure 7.4-6, the slope of the brace is independent of the roof slope.

Bracing of the chimney back to the roof framing is a requirement found in the Los Angeles Department of Building and Safety Information Bulletin

P/BC 2014-070 (LADBS, 2014). The prescriptive detail necessarily penetrates the roof weatherproofing membrane, and some may wish to engineer the chase to cantilever past the roof, or to provide some alternate support. This section provides some flexibility by providing a prescriptive brace while allowing any support that satisfies the requirements of the building official.

C.7.4.4 Reconstruction from Chimney Base Using a Factory-Built Fireplace Insert

The scope of this section is similar to Section 7.3.3, with the difference being that this section applies to cases wherein the masonry below the chimney remains in place but is unused. Instead, the working fireplace is a prefabricated insert and the entire assembly (fireplace and chimney) is composed of factory-built, listed components. No custom transition pieces are required for this system since all pieces are designed and prefabricated. The concrete bond beam at the base of the light-framed chase is similar to that of Section 7.3.3, but instead of an adapter cone, the bond beam is formed with a block-out through which the rated chimney assembly can pass. The block-out could be accomplished with a potentially combustible, round cardboard form, and therefore a requirement was added to remove all block-out form materials.

C.7.5 Masonry Fireplace Surround Prescriptive Retrofit

These provisions for anchored veneer on an interior wall are generally adapted from TMS 402. The requirements for Type S mortar is based on both its strength and tensile capacity/adhesion. The requirement in Item 4 for a registered design professional to check the stud capacity to support the veneer is taken from Section R703.8.1 of the 2015 IRC.

C.7.6 Engineered Retrofit of Masonry Chimneys

C.7.6.1 Building Code-Based Retrofit

Consistent with ASCE/SEI 7, the chimney is treated as either a nonbuilding structure or a nonstructural component as determined by its weight relative to the weight of the dwelling. For dwellings with multiple chimneys, individual chimneys can be treated as individual components, unless they are anchored to the same diaphragm, in which case they should be treated as nonbuilding structures because it is possible that the diaphragm has insufficient capacity to support multiple chimneys. If the weight of multiple chimneys exceeds 25 percent of the dwelling, chimney retrofit designs should be based on self-supporting or a comprehensive building plus chimney analysis.

Retrofits of existing structures are traditionally designed to loads less than those used to design new structures of the same occupancy. Historically, the retrofit seismic demand was prescribed to be 75 percent of the demand for new structures, and that option is adopted as an option in this section. In more recent standards retrofit loads are based on probabilistic seismic hazards. For instance, ASCE/SEI 41 defines a Basic Safety Earthquake for derivation of seismic loads for retrofit of existing structures, BSE-1E, which is the hazard associated with a 20 percent exceedance probability in 50 years (with the allowance that it not exceed loads for new construction contained in ASCE/SEI 7-10). The BSE-1E option is adopted as an option for defining retrofit design loads.

The following elaborates on the intent of the engineered design provisions of Section 7.6.1:

- Assumption of a rigid chimney is consistent with the approach often used for tilt-up wall panels. If story stiffness in multi-story dwellings are approximately equal, this assumption will cause the calculated strap demands at each floor or roof level to be closer to equal.
- Combining capacities of new and existing anchor straps should only be done if the stiffnesses can be shown to be compatible. Note that the requirement to verify the strap engagement with the chimney reinforcement will require some destructive investigation, and is therefore more robust than the anchor strap assessment in Section 7.3.3 Item 4. The use of existing straps in an engineered solution requires a higher confidence in the anchor strap capacity.
- The intent of checking the diaphragm capacity is to ensure tie loads can be transferred to the walls at the perimeter of the diaphragm. It is not necessary to check wall strength, nor is it necessary to model the entire house. This chapter allows engineers to utilize the subdiaphragm concept to ensure the load gets into the diaphragm and spread to the walls. Diaphragm loads from chimneys need not be combined with dwelling seismic demands.
- The requirements for the chimney to be able to carry design moment and shear may require assessment beyond what is required in Section 7.3.3 Item 3. If the design relies on base moment to resist seismic loads, then reinforcing anchorage and soil capacity should be verified. If a pinned base is assumed, then only shear capacity need be verified.
- Potential components that might warrant special inspection include anchor strap connections, rebar anchorage, and/or nailing to strengthen the supporting diaphragm.

C.7.6.2 Performance-Based Retrofit

Performance-based design of residential chimneys is unlikely, but is included here for completeness. Performance-based retrofit design requires substantially more effort than a code-based retrofit, including extensive modeling and analysis that addresses the house-chimney interaction. If a model of the house and chimney is used to determine strap and anchorage forces, it is not the intent of this chapter that the forces from the chimney be traced through the entire structure and used to size structural components of the dwelling other than the local (sub)diaphragms supporting the ties.

C.8 Detailed Vulnerability-Based Assessment

The provisions of this chapter are referenced from the detailed assessment sections of Chapters 4, 5, and 6. The purpose of this chapter is to provide detailed assessment of existing construction in order to determine compliance with the prestandard for the vulnerability being considered. Where compliance with the prestandard is demonstrated, retrofit is not required. Where existing construction is not in compliance, retrofit is required. The exception to this is where conditions such as incomplete or inadequate installation, component damage, or adjacent material deterioration have been deemed to significantly affect seismic performance causing non-compliance. Where these conditions are reasonably repaired or supplemented and compliance can subsequently be demonstrated, no retrofit work is required. These instances are specifically noted in Chapter 8.

In general, the detailed assessments of this section check compliance of existing construction with previous prescriptive retrofit or previous new construction provisions. In accepting these previous retrofit or new construction provisions, the prestandard “grandfathers” the existing construction, recognizing the dwelling to be notably less susceptible to the vulnerability than dwellings non-compliant with the assessment, but more susceptible than those retrofit in accordance with the prestandard. The provisions being used for grandfathering are understood to provide lower strength and stiffness than the retrofit requirements of this prestandard. They are being grandfathered in, however, because they represent a reasonable step towards meeting the purpose of these provisions, identified in Section 1.2 as “...reducing earthquake-induced damage to existing wood light-frame dwellings.” Where assessment finds that a dwelling is eligible to be grandfathered, but would fall below the retrofit requirements of this prestandard, further retrofit to meet this prestandard might be considered as a step towards better performance, but is not mandatory in order to comply with this prestandard.

Because a number of the assessment provisions are referenced in more than one chapter, they are grouped in Chapter 8. Several of the Chapter 8 sections contain assessment provisions not applicable to all dwelling types. Each section of this chapter is only meant to be used when and to the extent that it is applicable to the dwelling being assessed.

If it has been determined that retrofit of an element is to be provided, assessment is not required. The only reason to make an assessment is to identify elements that do not require retrofit.

C.8.1 Foundation

Section 8.1 Item 1. This is used to confirm that a dwelling has continuous *perimeter foundations* adequate to support the perimeter cripple walls or shear walls that are intended to serve as the seismic resistance for retrofits. The continuous foundation being assessed is intended to be under the main dwelling exterior walls. The foundation need not be under porches and other appurtenances outside the main dwelling. Alternately, foundations that follow the perimeter of a porch or similar appurtenance rather than the main dwelling walls are acceptable provided that the majority of the length of cripple wall bracing and anchorage can be provided on the portions of the foundation that are directly under main building walls above. An example of this is a front porch that is set into the main dwelling footprint (Figure C.8.1-1).



Figure C.8.1-1 Dwelling with a front porch that is set into the main dwelling footprint.

No minimum foundation size is specified, as the foundations are assumed to be of dimensions typical of minimum construction practice. Foundations are permitted to be of concrete or masonry, reinforced, or unreinforced. This is because the loads imparted to the foundation by anchor bolts and other proprietary anchors are relatively small and do not put significant demand on

the foundation. An exception is when tie-down anchors are attached with adhesive anchors. Additional dimensional limitations and testing requirements apply to the foundations and installation when such tie-down anchors are used.

- **Table 8.1-1 Item F1.** This item is intended to identify deterioration to an existing foundation, extensive enough that it has already caused notable loss of capacity. In this case, continued loss of capacity is likely to occur. Significant strength loss would include loss of 20% or more of cross sectional area of the foundation or reinforcing steel area. It would include other types of damage thought to result in loss of strength on the order of 20% or more. Repair of deterioration is permitted in order to bring the foundation into compliance with the assessment statement.
- **Table 8.1-1 Item F2.** Cracks in existing foundations are often found, due either to seasonal or long-term movement of the supporting soils. Cracks often vary in width over the height or width of the foundation, while the foundation is still able to lock together across cracks and transmit some level of load. The width of 1/2-inch or wider is chosen as the point at which it becomes difficult for the foundation sections on either side of the crack to engage and transmit load. At this magnitude of movement, a soil-related issue is indicated, and involvement of a geotechnical engineer is needed. This also represents a level of movement at which damage might occur to any retrofit cripple walls or anchorage installed in the vicinity. Repair is permitted to bring the foundation into compliance with the assessment statement.
- **Table 8.1-1 Item F3.** Similar to Item F2, damage to finish materials above the foundation is an indicator of significant foundation movement, and likely an underlying soils issue needing the involvement of a geotechnical engineer.
- **Table 8.1-1 Item F4.** Undermining of existing foundations can lead to the foundations being vulnerable to damage, and can reduce sliding resistance under seismic loads. This is of particular concern on steeper slopes where significant undermining can occur.
- **Table 8.1-1 Item F5.** Spalling in concrete or masonry foundations generally occurs when moisture seeps in and causes corrosion of the reinforcing steel. As the steel corrodes, the corrosion products push outward on the concrete or masonry covering the rebar, eventually causing the concrete or masonry cover to peel off. When this type of behavior occurs over a length of more than 16 inches, fairly significant loss of foundation integrity has occurred and is likely to continue.

Repair of corrosion and spalled concrete or masonry is permitted to bring the foundation into compliance.

Section 8.1 Items 2 and 3. These items identify foundation conditions for which assessment is outside the scope of this prestandard. These are less common and more complex conditions for which a general engineered assessment is appropriate.

Section 8.1 Item 4. Item 4 identifies a type of construction that is generally more susceptible to earthquake damage. Discontinuous shallow pier foundations often occur in dwellings that have isolated posts rather than cripple walls at the dwelling perimeter (Figure C.8.1-2). Although it is permitted to provide a general engineering assessment, such assessment is not very likely to show compliance. Construction of a new foundation is generally the most practical way to retrofit this dwelling configuration.



Figure C.8.1-2 Dwelling on post and pier foundation.

C.8.2 Foundation Sill Plate Anchorage to Foundation

This section assesses anchorage of the foundation sill plate to the foundation. The section is applicable to cripple walls in *crawlspace dwellings* and *hillside dwellings*, and existing ground story *bracing walls* in *living-space-over-garage dwellings*. Criteria are given for assessment of both existing anchor bolts and proprietary foundation anchors. When used in this section, the term proprietary anchor is used to mean an anchor attaching the foundation sill plate to the inside face of the foundations, seen as Item B2 in Figure 4.1-2. This type of anchor is used when there is not enough clear height for roto-hammer access to drill for additional anchor bolts. These anchors do not have significant uplift capacity and should not be used in cripple walls over 2 feet in height.

Homes may have a combination of anchor bolts and proprietary foundation anchors. When this is the case, each wall line or portion of a wall line should be assessed for the type of anchor provided. While it is acceptable for one

length of a wall line to have anchor bolts and another length of wall line to have proprietary anchors, within a given length of wall line, only one type of anchor or the other should be counted, and the two should not be summed.

Where anchorage is found non-compliant, retrofit is required. This is because it is very unlikely that further assessment will find the condition compliant, and because once work is required, it makes most sense to install compliant anchorage.

Section 8.2 Item 1. Anchor bolts assessed in this section can include cast-in anchors, adhesive anchors, expansion bolts, or concrete screws. Each of these types is generically considered to be an anchor bolt. Where previous retrofit has occurred, it is possible that the retrofit anchor bolts will not be visible (hidden behind retrofit sheathing). Many contractors will bore a small diameter hole through the wood structural panel immediately above retrofit anchors, providing an inspection opening. Where this has not been done, it is suggested that small diameter holes (1-1/2 to 2-1/2-inch diameter) be added centered on stud bays and several inches from the bottom of the wood structural panel. This does not need to be added throughout, but enough should be added that the general spacing and condition of the anchor bolts can be determined.

- **Table 8.2-1 Item AB1.** Where anchor bolt installation was part of the original dwelling construction, it is anticipated that anchor bolts will be installed at a regular spacing at all perimeter foundation sill plates. In this case, spacing of 4 to 6 feet on center would be anticipated. Four foot spacing is more common under more recent codes. 5/8-inch diameter bolts at 6 feet on center are considered an equivalent to 1/2-inch diameter bolts at 4 feet on center.
- **Table 8.2-1 Item AB2.** Where anchor bolts were installed as part of a previous seismic retrofit, it is more likely that added anchor bolts are concentrated in the vicinity of retrofit sheathing. For this reason, this assessment looks for anchor bolts more closely spaced over the length of retrofit sheathing. Spacing notes corresponds to IEBC Appendix Chapter A3 requirements.
- **Table 8.2-1 Item AB3.** Where anchor bolts were installed as part of original construction, it is possible that they have just nuts or both nuts and cut washers. Unless constructed since circa 2000, it is unlikely that they will have steel plate washers. This assessment item requires that they as a minimum have nuts, and allows the nuts to be gapped from the top of the foundation sill plate, as sometimes occurs due to wood shrinkage. Often the nuts on older anchor bolts are corroded in place.

Where they are not corroded in place, it is good practice to add steel plate washers and then tighten them when the bolt projection is long enough, or finger tighten them when the projection is too short to allow for washers. The washers help prevent splitting of sill plates due to uplift forces and thus are more critical in taller cripple walls and sheathed panels with higher height to length ratios. The most critical locations for plate washers are ends of sheathed panels where uplift forces are greatest.

- **Table 8.2-1 Item AB4.** Where anchor bolts were installed as part of a previous retrofit, it is anticipated that they will have steel plate washers consistent with IEBC Appendix Chapter A3.
- **Table 8.2-1 Item AB5.** This item addresses the adequacy of installation and potential deterioration of the anchor bolts. This is intended to capture conditions that can be identified visually and with limited probing. Probing with an awl can be used to identify a pattern of decay on the sill plate. A wrench applying a torque of 10 to 20 foot-pounds can be used to detect inadequate installation or extensive corrosion. Both decay and corrosion are generally most severe at the underside of the foundation sill plate where it is in contact with the foundation. The 10% trigger to indicate a somewhat widespread condition, rather than one or two isolated occurrences of conditions. It is understood that the assessment is limited to visible conditions supplemented by limited evaluation techniques. The assessor is not expected to speak to conditions not visible or techniques in addition to those noted.

Section 8.2 Item 2. Under the retrofit provisions of this prestandard, proprietary retrofit anchors are only intended to be used on cripple walls two feet in height or less. This is because the proprietary anchors provide very little resistance to uplift due to overturning. This limitation is not included in the assessment, but should be considered when assessing existing foundation anchorage.

Proprietary retrofit anchors are generally readily visible as they are anchored to the inside of the existing foundation or stem wall.

- **Table 8.2-2 Item PA1.** Spacing noted is based on IEBC Appendix Chapter A3 which directs that the spacing of retrofit anchors be the same as would be provided for anchor bolts.
- **Table 8.2-2 Items PA2 and PA3.** Proprietary retrofit anchors should be checked against the manufacturer's installation instructions to verify that installation configuration and fasteners comply with the instructions. As with anchor bolts, the assessor is only responsible for visible conditions,

and what can be readily determined. Tightening bolts to the foundation with a torque wrench can help to detect improper installation. Light to moderate corrosion is not likely to influence the capacity of the anchor, so significant deterioration would imply very heavy corrosion.

Section 8.2 Item 3. It is possible that existing anchorage was custom engineered for a particular condition. In this case, engineered assessment would be required to determine compliance with this section.

Section 8.2 Item 4. Where no anchorage is evident, retrofit of anchorage is required. Note that it is possible that foundation sill plates that do not appear to have anchorage do have some anchorage provided by cast-in nails at the underside of the sill plate. Even where these are known to occur, this prestandard requires the addition of new foundation anchors.

C.8.3 Bracing Wall Sheathing

This section assesses the adequacy of existing cripple wall or crawlspace wall sheathing and sheathing fastening. The section is applicable to *cripple walls* in *crawlspace dwellings* and *hillside dwellings*. Criteria are given for minimum materials and installation.

Section 8.3 Item 1. This item provides assessment of wood structural panel siding products that provide both bracing and the exterior wall finish. This includes but is not limited to T1-11 siding that was widely used for home construction in the 1970s and 1980s.

- **Table 8.3-1 Item PS1.** Where this siding occurs at the perimeter of the crawlspace, it is anticipated that it extends to nearly the full length of the crawlspace walls, leaving openings for ventilation and access openings.
- **Table 8.3-1 Item PS2.** This assessment is based on readily visible conditions, and intended to identify decay and similar damage.
- **Table 8.3-1 Items PS3, PS4, and PS5.** These items reflect long standing code nailing requirements where the siding is also recognized to provide bracing. In many instances, this type of siding is found to not have edge nailing at the full perimeter of each siding panel. At vertical panel joints where a tongue and groove lap occurs, it is common to only find the panel with the outside lap nailed. It is also common to find nail spacing greater than 8 inches. Where inadequate nailing is found, repair should be by installing proper nailing is permitted to bring this item into compliance.

Section 8.3 Item 2. This item assesses sheathing installed as part of original home construction. It is anticipated that the sheathing was installed on the

exterior face of the exterior wall studs. As such, it is not visible on the building exterior, and assessment is limited to what can be seen from the crawlspace.

- **Table 8.3-2 Item OC1.** It is anticipated that the cripple walls will be fully sheathed. Where full length sheathing is provided, the need to positively determine nail size and spacing is somewhat diminished, because typical construction practices are considered to be adequate.
- **Table 8.3-2 Item OC2.** This assessment is based on readily visible conditions, and intended to identify decay and similar damage.
- **Table 8.3-2 Item OC3.** This is a common minimum sheathing thickness.
- **Table 8.3-2 Item OC4.** Because of the very limited access for observation, the assessor is asked to observe what is available, and look for signs that the existing construction might be less than typical construction practice. If there were signs that it is less, it would be important to find a location to verify sheathing nail size and spacing, or provide retrofit sheathing on the interior face.

Section 8.3 Item 3. This item assesses sheathing added as part of a previous retrofit. It is anticipated that the sheathing is readily visible on the inside face of the cripple wall. It is also anticipated that rather than extending the full length of the cripple wall, the sheathing is provided in several sections over a portion of the length. Note that where sheathing is found to be non-compliant, Section 4.4.1 requires retrofit of sheathing, anchorage to foundation, and connectors to framing above. This is done because the addition of sheathing is of marginal benefit without the load path connections being improved to help ensure that the sheathing strength can be developed.

- **Table 8.3-3 Item PR1.** The length of cripple wall sheathing is checked against prescriptive bracing from IEBC Appendix Chapter A3. This is one of the more lenient length of sheathing requirements available, but is believed to have been commonly used for existing retrofits.
- **Table 8.3-3 Item PR2.** This assessment is based on readily visible conditions, and intended to identify decay and similar damage.
- **Table 8.3-3 Item PR3.** This is a common minimum sheathing thickness.
- **Table 8.3-3 Items PR4 to PR8.** These items reflect installation details consistent with IEBC Appendix Chapter A3.
- **Table 8.3-3 Item PR9.** This item reflects the concern that finish materials might have been added over retrofit sheathing, making it

inaccessible for assessment. Where more than a small portion of the retrofit sheathing is inaccessible, it will be necessary to selectively remove finishes to verify extent and construction, or neglect the sheathing that is covered and add sheathing over other portions of the cripple wall.

Section 8.3 Item 4. Where there is another type of wood structural panel based siding product that is thought to have moderate to high capacity for seismic loading, further assessment is required to determine if the siding and its installation are compliant. Many common alternative siding products are very lightly nailed during installation and provide very little strength or stiffness. Siding products that are not wood structural panel based are not permitted to be considered for purposes of this assessment section.

Section 8.3 Item 5. Where no plywood or OSB is present, sheathing retrofit shall be provided. Other bracing materials allowed by the building and residential codes are not acceptable in this case because studies behind the development of this prestandard have identified that materials other than plywood and OSB do not have enough strength and ductility to meet the seismic performance objectives of this prestandard.

C.8.4 Floor Framing Rim Joist and Blocking

This section assesses the adequacy of connections to the floor framing immediately above the crawlspace. Where cripple walls are present, this assesses the connection between the cripple wall top plate and the framed floor above. Where there are no cripple walls and the floor framing is directly supported on a foundation sill plate, this assesses the connection of the foundation sill plate to the floor framing above. These are shown as connections A1 and B1 in Figures 4.1-1 and 4.1-2. This connection is a load path connection, transferring seismic forces from the dwelling into the sheathed cripple wall (A1) or foundation sill plate (B1). Table 8.4-1 addresses one-story dwellings and Table 8.4-2 addresses two-story dwellings. Commentary that follows addresses both one- and two-story buildings.

Tables 8.4-1 and 8.4-2 Items RJB-1 and RJB-2. These items assess the presence and condition of solid blocking or rim joists in the floor framing depth.

Tables 8.4-1 and 8.4-2 Item RJB-3. These items assess the connection of the rim joist or blocking to the top or sill plate below. Where the condition is original construction without retrofit, this connection would have been made

with toe nails, and is very often not visible. Where nailing cannot be identified, retrofit of the connection should be provided.

Table 8.4-1 and 8.4-2 Item RJB-4. Where seismic retrofit has occurred, the connectors should be readily visible. The spacing noted is consistent with IEBC Appendix Chapter A3.

C.8.5 Ground Story Bracing Walls for Living-Space-Over-Garage Dwellings

This section assesses the adequacy of existing bracing wall sheathing and fastening. Section 5.3 grandfathers in dwellings conforming to 1994 or later building codes, allowing either prescriptive/conventional construction or engineered designs. Section 8.5.1 provides detailed information by which conformance with the conventional construction provisions of the 1994 and 1997 UBC can be determined. Consistent with the requirements of the UBC, the assessment requires that a series of *braced wall lines* be provided at no more than 25 feet on center in higher seismic regions, and that the type, amount and construction of bracing meet minimum requirements, transcribed into Section 8.5 tables. Dwellings conforming to these provisions are thought to be considerably less vulnerable than older construction that might have had limited or no consideration of seismic bracing. The conventional construction provisions of 1994 and 1997 UBC have been brought into this prestandard because it is practical to do so. Assessment in accordance with the seismic bracing provisions of the IRC is also permitted, as is assessment in accordance with engineered provisions.

Appendix L

Summary of Loads for Simplified Engineering Retrofit

The following tables provide a detailed summary of loads used during the development of prescriptive design procedures presented in this prestandard. They are provided as guidance for the registered design professional where “Simplified Engineering Retrofit” is used. The registered design professional will need to verify actual roof, floor and wall assemblies and modify these loads as necessary based upon actual condition. The tables below were developed for *crawlspace dwellings*. Modifications may be appropriate for other dwelling types.

Table L-1 Suggested Roof Design Dead Loads—Gravity/Seismic Flat Weight Takeoff (psf)

Roof Light		Roof Heavy	
Material	Seismic Weight (psf)	Material	Seismic Weight (psf)
Roofing (Asphalt Shingles- max 2 layers)	4.0	Roofing *(Conc. Tiles)	11.0
Solar / other	0.0	Solar / other	0.0
Topping	0.0	Topping	0.0
1x skip sheathing + new 1/2 sheathing	2.0	1x skip sheathing + new 1/2 sheathing	2.0
Insulation	0.5	Insulation	0.5
M.E.P.	0.5	M.E.P.	0.5
Ceiling (1/2") gyp	2.5	Wood lath and 1" gypsum plaster (1 side)	8.0
Ceiling joists (2x6 @24")	1.0	Ceiling joists (2x6 @24")	1.0
Roof rafters (2x8 @24")	1.3	Roof rafters (2x8 @24")	1.3
Girders (4x8 @ 8')	0.8	Girders (4x12@ 8')	1.2
Columns	0.0	Columns	0.0
Misc.	0.4	Misc.	0.4
Dead Load	13.0	Dead Load	25.9
Roof Medium (Type 2)		Roof Medium (Type 1)	
Material	Seismic Weight (psf)	Material	Seismic Weight (psf)
Roofing *(Conc. Tiles)	11.0	Roofing (Asphalt Shingles- max 2 layers)	4.0
Solar / other	0.0	Solar / other	0.0
Topping	0.0	Topping	0.0
1x skip sheathing + new 1/2 sheathing	2.0	1x skip sheathing + new 1/2 sheathing	2.0
Insulation	0.5	Insulation	0.5
M.E.P.	0.5	M.E.P.	0.5
Ceiling (1/2") gyp	2.5	Wood lath and 1" gypsum plaster (1 side)	8.0
Ceiling joists (2x6 @24")	1.0	Ceiling joists (2x6 @24")	1.0
Roof rafters (2x8 @24")	1.3	Roof rafters (2x8 @24")	1.3
Girders (4x12@ 8')	1.2	Girders (4x8 @ 8')	0.8
Columns	0.0	Columns	0.0
Misc.	0.4	Misc.	0.4
Dead Load	20.4	Dead Load	18.5

* Use 19 psf for clay tile roofs.

Table L-2 Suggested Floor Design Dead Loads

2nd Floor - Light		2nd Floor - Heavy	
Material	Seismic Weight (psf)	Material	Seismic Weight (psf)
Floor finish* (assumes carpet and pad)	1.4	Floor finish *(assumes 7/8" hardwood)	3.6
Other	0.0	Other	0.0
Topping	0.0	Topping	0.0
Sheathing / (assume 1" horiz. Lumber)	2.3	Sheathing / (assume 1" horiz. Lumber)	2.3
Insulation	0.5	Insulation	0.5
M.E.P.	0.5	M.E.P.	0.5
1/2" Gyp. wall board	2.5	Wood Lath +1" Gypsum Plaster (1 side)	8.0
Sprinklers	0.0	Sprinklers	0.0
Joists (2x8 @ 16")	2.1	Joists (2x8 @ 16")	2.1
Girders (4x12@ 8')	1.2	Girders (4x12@ 8')	1.2
Columns	0.0	Columns	0.0
Tile	1.0	Tile	2.0
Misc.	0.5	Misc.	0.8
Dead Load	12.0	Dead Load	21.0
1st Floor (no ceiling finish at underside of floor framing)			
Material	Seismic Weight (psf)		
Floor finish**(assumes 7/8" hardwood)	3.6		
Other	0.0		
Topping	0.0		
Sheathing / (assume 1" horiz. Lumber)	2.3		
Insulation	0.5		
M.E.P.	0.5		
Ceiling (unfinished)	0.0		
Sprinklers	0.0		
Joists (2x8 @ 16")	1.9		
Girders (4x12@ 8')	1.2		
Columns	0.0		
Tile	2.0		
Misc.	0.0		
Dead Load	12.0		

* Use 6 psf for areas with tile or other heavy floor finish.

**Use 2 psf for tile (6 psf is unit weight).

Table L-3 Suggested Exterior Wall Design Dead Loads

EXTERIOR - Light (Type 1)		EXTERIOR - Medium- (Type 2)	
Material	Weight (psf)	Material	Weight (psf)
exterior paper	0.4	exterior paper	0.4
1" Lumber siding	2.3	1" Lumber siding	2.3
2x4 @ 16"oc	1.0	2x4 @ 16"oc	1.0
Insulation	0.5	Insulation	0.5
1/2" gyp. wall board (1 side)	2.5	Wood lath and 1" gypsum plaster (1 side)	8.0
Misc.	0.3	Misc.	0.8
TOTAL	7.0	TOTAL	13.0
EXTERIOR - Medium+ (Type 3)		EXTERIOR - Heavy (Type 4)	
Material	Weight (psf)	Material	Weight (psf)
Stucco (7/8" thick one side)	10.0	Stucco (7/8" thick one side)	10.0
	0.0	1" lumber siding and waterproofing	2.7
2x4 @ 16"oc	1.0	2x4 @ 16"oc	1.0
Insulation	0.5	Insulation	0.5
1/2" gyp. wall board (1 side)	2.5	Wood lath and 1" gypsum plaster (1 side)	8.0
Misc.	0.5	Misc.	0.8
TOTAL	14.5	TOTAL	23.0

Table L-4 Suggested Exterior Cripple Wall Design Dead Loads

EXTERIOR Cripple Wall – Light Retrofitted		EXTERIOR Cripple Wall – Heavy Retrofitted	
Material	Weight (psf)	Material	Weight (psf)
Waterproofing	0.4	Stucco (7/8" thick one side)	10.0
1" Lumber siding	2.3	1" lumber siding and waterproofing	2.7
2x4 @ 16"oc	1.0	2x4 @ 16"oc	1.0
1/2 in Plywood	2.0	1/2 in Plywood	2.0
Misc.	0.3	Misc.	0.3
TOTAL	6.0	TOTAL	16.0
EXTERIOR Cripple Wall - Light (As is) GABLE WALL - Light		EXTERIOR Cripple Wall - Heavy (As-Is) GABLE WALL - Heavy	
Material	Weight (psf)	Material	Weight (psf)
Waterproofing	0.4	Stucco (7/8" thick one side)	10.0
1" Lumber siding	2.3	1" lumber siding and waterproofing	2.7
2x4 @ 16"oc	1.0	2x4 @ 16"oc	1.0
Misc.	0.3	Misc.	0.3
TOTAL	4.0	TOTAL	14.0

Table L-5 Suggested Interior Wall Design Dead Loads

INTERIOR -Light		INTERIOR - Heavy	
Material	Weight (psf)	Material	Weight (psf)
1/2" gyp. wall board (2 sides)	5.0	Wood Lath and 1" Gypsum Plaster (2 sides)	16.0
2x4 @ 16"oc	1.0	2x4 @ 16"oc	1.0
Insulation	0.0	Insulation	0.0
MEP	0.5	MEP	0.4
Misc.	0.5	Misc.	0.6
TOTAL	7.0	TOTAL	18.0

Other Vulnerabilities

O.1 General

As discussed in Sections 1.7 and C1.7, this prestandard is vulnerability-based, focusing on assessment and retrofit of known seismic vulnerabilities judged to be of priority for improving seismic performance. There are a number of other common sources of seismic vulnerability or damage that a homeowner or resident might be interested in addressing. This section provides a partial list of other common vulnerabilities and resources for mitigation.

O.2 Other Common Vulnerabilities

The following are sources of vulnerability or damage not specifically addressed by the assessment and retrofit provisions of this prestandard. The items listed range in level of risk and effort and cost required to mitigate the risk.

- **Water heaters.** Water heaters are a very common source of damage, ranging from fire started by damaged gas lines, to water damage that occurs when the tank fractures. Bracing of water heaters is relatively easy and inexpensive, with premanufactured seismic strapping kits available at many local hardware stores.
- **Contents.** Furniture and other home contents can fall during an earthquake, potentially injuring occupants. Practical and inexpensive approaches are available for anchoring contents to walls and the floor. Alternatively, some contents might be moved away from commonly used areas, paths of travel, and particularly exits. Priority should be given to taller and heavier contents that provide higher seismic hazard to occupants.
- **Decks and exit porches.** Decks and porches are often only nominally fastened to the dwelling that is supporting them. Under moderate to high earthquake shaking, they can pull away and collapse. Practical methods are available to better anchor decks and porches to the dwelling, or to provide bracing between the deck or porch and the supporting foundation.

- Roof tiles. Clay tiles can become dislodged from roofs and pose a falling hazard, particularly when not installed and fastened per recent building code requirements. While the short-term risk can be addressed by keeping clear of the edge of the roof, it is also possible to better anchor the roof tiles to resist falling.
- Wood burning stoves and propane tanks. When not anchored or restrained, wood burning stoves and propane tanks can shift or topple in an earthquake, causing damage and potential fire hazards.
- Overhead windows and skylights. Where large areas of glass (or mirror) occur, there is higher likelihood of breakage. Measures available to mitigate risk include applying films to glazing. Films will not reduce breakage, but could help to reduce spread of broken glass.
- Wall bracing in occupied stories. Existing walls, both interior and exterior, provide earthquake bracing to dwellings. However, the amount of bracing wall in a dwelling can vary widely. Dwellings with very low amounts of bracing wall are more susceptible to earthquake damage including cracking of finishes, permanent wall deflection, and jamming of doors. Earthquake performance can be improved by adding more walls or adding more strength and stiffness to existing walls. This is particularly easy to accomplish during remodeling. When remodeling the interior of a dwelling, it is reasonable to add wood structural panel sheathing to walls where finish materials are being removed and reinstalled. The benefit of adding wood structural panel sheathing will vary significantly based on the overall configuration of the dwelling, but will improve the seismic performance.
- Anchorage to slab-on-ground foundations. Although not seen as a significant source of damage in recent earthquakes, inadequate anchorage of wood light-frame dwellings to slab-on-ground foundation is a potential vulnerability. Typical damage modes include shifting of the dwelling walls relative to the foundation, and associated damage to the wall framing and finish materials. Addition of supplemental anchorage can mitigate this vulnerability.
- Split-level dwellings. The term split-level is used for dwellings that have vertical offsets in their framed floors. In past earthquakes separations have occurred between portions of the dwelling having different floor levels, in some cases leading to collapse of a portion of the dwelling. Mitigation for split-level dwellings involves adequate connections between portions of the dwelling to resist separation.

- Roof sheathing. Adding wood structural panel sheathing to a roof sheathed with solid or space lumber sheathing will not make the dwelling more vulnerable, and may make it marginally better. Addition of roof wood structural panel sheathing should only occur when the roofing is to be replaced for other reasons.

O.3 Resources for Addressing Vulnerabilities

The following are recommended resources for those interested in addressing other vulnerabilities:

- FEMA P-50, *Simplified Seismic Assessment of Detached, Single-Family, Wood-Frame Dwellings* (FEMA, 2012a)
- FEMA P-50-1, *Seismic Retrofit Guidelines for Detached, Single-Family, Wood-Frame Dwellings* (FEMA, 2012b)
- FEMA E-74, *Reducing the Risks of Nonstructural Earthquake Damage* (FEMA, 2012c)
- *Homeowner's Guide to Earthquake Safety* (CSSC, 2005)
- *Guidelines for Earthquake Bracing Residential Water Heaters* (DSA, 2014)
- FEMA 528, *Earthquake Home Hazard Hunt* (FEMA, 2014a)
- FEMA P-909 CD, *Home and Business Earthquake Safety and Mitigation* (FEMA, 2014b)
- FEMA 530, *Earthquake Safety Guide for Homeowners*, currently out of print and being updated

As discussed in Section 1.9, use of this prestandard is permitted whether or not there is potential for or occurrence of a site soil hazard that could impact the performance of a dwelling. This is permitted because retrofit of the vulnerabilities addressed by this prestandard are thought to provide benefit, even if somewhat reduced by the occurrence of site soils hazards.

Although this approach has been taken by the prestandard, where dwellings are potentially subjected to site soil hazards, the owners should be aware and encouraged to further understand the implications of the site soil hazards for the performance of their dwelling. This appendix provides background information to assist the owner in understanding site soil hazards, and identifies resources to help the homeowner determine if such hazards potentially affect the dwelling.

S.1 Overview

When evaluating the need to improve the performance of a single-family dwelling during an earthquake, an important factor is the behavior of the ground supporting the dwelling. Location of dwelling will govern the level of shaking and the earthquake-induced potential hazards. There are two types of ground related issues: static and earthquake. Static ground-related issues are generally associated with movements of loose sand, soft clay, expansive soil (soil that expands and shrinks with moisture changes), and/or presence of ground water.

Earthquake related site factors include level of ground shaking, ground rupture, loss of foundation support and excessive ground and foundation movement. Geologic hazards, such as stability of slopes, may also be present and may impact the structural performance of the dwelling during an earthquake and warrant evaluation. To properly assess whether hazards exist may require the services of a geologist or geotechnical engineer.

S.2 Site Soil Hazard Definitions

Site soil hazards that should be considered include: ground shaking, fault rupture, liquefaction, slope stability, densification, and differential compaction. This section provides an introduction to these hazards.

S.2.1 Ground Shaking

The intensity of ground shaking is the primary factor that affects the performance of structures during earthquakes. The level of shaking depends on the closeness to the fault; the closer to the fault, the greater the level of shaking. Geologic maps prepared by the United States Geological Survey (USGS) or by Geological Surveys of particular states, e.g., California Geological Survey (CGS), provide location of mapped faults. Fault Rupture Hazard Zone maps for California provide location of faults. Also, local jurisdictions may have maps that show faults.

USGS has prepared ground shaking maps for the United States and its territories that are part of the national building codes and standards such as the IRC, IBC, ASCE 7, and ASCE 41. These maps can be used to assess the level of shaking from earthquakes at dwelling. The knowledge of how strong the ground will shake in earthquakes will form the basis for retrofit of dwellings. As discussed in Section 1.6, ground shaking hazard is directly considered in the design of retrofits, whether by prescriptive or engineered methods.

S.2.2 Fault Rupture

Dwellings that are close to active faults may be impacted by ground rupture resulting from earthquakes. Fault Rupture Hazard Zone maps for California present areas close to the main traces of active faults where ground rupture could occur. In California, these maps are also known as Alquist-Priolo maps and can be obtained from the Public Information office of the California Geological Survey (CGS) or on the website (http://www.quake.ca.gov/gmaps/ap/ap_maps.htm). If a dwelling straddles a fault, a geologist and geotechnical engineer should be retained to assess if a retrofit is warranted to reduce the potential for collapse as a result of fault movement.

S.2.3 Liquefaction

Liquefaction is a phenomenon where saturated, loose, sandy soil loses strength because of earthquake shaking. Once liquefaction occurs sandy soil transforms from a solid to a liquefied state. The manifestation of liquefaction is loss of foundation bearing and formation of sand boils at the surface. Consequences of liquefaction are loss of bearing, vertical settlement, and lateral movement of the ground. Depending on the severity of liquefaction, dwellings on potentially liquefiable soil can suffer significant damage or collapse.

Typical measures for mitigation against liquefaction of loose sandy soil are densification or solidification. Compaction grouting consists of pumping

low slum cement grout into the ground and displaces the soil and densifies it. Solidification is achieved by mixing the soil with cement or injecting ultra-fine cement into the soil mass.

In addition, impacts of liquefaction can be reduced by: transferring the foundation loads to competent soil below the liquefiable layers (this can be achieved by using micropiles - small diameter piles); constructing tie beams between isolated footings to form a grid system; or by, constructing a stiffened foundation mat that can withstand liquefaction-induced deformations and localized loss of foundation bearing.

For areas where lateral movement (lateral spreading) of the ground can occur, large volumes of soil should be strengthened to create a buttress structure capable of resisting lateral movement. Mitigation against lateral spreading is difficult to achieve because the conditions associated with lateral spreading are global and not site-specific; that is, the mitigation may involve more than the single-family dwelling.

S.2.4 Slope Stability

If a dwelling is constructed on a hillside, stability of slopes during earthquake shaking is critical to its structural performance. Geologic maps that delineate slope stability hazard can be checked to evaluate the hazard at a dwelling. If slope stability hazard is present; mitigation measures that could be implemented are improving drainage and building a buttress or a wall. Less costly alternatives could include strengthening the dwelling to resist movements by construction of grade beams or shear walls.

S.2.5 Densification and Differential Compaction

Densification and differential compaction are phenomena in which non-saturated, sandy soil is compacted by earthquake vibrations. This phenomenon can cause differential settlement and may occur during strong ground shaking in loose, clean, sandy soil above the water table, resulting in ground settlement. Typically, the impact of this factor is relatively small and usually, the amount of differential compaction is on the order of a few inches or less. To improve performance, tying the foundations together is a relatively inexpensive and simple solution.

S.3 Simplified Site Assessment/Screening

For those interested in evaluating the potential for site soil hazards at a particular dwelling site, this section identifies available resources.

S.3.1 Ground Shaking

Refer to USGS website, USGS maps, geologic maps, California Fault Rupture Hazard Zone maps and/or local jurisdictions.

S.3.2 Fault Rupture

Refer to geologic fault maps, e.g., USGS, local State Geologic surveys, California Fault Rupture Hazard Zone maps and/or local jurisdictions.

S.3.3 Liquefaction

Refer to hazard maps (e.g., California), building codes, and consult with local jurisdiction. If the dwelling is in an area where the potential for liquefaction exists, local jurisdictions may mandate the need to retain the services of geotechnical engineer to quantify and evaluate the impact of liquefaction on the performance of the structure.

S.3.4 Slope Stability

Refer to geologic hazard maps published by USGS or State geological surveys and check with local jurisdiction requirements. In general, if a site is underlain by stiff soil (Site Class D) with a ground inclination of flatter than four horizontal to one vertical (4:1), stability of the slope should not be an issue. If the site inclination is steeper than 4:1, then subsurface condition and stability should be assessed by a geologist or geotechnical engineer. Local jurisdictions/codes may require a geotechnical/geologic report as part of the assessment.

S.3.5 Densification and Differential Compaction

Hazard zone maps for the local jurisdiction should be screened. Generally, even with the presence of thick deposits of dry loose sand, densification and differential compaction are small, and therefore, typically not a factor.

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