City and County of San Francisco
Department of Building Inspection

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ADMINISTRATIVE BULLETIN

NO. AB-107

DATE : May 19, 2016 (Supersedes Bulletin dated November 12, 2013; November 10, 2014; and, December 16, 2015) (Updated 01/01/2017 for code references)

SUBJECT : **Seismic Strengthening of Soft Story Wood Frame Buildings**

TITLE : **Application of Engineering Criteria in SFEBC Chapter 4D**

PURPOSE : The purpose of this Bulletin is to establish acceptable design criteria, standards and technical provisions for complying with Chapter 4D of the 2016 San Francisco Existing Building Code, as amended by Ordinance No. 66-13.

REFERENCE :

Chapter 4D, 2016 San Francisco Existing Building Code;
San Francisco Building Code Section 1905
2016 California Existing Building Code, Appendix Chapter A4
ASCE 31-03, Seismic Evaluation of Existing Buildings
ASCE 41-06, Seismic Rehabilitation of Existing Buildings
ASCE 41-13, Seismic Evaluation and Retrofit of Existing Buildings
FEMA P-807, Seismic Evaluation and Retrofit of Multi-Unit Wood-Frame Buildings with Weak First Stories
Administrative Bulletin AB-106, Procedures for Implementation of SFEBC Chapter 4D
ABK, 1981, "Methodology for Mitigation of Seismic Hazards in Existing Unreinforced Masonry Buildings: Diaphragm Testing [Topical Report 03]," ABK, A Joint Venture, El Segundo, California, December.
AF&PA, 2009, *ASD/LRFD Wind & Seismic: Special Design Provisions for Wind and Seismic, 2008 Edition* [ANSI/AF&PA SDPWS-2008]. American Forest & Paper Association, Inc.
Countryman, D., 1952. "Lateral Tests on Plywood Sheathed Diaphragms [Laboratory Report Number 55]," Douglas Fir Plywood Association, March 28, *Information reaffirmed August 1963.*
Countryman, D. and Colbenson, P., 1955. "1954 Horizontal Plywood Diaphragm Tests [Laboratory Report 63a]," Douglas Fir Plywood Association, January 25.
NDS 05 Table 11E
SEAOC Blue Book – Seismic Design Recommendations "Anchor Bolts in Light-Frame Construction at Small Edge Distances
ASTM E488/E488M-03 "Standard Test Methods for Strength of Anchors in Concrete Elements

DISCUSSION : SFEBC Chapter 4D, created with Ordinance 66-13, mandates the seismic retrofit of certain wood-frame residential buildings. Section 406D.2 allows different criteria, or compliance alternatives. Section 406D.4 calls for the development and publication of this Administrative Bulletin to "detail the technical requirements to be used for the evaluation and retrofitting of buildings required to meet the criteria established in Section 406D.2."

SCOPE : This bulletin covers only SFEBC Sections 406D.2 through 406D.4. AB-106 covers administrative and procedural requirements of Chapter 4D. This Bulletin is separate from, but intended to be in coordination with, other sections of Chapter 4D, other Administrative Bulletins, and other forms and instructions.

Part A of this Bulletin applies to all projects seeking to comply with Chapter 4D, regardless of the compliance alternative. Parts B through G apply, respectively, to the specific compliance alternatives allowed in Section 406D.2.

DEFINITIONS : In addition to the definitions in Section 403D, the following definitions shall apply for purposes of this Bulletin:

TARGET STORY. Any story above grade plane, or any basement or underfloor space that extends above grade at any point, in which the wall layout or plan configuration is substantially different from the wall layout or plan configuration in the story above, except that a story is not a Target Story if it is the topmost story or if the difference in configuration is primarily due to the story above being a penthouse, an attic with a pitched roof, or a setback story.

> ***Commentary:*** *This definition is taken from the Screening Form Instructions developed to implement Section 406D.2, but it has been modified to clarify that the consideration of "substantially different" wall layout or configuration applies to basements and underfloor areas as well as to stories above grade plane. As discussed in the Screening Form Instructions, "substantially different from" generally means "substantially weaker than" and can be a matter of engineering judgment, to be decided as part of the Screening Form approval process. As described in the Screening Form and Screening Form Instructions, Chapter 4D applies only to wood-frame target stories, that is, target stories in which the seismic force-resisting system in any direction relies on wood-frame wall elements. A building can have more than one target story.*

Part A. GENERAL REQUIREMENTS

A1. Compliance

A1.1. Required scope of evaluation and/or retrofit. Evaluation and/or retrofit shall address:

1. Vertical elements of the seismic force-resisting system (SFRS) in each target story in which the existing SFRS relies on wood-frame elements, and
2. Each floor diaphragm immediately above such a target story, and
3. Elements of the seismic force-resisting load path from each such diaphragm through the foundation.

Exception: Where the existing vertical elements of the SFRS are shown to comply by evaluation, the diaphragm immediately above each target story need to be evaluated.

A.1.1.1. Floor diaphragm evaluation and/or retrofit. Floor diaphragms subject to evaluation and/or retrofit shall be shown to have adequate strength at the following locations:

1. For straight lumber sheathed diaphragms without integral hardwood flooring: Throughout the diaphragm. At the discretion of the code official, this requirement may be waived where the condition occurs only in relatively small portions of each dwelling unit.

2. For other diaphragms: At locations where forces are transferred between the diaphragm and a new or strengthened vertical of the SFRS. Collector elements may be provided to distribute the transferred force over a greater force over a greater length of diaphragm.

> ***Commentary:*** *Evaluation of the diaphragm's adequacy is only required when new vertical elements are added to the target story or existing vertical elements in the target story are strengthened. This allowance is considered appropriate for the limited objective of Chapter 4D. Therefore diaphragm adequacy need only be confirmed in two cases.*
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> *Case 1. Straight lumber sheathed diaphragms without integral hardwood flooring are thought to be considerably weaker and more flexible than other diaphragm systems. Though there are no known collapses due to this condition, expected poor performance could compromise the building's ability to meet even the limited objective of Chapter 4D. Integral hardwood flooring – but not newer "floating" wood flooring – provides significant added strength and stiffness. Even in buildings with original hardwood flooring, some remodeled, carpeted, or tiled areas might have had the original wood flooring removed. Areas of the diaphragm that form a roof for the target story (such as the portion of a garage that extends beyond the wall line above, or at a lightwell or building setback) are also unlikely to have hardwood flooring to supplement the straight sheathing. These areas should be identified as part of the condition assessment (see Section A3) and evaluated. Small isolated areas without hardwood flooring are not expected to affect overall building performance, so the provision grants a waiver for these cases. As a rule of thumb, an area up to 150 square feet per unit might represent such an acceptable condition.*
>
> *Case 2. Where vertical SFRS elements are added or strengthened, an adequate load path and diaphragm must be provided. This provision requires a local check for each such element but does not require an overall analysis of the full diaphragm. The unit shear demand at each vertical element is calculated as the force in the element divided by the length of the element plus any collector. The shear demand is then compared to the unit shear capacity of the diaphragm. Where demand is greater than capacity, either the diaphragm is strengthened or the collector is lengthened. An existing diaphragm can be strengthened by adding a wood structural panel soffit attached to the bottom of the floor joists in the vicinity of the vertical SFRS element. The rules given in Section B5.1.1.2 may be useful for combining the capacities of new and existing diaphragm components. Diaphragm capacity need not be checked at existing vertical elements that are not strengthened because (except for Case 1) it is assumed that the unit capacities of the existing vertical elements and the diaphragm are comparable.*

A1.2. Other SFEBC requirements and Administrative Bulletins. Alterations and repairs required to meet the provisions of Chapter 4D shall comply with all other applicable structural requirements of the SFEBC unless specifically waived by those requirements, by this Bulletin, or by related Administrative Bulletins.

> ***Commentary:*** *See Administrative Bulletin 106 regarding procedural compliance with SFEBC Chapter 4D, specifically Section 406D.6.*

A1.3. Qualified historic buildings. In addition to or in place of the criteria allowed by SFEBC Section 406D.2, qualified historical buildings shall be permitted to use structural engineering criteria provided in the latest edition of the California Historical Building Code (California Code of Regulations Title 24 Part 8), subject to the eligibility requirements of that code.

> ***Commentary:*** *SFEBC Section 404D.5 also mentions the CHBC, but that provision is about historic preservation in accord with San Francisco Planning Department guidelines and has no direct bearing on the structural engineering criteria.*

A2. Seismicity, Soil, and Geotechnical issues

A2.1. Site Class E. Buildings located in areas labeled “NEHRP E” on the latest USGS map of “Soil Type and Shaking Hazard in the San Francisco Bay Area” will be assigned to Site Class E unless site-specific investigation in accordance with ASCE 7-10 Chapter 20 indicates otherwise.

> ***Commentary:*** *The map is available online at http://earthquake.usgs.gov/regional/nca/soiltype/map/*

A2.2. Site Class F. The requirement in ASCE 7-05 Section 11.4.7 for site response analysis of Site Class F sites is waived.

> ***Commentary:*** *SFEBC Chapter 4D does not require mitigation of existing geologic site hazards such as liquefiable soil. Also, many buildings subject to Chapter 4D would be exempt from site response analysis by the exception to ASCE 7-05 Section 20.3.1.*

A2.3. Seismic ground motion values. Where seismic ground motion values are calculated per ASCE 7-05 Section 11.4 or by similar provisions, the value of F_a shall be taken as 1.3 for Site Class E.

> ***Commentary:*** *This requirement applies to any code-based procedure for calculating seismicity parameters, such as that used by CEBC Appendix Chapter A4 and application of “regular code” provisions through the California Historical Building Code. It also applies where criteria such as ASCE 31, ASCE 41, and FEMA P-807 apply equations similar to those in ASCE 7 Section 11.4.*

A3. Assessment of Existing Building Conditions

A3.1. Building investigation and report. In support of an engineering evaluation or retrofit design, the owner shall conduct or cause to be conducted an investigation of the existing building. The engineer of record shall prepare a written report documenting procedures, findings, and conclusions of the investigation. The report may reference other materials submitted to demonstrate compliance or to support findings and conclusions.

A3.1.1. Scope of investigation. At minimum, the investigation shall comply with any investigation and assessment provisions in the engineering criteria selected from SFEBC Section 406D.2, as modified by subsequent Parts of this Bulletin. Otherwise, the investigation scope and methods may generally be set at the discretion of the engineer of record, but all findings shall be reported. The Department is authorized to require additional investigation as needed to fulfill the purpose of the report and the intent of SFEBC Chapter 4D. With the approval of the Department, field verification of assumed conditions may be performed during the construction phase.

As needed or required, the investigation shall include identification, verification, and assessment of existing conditions relevant to the engineering assumptions applied in the evaluation or retrofit design. The investigation shall be based on a combination of non-destructive testing or inspection, destructive testing or inspection, and reference to record documents. Where record documents are used to reduce the scope of testing or other on-site work, appropriate field verification is required.

> ***Commentary:*** *With respect to evaluation, the primary purpose of the investigation is to identify or confirm the nature of the existing construction as needed to justify load drift curves, tributary floor weights, load path assumptions, etc. A secondary purpose is to provide condition assessment sufficient to rule out deterioration or construction defects significant enough to affect earthquake performance of the structure as a whole. The investigation should therefore seek evidence of damage, deterioration, or defective construction sufficient to affect significantly the performance of the seismic force-resisting system. With respect to retrofit design, the primary purpose of the investigation is to confirm design assumptions regarding the adequacy of existing seismic load path components within the context of the retrofitted structure. In addition, though it need not be stated in*

the provision, the Department is always authorized to require repair of damage, correction of defects, and elimination of dangerous conditions; hence the requirement that "all findings shall be reported."

A3.1.2. Timing of investigation. Unless otherwise required by the engineering criteria selected from SFEBC Section 406D.2, as modified by subsequent Parts of this Bulletin, with the approval of the Department, investigation may be deferred to a confirmation or construction phase. The deferred investigation shall be specified as a special inspection item in accordance with SFBC Chapter 17.

Commentary: *This allowance is offered for the benefit of owners for cases in which destructive investigation will be unusually disruptive or expensive. However, the owner will bear the risk of change orders, design revisions, and supplemental design review if actual conditions differ from those assumed by the evaluation or design. Approval of the Department is required to allow the Department to identify cases where deferred investigation will complicate its review and approval process. The Department may allow some parts of the investigation to be delayed while requiring other parts of the investigation to be completed prior to review of calculations.*

A3.2. Existing materials and components. Where the applicable engineering criteria specify material or structural properties of existing elements, those criteria shall be used. Otherwise, the general rules of this section apply.

A3.2.1. Damage and defects. The capacity of any element damaged by deterioration, wear, or other causes or constructed or altered so as to differ from its intended condition shall be reduced based on the judgment of the engineer of record, subject to review of condition assessment findings and the approval of the Department. This provision shall apply where the applicable engineering criteria do not make an explicit provision for capacity reduction.

Commentary: *This provision is consistent with ASCE 31-03 Section 4.2.4.4.*

A3.2.2. Relation of nominal and expected strength to allowable stress. Where element capacities are based on allowable stresses from codes and standards, nominal strengths shall be taken no greater than the allowable stresses multiplied by the following factors: 1.7 for steel; 2.5 for masonry; 2.0 for wood. Where the element is ductile or deformation-controlled, the expected strength shall be taken as 1.25 times the nominal strength.

Commentary: *This provision is consistent with ASCE 31-03 Section 4.2.4.4.*

A3.2.3. Concrete footings and stem walls. Evaluation and design of existing concrete footings shall be permitted to assume default concrete strength based on ASCE 41-13.

A3.2.4. Unreinforced brick footings. The capacity of an existing brick footing to resist shear or pullout of an existing or new anchor shall be established by testing or by reference to approved tests of similar conditions. Where the capacity of an anchor is limited by failure of the footing or grout, the anchored wall or frame element shall be considered non-ductile or force-controlled.

Commentary: *Because FEMA P-807 presumes ductile retrofit elements, the last sentence of this provision means that retrofit elements designed with FEMA P-807 may only be used with brick footings when testing has demonstrated that the anchor will develop the strength of the wall or frame element or will yield itself in a ductile fashion.*

A3.2.5. Concrete or masonry retaining walls.
Reserved.

A3.2.6. Sheathed wood-frame walls and partitions. Wood-frame walls and partitions shall be permitted to use peak strength values from Bulletin Section B5.1.1. Where these values are used, they shall be taken as expected strengths and reduced to nominal strength per Bulletin Section A3.2.2 where used on non-ductile or force-controlled elements. This provision is subject to the following limitations:

1. A wall assembly may be considered deformation-controlled if all sheathing materials that are individually force-controlled are ignored in the strength calculation.
2. Retrofit designs based on *R* values from the building code shall use only code-approved sheathing materials and combinations appropriate to the assumed *R* value.

A3.2.7. Anchorage of sill plates.
Sill plates of all walls that are considered to resist seismic shear forces shall be anchored to the foundation, structural slab or stem walls that they rest on. Total shear capacity of competent existing bolts and any added anchor bolts shall be adequate to resist the shear demand on the wall. Anchors in walls that are not considered to resist seismic shear forces are not required to be investigated.

When investigation confirms the presence of concrete foundations supporting 2x or 3x sill plates anchored with ½" to ¾" diameter bolts with washers and nuts, it is acceptable to determine in-plane shear capacities in accordance with applicable tables in ANSI/AWC National Design Specification, provided that the supporting concrete is sound, sill plates are in good condition, anchor bolts do not show extensive corrosion, and anchors are located in the concrete per SFBC Section 1905.

The capacity of existing sill plate anchors in brick footings or stem walls shall be established per Section A3.2.4.

Maximum spacing between existing sill plate anchor bolts shall be six (6) feet for walls with plywood sheathing and ten (10) feet for other shear walls (archaic walls). There shall be a minimum of two (2) shear anchors per each wall segment that is considered to resist seismic forces.

All anchors for which capacity cannot be determined by calculation, or for which capacities are not published in an approved Standard, may have capacities established by testing. Anchor bolts that are placed out of plumb, are loose, show extensive signs of corrosion, or are otherwise damaged shall not be considered to provide lateral load resistance.

Where new anchors are required, strength, spacing and installation requirements shall be determined in accordance with the SFBC.

> ***Commentary:*** *Reliable performance of a lateral load resisting system depends on the presence of a complete load path, from floor diaphragm through the lateral load resisting elements and their foundation, to the supporting soils. Absence of an adequate connection between the wood sill and foundation is a gap in the load path that limits the ability of the shear wall to resist seismic forces.*

A3.2.8. Default strength values for diaphragms. Default values for evaluation and retrofit design of existing or strengthened diaphragms may be taken from ASCE 41-13 Table 12-2 or 15-2 when using ASCE 31 or ASCE 41, or from SDPWS-08 Tables 4.2A through 4.2D (AF&PA, 2009) when using CEBC Chapter A4, with adjustments for nominal v. expected strength, ASD, or LRFD. When using FEMA P-807, diaphragm strength may be determined using the nominal strength from ASCE 41 or SDPWS multiplied by *phi* = 1.0, or peak expected strength as provided in Table A3.2.8.

Table A3.2.8 Peak Expected Strength of Existing or Strengthened Horizontal Diaphragms for use with FEMA P-807.

Diaphragm Description	**Peak Expected Strength (plf)**
Unblocked wood structural panel with thickness 3/8 in. or greater, any case[1]	730
Unblocked wood structural panel with thickness ½ in. or greater, Case 1[1] with 8d common nails	1380

Diaphragm Description	Peak Expected Strength (plf)
Blocked wood structural panel with thickness 15/32 in. or greater and 8d nails, any case[1]	1380
Blocked wood structural panel with thickness 15/32 in. or greater and 10d nails @ 4/6/12 or better, any case[1]	1710
Diagonal wood sheathing with directly applied built-up roofing (derived from ABK Topical Report 03)	860

[1] Case refers to load case diagrams in SDPWS Table 4.2A

> ***Commentary:*** *This section identifies sources of diaphragm capacities suitable where Chapter 4D requires diaphragm evaluation or strengthening. Table A3.2.8-1 is for use only with procedures like FEMA P-807 in which capacities are based on estimated peak strength. Because FEMA P-807 is based on the estimated peak strength of vertical elements, the diaphragm strength is allowed to be derived on a similar bases, with a phi factor of 1.0. Expected strengths in Table A3.2.8-8 are based on test information from APA (Countryman, 1952; Countryman and Colbenson, 1955) and ABK (1981). Reference to SDPWS in the table is only for load case diagrams; expected strengths are to be taken from the table.*

A4. Structural Calculations and Project Documentation

A4.1. Submittals. Structural calculations and supporting documents shall be prepared and submitted as required by Bulletin Section A4.2. Other documents shall be prepared and submitted as required by Administrative Bulletin 106.

A4.2. Structural calculations and supporting documents. Structural calculations shall be submitted as required to confirm compliance with the selected engineering criteria. Calculations shall be specific to the engineering criteria used and shall include, at minimum:

1. A statement that the evaluation or retrofit design was prepared to demonstrate compliance with SFEBC Chapter 4D.
2. Identification of the engineering criteria used for the evaluation or retrofit design, including the performance objective used with FEMA P-807, ASCE 41-06, or ASCE 41-13.
3. All building investigation, soils, geotechnical, or other supporting reports, as well as a summary of such reports indicating how the findings or conclusions are reflected in the structural calculations.
4. Identification of structural properties and capacities assumed for all existing materials and elements, including any capacity reductions for damage, deterioration, or defect.
5. Identification of structural properties and capacities assumed for all new materials and elements, including product literature for proprietary devices.
6. If requested by the Department, verification calculations for any engineering software used.
7. Other information as required by the Department.

A5. Construction Quality Assurance

A5.1. Testing and inspection. All work shall comply with inspection and testing requirements of the building code as they apply to existing buildings and structures. Additional field verification, structural observation, testing, and inspection may be required in accordance with the selected engineering criteria or as directed by the Department.

A6. Additional Technical Requirements

A6.1. Use of Steel Special Moment Frames. Special Steel Moment Frames shall comply with all applicable provisions of AISC 341-10, including but not limited to connection design and lateral bracing of beams.
Exception: The "strong-column/weak-beam" provision of AISC 341-10, Section E3.4a is waived, provided that the columns carry no gravity load.

It is permitted to employ approved commercially available proprietary frame systems to achieve the Special Moment Frame classification.

A6.2. Use of Steel Ordinary Moment Frames or Steel Intermediate Moment Frames. CEBC Chapter A4 allows the use of any seismic force resisting system permitted in the building code, when the applicable R factor is employed. The building code (through reference to ASCE7) permits the use of steel moment frames other than Steel Special Moment Frames in light frame construction only when specific limitations regarding the building height and unit weights of floors and walls are met. These limitations are waived for buildings with no more than three stories above the highest Target Story. The R, Ω_0, and C_d factors employed shall be those applicable to the selected system.

A6.3. Use of Cantilevered Column Systems. Cantilevered column systems conforming to the following provisions may be considered as moment frame systems (Special, Intermediate, or Ordinary, as applicable, based on detailing) with regard to determination of the R, Ω_0, and C_d factors.
1. Columns shall not carry gravity load.
2. Columns shall be configured in pairs (or larger groups) connected by a continuous foundation or grade beam.
3. The continuous foundation or grade beam shall be designed to resist the expected plastic moment at the base of each column, computed as $R_y F_y Z$, as defined in AISC 341-10.
4. The flexibility of the continuous foundation or grade beam, considering cracked section properties of reinforced concrete, shall be included in computing the deformation of the cantilevered column system.
5. Cantilevered columns shall be considered as twice their actual height when checking lateral torsional buckling.

Part B. APPLICATION OF FEMA P-807 TO EVALUATION AND RETROFIT DESIGN

DISCUSSION : FEMA P-807, unlike the other documents cited by Section 406D.2, is not a code or standard and is written in a guideline or narrative style. Enforceable provisions in "code language" are therefore provided here, adapted from FEMA P-807 Appendix B. In general, use of FEMA P-807 for compliance with SFEBC Chapter 4D shall mean compliance with the code language provisions in this Bulletin; FEMA P-807 itself constitutes a commentary to these provisions.

B1. Compliance

B1.1. Performance Objective

B1.1.1. Hazard level. The spectral demand shall be $0.5S_{MS}$, calculated in accordance with ASCE 7-05 Section 11.4 except that for sites in Site Class E, the value of F_a shall be taken as 1.3.

Commentary: *The value of F_a is modified for Site Class E to adjust the demand for site effects not considered explicitly in the development of FEMA P-807 (see FEMA P-807 section 2.6.1).*

B1.1.2. Performance level. Acceptable performance shall be based on drifts corresponding to the Onset of Strength Loss in the seismic force-resisting wood-frame elements.

Commentary: *This provision merely reflects the requirements of the ordinance, referencing the Onset of Strength Loss performance level defined in FEMA P-807. It does not require any additional work by the engineer, since the Onset of Strength Loss criteria are already embedded in the criteria given in this Bulletin.*

B1.1.3. Maximum drift limit probability of exceedance. The maximum drift limit *POE* for evaluation or retrofit design shall be 30 percent.

Exception: Where the story or underfloor area subject to evaluation or retrofit contains only parking, storage, or utility uses or occupancies, the maximum drift limit *POE* for evaluation or for retrofit design shall be 50 percent, as long as the additional requirements of Bulletin Section B7.3 are met.

Commentary: *This Exception incorporates the alternative criteria given in SFEBC Section 406D.3. The alternative criteria apply to what FEMA P-807 calls "optimized retrofit," as discussed in FEMA P-807 Sections 6.3.1 and 6.4.2.*

B1.2. Required scope of work. Compliance with the provisions of SFEBC Chapter 4D using FEMA P-807 requires:

1. Correction of all aspects of eligibility non-compliance per Bulletin Section B3, and
2. Correction of all building survey non-compliance per Bulletin Section B4; and either,

3a. Demonstration of an acceptable existing condition per Bulletin Section B6; or, 3b. Design and execution of a retrofit in accordance with Bulletin Section B7 and other applicable codes and regulations.

Where retrofit is required but the provisions of Bulletin Section B7 cannot be satisfied, the building shall be considered ineligible for compliance with SFEBC Chapter 4D using FEMA P-807.

B2. Definitions

Commentary: *In some instances, the notation and terminology differ slightly from those in FEMA P-807 Chapters 1-7.*

B2.1. Terminology. Terms used in Bulletin Part B shall have the meanings provided here. Terms not defined here shall have the meanings provided in the building code.

CENTER OF STRENGTH. At each story, the location in plan that represents the weighted average location of the load in all wall lines, at the drift associated with the story strength.

DRIFT. For a given story, the calculated or postulated lateral deflection within that story divided by the story height, normally expressed as a percentage.

FIRST STORY. Any target story subject to SFEBC Chapter 4D.

LOAD-DRIFT CURVE. For a wall assembly, wall line, or story, the relationship characterizing the variation of shear resistance versus drift, for the full range of relevant drifts. For a wall assembly, the load value is given in units of force per unit length. For wall lines and stories, the load value is given in units of force.

LOAD-ROTATION CURVE. For a story, the relationship characterizing the variation of torsional resistance versus story rotation, for the full range of relevant rotations, given in units of torque as a function of rotation angle.

PROBABILITY OF EXCEEDANCE (*POE*). The desired or calculated probability that the structure will respond beyond the drift limits representing the desired performance level, in at least one direction, when subjected to a specified hazard level. Within SFEBC Chapter 4D and this Bulletin, *POE* means the probability of exceeding the drift limits associated with Onset of Strength Loss.

Commentary: *As used in SFEBC Chapter 4D and this Bulletin, POE is identical to what FEMA P-807 Chapters 1 through 7 typically call "drift limit POE."*

QUALIFYING WALL LINE. For purposes of checking eligibility of floor or roof diaphragms, a wall line that contributes substantially to the peak story strength and has an adequate load path connecting it to the diaphragms it affects.

Commentary: *See FEMA P-807 Section 2.6.4 for discussion of rules for "qualifying" wall lines. The definition is subject to the judgment of the engineer of record and the Department.*

SPECTRAL CAPACITY. For a given POE, the highest level of spectral acceleration a structure can sustain without responding beyond the drift limits representing the desired performance level, given as a multiple of the acceleration of gravity, and calculated separately in each principal direction.

SPECTRAL DEMAND. See Bulletin Section B1.1.1. The spectral demand is given as a multiple of the acceleration of gravity.

STORY. For purposes of applying engineering criteria in SFEBC Section 406D and this Bulletin, see the building code definition and this Bulletin's definition of First Story. The definition in SFEBC Section 403D applies only to the counting of stories for determining scope per SFEBC Section 402D.

STORY STRENGTH. The maximum load value from the story load-drift curve, calculated separately in each principal direction.

STORY STRENGTH, BASE-NORMALIZED. The story strength divided by the total seismic weight of the building.

STORY STRENGTH, STORY-NORMALIZED. The story strength divided by the sum of the tributary floor weights of all the floors above the story in question.

STORY TORSIONAL STRENGTH. The maximum torsional resistance value from the story load-rotation curve.

STRENGTH DEGRADATION RATIO. In each direction, a value between 0.0 and 1.0 calculated as the first story strength divided by the load corresponding to a drift of 3 percent from the first story load-drift curve.

TORSION COEFFICIENT. A value that need not be taken greater than 1.4, calculated as the first story torsional demand divided by the first story torsional strength.

TORSIONAL ECCENTRICITY. The absolute value of the plan distance, in x and y components, between the second story center of strength and the first story center of strength.

TRIBUTARY FLOOR WEIGHT. The total seismically active weight tributary to a single floor level comprising dead load and applicable live load, snow weight, and other loads as required by the building code.

UPPER STORY. Any story above the first story.

WALL ASSEMBLY. A unique combination of sheathing materials over wood-stud framing.

WALL LINE. A collection of full-height and partial-height wall segments or frames within a single story that satisfies the rules in Bulletin Section B5.1.2.

Commentary: *A wood-frame wall line is generally assumed to contribute strength only in the direction parallel to its length. A wall line expected to contribute strength in a direction other than parallel to its length, such as a cantilever column or fixed-based moment frame, must be modeled appropriately.*

WALL SEGMENT. A portion of wood-frame wall made from a single wall assembly. For purposes of this definition, any sheathed run of wood-stud framing that could contribute to a story's lateral strength or stiffness shall be considered a potential wall segment, whether or not the framing and sheathing were intentionally designed, detailed, sized, or located to contribute that strength or stiffness.

B2.2. Notation

A_U The base-normalized upper-story strength, calculated separately for each direction.

A_W The weak-story ratio, calculated separately for each direction.

C_D The strength degradation ratio, calculated separately for each direction.

C_T The torsion coefficient.

C_U The minimum of the story-normalized story strengths of any of the upper stories, calculated separately for each direction.

Commentary: *Where the story strength is roughly constant for all upper stories,* C_U *will generally be the story-normalized strength of the second story.*

COS_i The plan location, in *x* and *y* coordinates, of the center of strength of story *i*.
e_x, e_y The *x* and *y* components, respectively, of the torsional eccentricity.
f_w The load-drift curve for wall line *w*.
F_i The load-drift curve for story *i,* calculated separately for each direction.
h_w The floor-to-ceiling height of wall line *w*.
H_1 The floor-to-ceiling height of the tallest first story wall line, determined separately in each direction.
I A subscript index indicating floor or story. Story *i* is between floor *i* and floor *i+1*.
L_w The length of wall line *w*, taken as the longest possible length of wall that satisfies the rules in Bulletin Section B5.1.2, including the length of any openings within it.
L_x The overall building dimension in the *x* direction.
L_y The overall building dimension in the *y* direction.
POE Probability of Exceedance
Q_{open} The adjustment factor for openings in a wall line.
Q_{ot} The adjustment factor for overturning of a wall line.
Q_s The story height factor for the first story, calculated separately for each principal direction.
S_c The spectral capacity, calculated separately for each direction.
S_d The spectral demand.
t_i The load-rotation curve for story *i*.
T_i The story torsional strength of story *i*.
V_{1r} The story strength of the retrofitted first story, calculated separately for each direction.
V_i The story strength of story *i*, calculated separately for each direction.
V_U The story strength of the upper story that determines the value of C_U.
Commentary: *Where the story strength is roughly constant for all upper stories,* V_U *will generally be the second story strength.*
w A subscript index indicating a single wall line.
W The total seismic weight of the building, equal to the sum of all the tributary floor weights.
W_i The tributary floor weight of floor *i*.
WSP Wood structural panel
x A subscript index indicating one of two principal directions.
$\alpha_{POE,0}$ The *POE* adjustment factor for a C_D value of 0.0.
$\alpha_{POE,1}$ The *POE* adjustment factor for a C_D value of 1.0.
δ_j Drifts at which load-drift curves are characterized. See Table B5.1.1.
Δ_i In each direction, the drift at which the story strength of story *i* occurs.
τ_1 The first story torsional demand.

B3. Eligibility

B3.1. General. Buildings that do not comply with the requirements of Bulletin Section B3 shall be considered ineligible for compliance using FEMA P-807.
Exception: Buildings in which all aspects of non-compliance will be eliminated through alteration or retrofit are eligible for compliance using FEMA P-807.

B3.2. Massing

1. The building has no more than four stories above grade plane at any point around its perimeter.
2. The building's wood-framed stories are not supported by an above-grade podium structure.
Commentary: *Item 1 relies on the building code's definition of story above grade plane. Item 2 is referring to a concrete podium structure generally extending at least one story above grade and topped by a concrete diaphragm that provides a base for wood framing above. Item 2 is not intended to rule out concrete foundation elements or stem walls that extend above grade.*

B3.3. Upper stories

1. The upper-story seismic force-resisting systems are bearing wall or building frame systems of wood-frame walls with shear panels.
2. The upper-story floor-to-floor heights are between 8 feet and 12 feet and are constant within each story.
3. In each upper story, in each principal direction, the distance from the center of strength to the center of mass of the floor below it is no more than 25 percent of the corresponding building dimension.

   Commentary: *The intent of this approximate rule is to ensure that no upper story is prone to significant torsion, and that inertial forces from upper stories should transfer to the first story near the geometric center of the second floor. See FEMA P-807 Section 2.6.2.*
4. No upper story or floor above an upper story has a weight irregularity as defined by ASCE/SEI 7-05 Table 12.3-2, Type 2.
5. No upper story has a vertical geometric irregularity as defined by ASCE/SEI 7-05 Table 12.3-2, Type 3.

B3.4. First story, basement and foundation

1. The first story height may vary, but the maximum first story height, from top of foundation to top of second floor framing is between 8 feet and 15 feet.
2. The first story seismic force-resisting systems are bearing wall or building frame systems of wood-frame walls with shear panels or combine such systems with steel moment-resisting frame systems, steel cantilever column systems, or steel buckling-restrained braced frame systems.

   Commentary: *FEMA P-807 is not suitable for evaluating or designing concentrically braced frames, concrete shear walls, or reinforced masonry shear walls. See FEMA P-807 Section 6.5. If these systems exist or are proposed for as retrofit elements, compliance must be demonstrated using one of the other methods allowed by SFEBC Section 406D.2.*
3. The first story includes no full-height concrete or masonry walls.

   Commentary: *Buildings with full-height concrete or masonry walls at the full perimeter of the story of interest are expected to be exempt from SFEBC Chapter 4D. Buildings with a combination of full-height concrete or masonry walls and other systems (wood-frame walls, steel moment frames, etc.) might be required to comply with SFEBC Chapter 4D but will not be able to use FEMA P-807 to demonstrate compliance.*
4. The first story walls and frames have continuous concrete footings or concrete slab-on-grade foundations. If some or all of the first floor is raised over a crawl space, the crawl space has concrete stem walls to the underside of the first floor framing.

   Commentary: *Concrete stem walls are considered to provide a base similar to a concrete foundation. Wood-framed cripple walls, whether braced or unbraced by sheathing of any type, are not adequate to meet this provision.*
5. First story walls and frames may be partial height over a concrete or reinforced masonry retaining wall or foundation stem wall, but any partial-height wall or frame is at least four feet tall from top of stem wall to underside of second floor framing.
6. If the building has a basement, the basement walls and the floor diaphragm just above them are capable of transferring seismic forces between the foundation and the first story, and the basement story is laterally stronger than the first story above it.

B3.5. Floor and roof diaphragms. Floor and roof diaphragms shall satisfy the eligibility requirements of this subsection.

Exception: Diaphragms shown to have no deficiencies or irregularities that would prevent development of the strength of any seismic force-resisting wall or frame or would otherwise control the overall seismic response of the structure need not satisfy the eligibility requirements in this subsection.

> ***Commentary:*** *The intent of these approximate rules for diaphragms is to ensure that the structure does not develop a premature mechanism or failure mode. See FEMA P-807 Section 2.6.4 for additional explanation and guidance.*

1. No portion of the second floor diaphragm between qualifying wall lines has an aspect ratio greater than 2:1.
2. The second floor diaphragm does not cantilever more than 25 feet from a qualifying wall line.
3. If the second floor diaphragm cantilevers more than 10 feet from a qualifying wall line, diaphragm chords are adequate to develop the lesser of the strength of the diaphragm or the diaphragm forces associated with the peak strength of the qualifying wall line.
4. No floor or roof diaphragm has a reentrant corner irregularity in which either projecting leg of the diaphragm beyond the reentrant corner is longer than 15 percent of the corresponding plan dimension of the building, unless each leg of the diaphragm satisfies the aspect ratio and cantilever rules of this subsection.

   Commentary: *This provision differs from the irregularity defined in ASCE/SEI 31-03 or as Type 2 in ASCE/SEI 7-05 Table 12.3-1 in order to limit diaphragm demands. See FEMA P-807 Section 2.6.4.*

5. No floor or roof diaphragm has a vertical offset unless load path components are present and adequate to develop the diaphragm strength across the offset.
6. No floor or roof diaphragm has cutouts or openings within it such that, along any line across the diaphragm, the sum of the opening widths along that line is more than 25 percent of the overall diaphragm dimension along that line.

B4. Building Survey

B4.1. General. Structural components shall be investigated in accordance with Bulletin Section B4 as needed to confirm eligibility per Bulletin Section B3 and to support structure characterization per Bulletin Section B5, evaluation per Bulletin Section B6, and retrofit design per Bulletin Section B7.

B4.2. Wall framing and sheathing. The investigation shall determine the length and location in plan of all wall segments and wall lines in all stories as needed to calculate load-drift curves.

The investigation shall determine the size and location of openings in each wall line as needed to calculate adjustment factors for openings and adjustment factors for overturning.

The investigation shall determine all unique frames or wall assemblies in the first story and representative wall assemblies in the upper stories. Where sheathing includes wood structural panels or where sheathing load-drift data is a function of nailing, the investigation shall also determine the nail size and edge nail spacing. Panel edge nailing shall be investigated over at least five nail spaces and as needed to confirm a reliable spacing assumption.

> ***Commentary:*** *Unless building-specific conditions indicate a need for more extensive investigation, the minimum recommended investigation should include one location of each distinct wall assembly in the first story and in any upper story, but not less than one perimeter and one interior wall line in the first story and in any upper story. If prior investigation reports based on destructive investigation are available, they may be relied on. If original drawings are available, they may be relied on to reduce the scope of investigation, but some investigation is still necessary to confirm the reliability of the drawings.*

B4.3. Floor and roof framing and diaphragm. The investigation shall determine the construction of floor and roof framing and diaphragm sheathing, including the direction of framing and the mechanism of gravity load transfer, as needed for calculation of adjustment factors for overturning. The second floor shall be investigated. Subject to approval of the Department, the roof and upper floors need not be investigated in detail where there is evidence that their relevant attributes are similar to those of the second floor.

B4.4. Load path components. The investigation shall determine the nature of the load path components and connections for transfer of forces between diaphragms and walls or frames as needed to confirm that the wall line will participate in resisting drift.

> ***Commentary:*** *For non-WSP sheathing, the intent is to confirm that fastening reasonably conforms to conventional construction requirements. For existing WSP shear walls with nail spacing closer than six inches, it should be confirmed at representative locations that shear wall top and bottom connection capacity is appropriate to the sheathing capacity.*

The investigation shall determine the presence or absence of hold-down hardware at the base of all first story walls, as well as the adequacy of installation of representative types at representative locations.

The investigation shall confirm that anchors are provided at the base of the first story walls.

Table B4.4 shows where the load path may be assumed adequate or is subject to investigation or confirmation. Table B4.4 applies only to walls whose strength is counted in the analysis. For any condition subject to investigation, the load path may be assumed lacking, and the corresponding wall strength may be ignored, but only if assumed so consistently throughout the building.

> ***Commentary:*** *The load path may be assumed lacking, but not selectively so as to "correct" torsion or other irregularities. This provision is similar to ASCE 31 and ASCE 41 limits on the designation of secondary components.*

Exception: Wherever the strength of two stories is being compared, an adequate load path must be assumed for all walls and partitions in the upper story.

> ***Commentary:*** *The exception prevents underestimating the upper story strength. The exception will apply for calculations of weak story or soft story ratio in ASCE 31/41, CEBC A4, and other code-based procedures; application of the 1.3 cap on retrofit strength for ASCE 41 and CEBC A4 retrofits; and calculation of spectral capacity with FEMA P-807.*

The adequacy of an investigated load path may be confirmed by the judgment of the design professional, without calculations, but is subject to approval by the Department. Judgment should be based on the presence of a positive connection with multiple or redundant attachments distributed over the length of the wall line. For partitions perpendicular to floor framing above, blocking between floor joists nailed to the partition top plate (through a lath nailer, if present) should be deemed adequate for partitions with non-WSP sheathing.

Table B4.4. Investigation Requirements for Load Path between Partitions and Floor Framing Above

Condition	**First / Target Story**	**Second / Upper Stories**
Perimeter walls with non-WSP sheathing	May be assumed adequate	May be assumed adequate
Demising walls/partitions between units or between units and common areas	May be assumed adequate	May be assumed adequate
Any wall or partition with WSP sheathing where the top of the panel is nailed directly to a header beam, floor girder, or rim joist	May be assumed adequate	May be assumed adequate
Any wall or partition with WSP sheathing where the top of the panel is nailed only to a single or double top plate.	Confirm or provide load path	Confirm or provide load path
Room partitions within units, perpendicular to floor framing above	Investigate	May be assumed adequate
Room partitions within units, parallel to floor framing above	Investigate	Investigate

B4.5. Foundation elements. The investigation shall determine the nature of the existing foundation elements and supporting soils as needed for calculation of adjustment factors for overturning.

B5. Structure Characterization

B5.1. Story strength

B5.1.1. Wall assemblies. For each wall assembly present, a load-drift curve shall be computed by summing contributions from Table B5.1.1 at each drift level for each layer of sheathing. With approval of the Department, test results specific to the wall assembly or its components may be used in place of Table B5.1.1.

> ***Commentary:*** *See FEMA P-807 Section 4.4 and Appendix F regarding the development of Table B5.1.1 and the use of alternate test data.*

The values in Table B5.1.1 are subject to the following additional requirements:
1. Horizontal wood sheathing or wood siding shall be at least 1/2" thick and fastened to existing studs with at least two nails per board per stud. Otherwise, the expected strength shall be taken as 0.
2. Where siding panel edges are lapped, each panel shall be nailed separately. Otherwise, the expected strength shall be taken as 0.

Table B5.1.1. Expected Strength for Load-Drift Curves [plf]

	Drift, δ_j [%]								
Sheathing Material	**0.5**	**0.7**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**4.0**	**5.0**
Stucco	333	320	262	0	--	--	--	--	--
Horizontal wood sheathing or wood siding	85	96	110	132	145	157	171	0	--
Diagonal wood sheathing	429	540	686	913	0	--	--	--	--
Plaster on wood lath	440	538	414	391	0	--	--	--	--
Plywood panel siding (T1-11), 6d@6	354	420	496	549	565	505	449	0	--
Gypsum wallboard	202	213	204	185	172	151	145	107	0
Plaster on gypsum lath	402	347	304	0	--	--	--	--	--
WSP, 8d@6	521	621	732	812	836	745	686	0	--
WSP, 8d@4	513	684	826	943	1,018	1,080	1,112	798	0
WSP, 8d@3	1,072	1,195	1,318	1,482	1,612	1,664	1,686	1,638	0
WSP, 8d@2	1,393	1,553	1,713	1,926	2,096	2,163	2,192	2,130	0
WSP, 10d@6	548	767	946	1,023	1,038	1,055	1,065	843	0
WSP, 10d@4	707	990	1,275	1,420	1,466	1,496	1,496	1,185	0

WSP, 10d@3	940	1,316	1,696	1,889	1,949	1,990	1,990	1,576	0
WSP, 10d@2	1,120	1,568	1,999	2,248	2,405	2,512	2,512	2,231	0

B5.1.1.1. Wall assemblies without wood structural panel sheathing. The assembly load drift curve is the sum of the load drift curves for each of the sheathing layers.

B5.1.1.2. Wall assemblies with wood structural panel sheathing. The assembly load drift curve is whichever of the following two load-drift curves has the larger peak strength:
1. The assembly load-drift curve using 50 percent of the strength of the wood structural panel layers and 100 percent of the strength of the other sheathing materials.
2. The assembly load-drift curve using 100 percent of the strength of the wood structural panel layers and 50 percent of the strength of the other sheathing materials.

B5.1.2. Wall line assignment. Each segment of sheathed wall framing within a story shall be assigned to a wall line. Wall lines shall satisfy the following rules:
1. Full-height wall segments separated by window or door openings but connected by sheathed segments and continuous framing above or below the opening shall be assigned to the same wall line, unless other rules require them to be treated separately.
2. Wall segments assigned to the same wall line shall not be offset out-of-plane from adjacent segments by more than four feet.
3. At bay windows, the wall segments within the common plane shall be assigned to the same wall line if they satisfy the other rules, but the wall segments within the cantilevered portions of the bay shall not be counted toward the wall-line strength.
4. Wall segments of different heights, including wall segments along a stepped foundation, shall be assigned to separate wall lines.
5. A wall segment of varying height due to a sloped foundation shall be assigned to a separate wall line, and its height shall be taken as the average height of the segment.
6. Wall segments of different wall assemblies shall be assigned to separate wall lines.
7. Where hold-downs exist at each end of a wall segment, that segment may be considered a separate wall line.
8. Wall segments less than one foot long shall be treated as openings.
9. Wall segments between openings with height-to-length ratios greater than 8:1 shall be treated as openings.
10. Steel elements (moment frames, cantilever columns, etc.) shall be assigned to separate wall lines.
11. Wall segments or frames considered to have significant damage, deterioration, or construction defects may be counted toward a wall line's strength but shall have their load-drift strength values reduced.

B5.1.3. Wall line load-drift curve. For each wall line, a load-drift curve shall be computed by multiplying the applicable wall assembly load-drift curve by the wall line's length and by applicable adjustment factors per Bulletin Equation B5.1.3-1.

$$f_w = (v_w)(L_w)(Q_{open})(Q_{ot}) \qquad \text{(Equation B5.1.3-1)}$$

where:

f_w is the load-drift curve of wall line w, expressed as a function of drift.

v_w is the load-drift curve of the wall assembly associated with wall line w, as derived per Bulletin Section B5.1.1 and adjusted for height variation per Bulletin Section B5.1.3.1.

B5.1.3.1. Adjustment for height variation. Where first story wall lines in a given direction are of different heights, the load-drift curve of the wall assembly of each wood-frame wall line shall be adjusted to account for increased drift demands in all but the tallest first story wall line. This may be done by shifting the assembly load-drift curve from the standard set of drifts given in Table B5.1.1 to an adjusted set of drifts for each wall line, given by Equation B5.1.3.1-1.

$$\delta_{jh} = (\delta_j)(h_w/H_1)^{0.7} \quad \text{(Equation B5.1.3.1-1)}$$

B5.1.3.2 Adjustment for openings. Each wall line load-drift curve shall account for the effects of openings within it. This may be done by applying the adjustment factor for openings, given by Equation B5.1.3.2-1 and Equation B5.1.3.2-2.

$$Q_{open} = 0.92a - 0.72a^2 + 0.80a^3 \quad \text{(Equation B5.1.3.2-1)}$$

$$a = \frac{1}{\left(1 + \frac{\sum A_o}{h_w \sum L_f}\right)} \quad \text{(Equation B5.1.3.2-2)}$$

where:

$\sum A_o$ = sum of the areas of the openings within the wall line

$\sum L_f$ = sum of the lengths of the full-height wall segments within the wall line.

B5.1.3.3. Adjustment for overturning. Each wall line load-drift curve shall account for the effects of overturning demand and resistance. This may be done by applying the adjustment factor for overturning, given by Equation B5.1.3.3-1 or, for existing upper-story wall lines only, by Table B5.1.3.3.

$$Q_{ot} = 0.4\left(1 + 1.5\frac{M_r}{M_{ot}}\right) \leq 1.0 \quad \text{(Equation B5.1.3.3-1)}$$

where:

M_{ot} is the overturning demand on the wall line and M_r is the resisting moment due to all available dead loads tributary to the wall line plus the effects of any tie-down hardware.

Commentary: *See FEMA P-807 Section 4.5.3.2 for guidance on calculating* Q_{ot}.

Table B5.1.3.3. Default Adjustment Factor for Overturning, Q_{ot}, for Existing Upper Story Wall Lines

Number of stories above	**Perpendicular to Framing**	**Parallel to Framing**	**Unknown or mixed**
Two or more	0.95	0.85	0.85
One	0.85	0.80	0.80
None (Top story)	0.75	0.75	0.75

B5.1.4. Story load-drift curves. For each story, in each direction, a load-drift curve shall be computed by adding the load-drift curves of all the walls in that story and aligned in that direction.

> ***Commentary:*** *Where all the wall line load-drift curves are mapped to the same set of drifts, the summation is straightforward. Where some first story wall lines have load-drift curves mapped to a height-adjusted set of drifts, load values at the standard drift values should be determined by linear interpolation. Once interpolated values are calculated, the various load-drift curves can again be added in a straightforward way based on the standard drift values. See FEMA P-807 Section 4.6 for additional discussion.*

B5.2. First story torsion

B5.2.1. Center of strength. The center of strength for the first and second stories shall be determined based on the wall line loads at the drift at which the story strength in the corresponding story and direction occurs.

> ***Commentary:*** *FEMA P-807 Section 4.6.4 illustrates the calculation of the center of strength.*

B5.2.2. First story torsional demand. The first story torsional demand represents the effect of the first story strength acting at the torsional eccentricity, given by Equation B5.2.2-1.

$$\tau_1 = e_x V_{1y} + e_y V_{1x} \qquad \text{(Equation B5.2.2-1)}$$

B5.2.3. First story load-rotation curve. For the first story, a load-rotation curve shall be derived, relating torsion about the story center of strength to the resulting rotation of the story, assuming a rigid second floor diaphragm and accounting for the load-drift behavior of each first story wall line. The load-rotation curve shall consider rotation angles up to at least the rotation associated with 5 percent in-plane drift in at least one first story wall line.

> ***Commentary:*** *FEMA P-807 Section 4.6.6 illustrates one method for calculating of the load-rotation curve, dividing the rotation range of interest into ten even increments.*

B5.3. Characteristic coefficients

B5.3.1. Base-normalized upper-story strength. The base-normalized upper-story strength shall be calculated for each principal direction per Equation B5.3.1-1.

$$A_U = \frac{V_U}{W} \qquad \text{(Equation B5.3.1-1)}$$

B5.3.2. Weak-story ratio. The weak-story ratio shall be calculated for each principal direction per Equation B5.3.2-1.

$$A_W = \frac{V_1}{V_U} \qquad \text{(Equation B5.3.2-1)}$$

B5.3.3. Strength degradation ratio. The strength degradation ratio, C_D, shall be calculated for each principal direction based on the first story load-drift curves.

> ***Commentary:*** *FEMA P-807 Section 4.7.4 illustrates the calculation of the strength degradation ratio.*

B5.3.4. Torsion coefficient. The torsion coefficient, given by Equation B5.3.4- 1, need not be taken greater than 1.4.

$$C_T = \frac{\tau_1}{T_1} \qquad \text{(Equation B5.3.4-1)}$$

B5.3.5. Story height factor. The story height factor shall be calculated for each principal direction per Equation B5.3.5-1, where H_1 is given in inches.

$$Q_s = 0.55 + 0.0047\, H_1 \qquad \text{(Equation B5.3.5-1)}$$

B6. Evaluation

B6.1. Evaluation relative to the performance objective. Subject to the additional requirements of Bulletin Section B1.2, any eligible structure shall be deemed to comply with the requirements of this Bulletin if its spectral capacity in each principal direction exceeds the spectral demand.

B6.1.1. Spectral capacity. Spectral capacity in each direction shall be calculated from Equations B6.1.1-1 through B6.1.1-5, using drift limit *POE* adjustment factors given in Table B6.1.1 for the drift limit *POE* specified in Bulletin Section B1.1.3. Drift limit *POE* adjustment factors for intermediate values of drift limit *POE* shall be calculated by linear interpolation.

> ***Commentary:*** *SFEBC Chapter 4D does not require the calculation of a POE. However, given a spectral demand, the POE of a structure can be calculated. See FEMA P-807 Section 5.4.2 or Appendix B model provision 6.2.*

$$S_c = C_D^3 S_{c1} + \left(1 - C_D^3\right) S_{c0} \qquad \text{(Equation B6.1.1-1)}$$

$$S_{c1} = \alpha_{POE,1} S_{\mu 1} \qquad \text{(Equation B6.1.1-2)}$$

$$S_{c0} = \alpha_{POE,0} S_{\mu 0} \qquad \text{(Equation B6.1.1-3)}$$

$$S_{\mu 1} = \left(0.525 + 2.24 A_W\right)\left(1 - 0.5 C_T\right) Q_s A_U^{0.48} \qquad \text{(Equation B6.1.1-4)}$$

$$S_{\mu 0} = \left(0.122 + 1.59 A_W\right)\left(1 - 0.5 C_T\right) Q_s A_U^{0.60} \qquad \text{(Equation B6.1.1-5)}$$

Table B6.1.1. Drift limit probability of exceedance adjustment factors.

POE	$\alpha_{POE,1}$	$\alpha_{POE,0}$
2%	0.36	0.29
5%	0.44	0.37
10%	0.53	0.46
20%	0.66	0.60
30%	**0.77**	**0.73**
50%	**1.00**	**1.00**
60%	1.14	1.16
70%	1.30	1.37
80%	1.52	1.66

B7. Retrofit

B7.1. Retrofitted first story strength. The first story strength of the retrofitted structure shall account for all existing unaltered elements, existing altered elements, new elements provided to increase story strength, and new elements provided to correct aspects of eligibility or building survey non-compliance.
Exception: Out-of-plane or weak axis strength of existing or retrofit elements need not be considered where the sum of those strengths is deemed insignificant to the total story strength.

> ***Commentary:*** *The Exception is intended to allow wood frame walls and pin-based frames to be ignored in their weak directions, and to allow the Department to accept the engineer's judgment or to require modeling of fixed-based frames and cantilever columns in their weak directions.*

B7.2. Retrofit compliance. The retrofit design shall demonstrate that both of the following conditions are true:

1. The retrofitted structure's spectral capacity in each principal direction exceeds the spectral demand.
2. The first story strength of the retrofitted structure in each principal direction satisfies Equation B7.2-1.

$$V_{1r} \leq 1.1V_U\left(0.11A_U + 1.22\right) \qquad \text{(Equation B7.2-1)}$$

> ***Commentary:*** *The intent of Equation B7.2-1 is to ensure that over-strengthening the first story is not miscounted as beneficial. Given the maximum POE, if the required first story strength cannot be achieved without exceeding this limit, it indicates that the proposed retrofit would push failure to the second story and would not achieve its intended effect. Where the exception to Bulletin Section B1.1.3 is applied, the higher POE value will give the same spectral capacity for less first story strength, effectively allowing a lighter retrofit that might satisfy the equation.*
>
> *FEMA P-807 Section 6.2.1 provides formulas for estimating the strength of the retrofitted first story needed to reach the required spectral capacity, but use of the estimating formulas is not required.*

B7.3 Additional requirements where the Exception to Bulletin Section B1.1.3 is applied. The retrofit design shall demonstrate that all of the following additional conditions are true:
1. The first story strength of the retrofitted structure in each principal direction satisfies Equation B7.3-1.
2. The retrofit design satisfies the requirements of Bulletin Section B7.3.1.

$$V_{1r} \geq 0.9V_U\left(0.11A_U + 1.22\right) \qquad \text{(Equation B7.3-1)}$$

B7.3.1 Minimized torsional eccentricity. Retrofit elements shall be located along perimeter wall lines so as to minimize the torsional eccentricity of the retrofitted structure, or so as to satisfy Equations B7.3.1-1 and B7.3.1-2. This requirement may be waived with the approval of the Department to accommodate other building or planning code requirements or to avoid disproportionate construction costs.

$$e_x \leq 0.10L_x \qquad \text{(Equation B7.3.1-1)}$$

$$e_y \leq 0.10L_y \qquad \text{(Equation B7.3.1-2)}$$

B7.4 Design criteria for retrofit elements. Retrofit elements shall conform to the general requirements in this section and to the applicable requirements in the following subsections.

> ***Commentary:*** *See Bulletin Section B3.4 for discussion of retrofit systems for which FEMA P-807 is suitable.*

1. Where retrofit elements are sized based on unit strengths from codes or standards, the expected strength, without strength reductions or resistance factors, may be used.

> ***Commentary:*** *The allowance of expected strength, which is typically greater than nominal strength (see Bulletin Section A3.2.2) is appropriate because FEMA P-807 requires retrofit elements to be ductile (or, in ASCE 31 or ASCE 41 terms, deformation-controlled).*

2. The load-drift curve of each retrofit element type shall be based on expected material properties, including over strength. The full expected capacity, without strength reduction or resistance factors, shall be used to calculate load-drift curves and peak strengths.
3. Each retrofit element shall be such that a load-drift curve based on similar elements alone would have a strength degradation ratio, C_D, greater than or equal to 0.8.
4. The load-drift curve of each retrofit element type shall be defined up to five percent interstory drift or as needed to fully characterize the retrofit design per Bulletin Section B5.
5. Materials and systems for all retrofit elements shall be generally consistent with provisions of the building code for new construction of the same occupancy and risk category. 2016 SFEBC Section 401.2.2 and other provisions that allow like materials for alterations do not apply to retrofits mandated by SFEBC Chapter 4D. However, the Department may waive restrictions on certain systems based on building height, irregularity, seismic design category, or other conditions not related to the critical deficiencies of the story being evaluated or retrofitted.

> ***Commentary:*** *FEMA P-807 presumes that retrofit elements will be reliably ductile (as indicated by the requirement for a minimum C_D value in item 3 above). Systems detailed as special should generally be deemed to comply with this requirement, but systems detailed as intermediate or ordinary may also be shown to be adequate. The final sentence of this provision allows intermediate and ordinary steel frames to be used in seismic design category D and E; see also ASCE 7-10 Sections 12.2.5.6 and 12.2.5.7.*

6. Design criteria for load path components and connections shall be appropriate to the performance objective and shall be based on the building code for new construction, appropriate provisions of other criteria allowed by SFEBC Section 406D.2, or principles of capacity design.

B7.4.1. Wood structural panel shear walls. Load-drift curves for wood structural panel retrofit elements shall be calculated in accordance with Bulletin Section B5. Existing shear walls modified by replacing sheathing materials or by adding supplemental wood structural panels shall be considered retrofit elements.

B7.4.2. Steel special moment-resisting frames. Steel retrofit elements that conform to the requirements of AISC 341-05 or AISC 341-10 for Special Moment Frames shall be deemed to comply with the provision requiring a C_D value greater than or equal to 0.8. The load-drift curve may be characterized per FEMA P-807 Figure 6-7 as follows: $V_y = ZF_{ye}$ with post-yield strengthening up to $1.2V_y$ at d_{max}, with $d_{max} = d_y + 4\%$.

B7.4.3. Steel intermediate moment-resisting frames. For steel retrofit elements that conform to the requirements of AISC 341-05 or AISC 341-10 for Intermediate Moment Frames, the load-drift curve may be characterized per FEMA P-807 Figure 6-7 as follows: $V_y = ZF_{ye}$ with no post-yield strengthening, and $d_{max} = d_y + 2\%$.

B7.4.4. Steel ordinary moment-resisting frames. For steel retrofit elements that conform to the requirements of AISC 341-05 or AISC 341-10 for Ordinary Moment Frames, the load-drift curve may be characterized per FEMA P-807 Figure 6-7 as follows: V_y per AISC 360 Chapter F, using F_{ye} instead of F_y, $d_{max} = 2\%$.

B7.4.5. Steel special cantilever columns. For steel retrofit elements that conform to the requirements of AISC 341-10 for Special Cantilevered Column systems, the load-drift curve may be characterized per FEMA P-807 Figure 6-7 as follows: $V_y = ZF_{ye}$ with no post-yield strengthening, and $d_{max} = d_y + 2\%$.

B7.4.6. Steel ordinary cantilever columns. FEMA P-807 shall not be used to demonstrate compliance of steel ordinary cantilever columns as retrofit elements.

B7.4.7. Steel buckling-restrained braced frames. Steel retrofit elements that conform to the requirements of AISC 341-05 or AISC 341-10 for buckling-restrained braced frames shall be deemed to comply with the provision requiring a C_D value greater than or equal to 0.8.

> ***Commentary:** FEMA P-807 Section 6.5.5 offers further guidance on characterizing and designing these elements.*

B7.4.8. Damping systems. FEMA P-807 may be used to demonstrate compliance of hysteretic damping systems that rely on the yielding of steel components by modeling the retrofit elements as bi-linear systems similar to other structural steel systems. The Department is authorized to require third party peer review at the expense of the permit applicant.

FEMA P-807 shall not be used to demonstrate compliance of other damping systems, including viscous- or friction-damped systems.

> ***Commentary:** Viscous- and friction-damped systems cannot be designed with FEMA P-807 because the FEMA P-807 surrogate models did not include these mechanisms.*

B7.5 Design criteria for load path elements and components. The retrofit design shall confirm or provide a load path from the second floor diaphragm through the first story seismic force-resisting elements and their foundations, to the supporting soils. The ultimate strength of load path components shall be reduced with strength reduction factors as needed to ensure that the load-path elements are able to develop the strength and the intended mechanism of first story wall and frame elements. Specific design criteria may be derived from principles of capacity design, from other criteria allowed by SFEBC Section 406D.2, or from building code provisions for new construction involving the overstrength factor, Ω_0.

B7.5.1. Foundations and overturning. New foundation elements shall be provided as needed to resist bearing, sliding, and overturning forces associated with the retrofit elements acting at their strength. Connections and load path components related to wall or frame overturning shall not assume any acting dead load except for the self-weight of the retrofit element unless the retrofit element incorporates existing gravity load-carrying framing or unless the design and construction explicitly transfer existing dead load to the retrofit element. The weight of foundation elements may be considered if adequately connected.

B7.5.2. Second floor diaphragm. The second floor diaphragm shall be strengthened as needed to ensure that expected forces can be transferred between the diaphragm and the first-story elements.

B7.5.3. Fixed-base frame columns. Moment-resisting frame systems and cantilever column systems whose capacity assumes other than a pin-based condition shall be provided with connection details demonstrated to develop the assumed fixity and the assumed column strength. In general, an anchor-bolted base plate without substantial embedment within a foundation element is not considered to provide a fixed-base condition.

B8. Design quality assurance

B8.1. Structural calculations. Structural calculations and documentation of evaluations and retrofit designs using FEMA P-807 shall include, at minimum:

1. Plans and/or elevations for each floor level identifying each wall line and showing the wall assembly, length, location, and openings.
2. A schedule of wall assemblies and load drift curves for existing, altered, and new elements.
3. A list or schedule of wall lines with overturning and opening adjustments.
4. Derivation of characteristic coefficients.
5. Spectral capacity calculations.
6. Site-specific spectral demand calculations.

B8.2. Use of the FEMA P-807 Weak Story Tool
Reserved

Part C. APPLICATION OF ASCE 41-13 TO EVALUATION AND RETROFIT DESIGN

DISCUSSION : Further development of this section is expected as needed to address issues specific to Chapter 4D. The sections outlined below cover broad issues consistent with Chapter 4D. Otherwise, use of this standard is subject to existing Department procedures for implementation of SFBC 104A.2.8, Alternate materials, design, and methods of construction.

C1. Required scope of work

1. No nonstructural evaluation or retrofit is required.
2. Retrofit strength need not exceed 1.3 times the strength of the story above. Wherever the strength of two stories is being compared, an adequate load path must be assumed for all walls and partitions in the upper story.

    Commentary: *This requirement prevents underestimating the upper story strength. It will apply for calculations of weak story or soft story ratio in ASCE 31/41, CEBC A4, and other code-based procedures; application of the 1.3 cap on retrofit strength for ASCE 41 and CEBC A4 retrofits; and calculation of spectral capacity with FEMA P-807.*

Part D. APPLICATION OF ASCE 41-06 TO EVALUATION AND RETROFIT DESIGN

DISCUSSION : Further development of this section is expected as needed to address issues specific to Chapter 4D. The sections outlined below cover broad issues consistent with Chapter 4D. Otherwise, use of this standard is subject to existing Department procedures for implementation of SFBC 104A.2.8, Alternate materials, design, and methods of construction.

D1. Required scope of work

1. No nonstructural evaluation or retrofit is required.
2. Retrofit strength need not exceed 1.3 times the strength of the story above. Wherever the strength of two stories is being compared, an adequate load path must be assumed for all walls and partitions in the upper story.

   Commentary: *This requirement prevents underestimating the upper story strength. It will apply for calculations of weak story or soft story ratio in ASCE 31/41, CEBC A4, and other code-based procedures; application of the 1.3 cap on retrofit strength for ASCE 41 and CEBC A4 retrofits; and calculation of spectral capacity with FEMA P-807.*

Part E. APPLICATION OF ASCE 31-03 TO EVALUATION

DISCUSSION : Further development of this section is expected as needed to address issues specific to Chapter 4D. The sections outlined below cover broad issues consistent with Chapter 4D. Otherwise, use of this standard is subject to existing Department procedures for implementation of SFBC 104A.2.8, Alternate materials, design, and methods of construction.

E1. Required scope of work

1. No nonstructural evaluation is required.
2. Wherever the strength of two stories is being compared, an adequate load path must be assumed for all walls and partitions in the upper story.

    Commentary: *This requirement prevents underestimating the upper story strength. It will apply for calculations of weak story or soft story ratio in ASCE 31/41, CEBC A4, and other code-based procedures; application of the 1.3 cap on retrofit strength for ASCE 41 and CEBC A4 retrofits; and calculation of spectral capacity with FEMA P-807.*

Part F. APPLICATION OF 2016 CEBC APPENDIX CHAPTER A4 TO RETROFIT DESIGN

F1. Modifications and interpretations of CEBC Appendix Chapter A4. Compliance with SFEBC Chapter 4D using 2016 CEBC Appendix Chapter A4 shall require compliance with that code chapter and its reference codes and standards except as otherwise modified, waived, or interpreted in this section and Bulletin Part A.

The following modifications and interpretations refer to Chapter A4 section numbers.

A401.1 Purpose

> ***Commentary:*** *This provision refers to "minimum standards." In the context of Chapter A4, this means minimum standards for policy equivalence with other criteria when retrofit is triggered elsewhere in the CEBC. In the context of SFEBC Chapter 4D, the provisions of Chapter A4 might or might not require the same scope of retrofit as other criteria allowed by SFEBC Section 406D.2. The other criteria are acceptable even if they require less retrofit scope or produce retrofit designs with lower capacity than Chapter A4.*

A401.2 Scope. Omit.

> ***Commentary:*** *When used for compliance with SFEBC Chapter 4D, the scope and applicability of Chapter A4 is established by Ordinance 66-13. The absence of any condition listed by Section A401.2 has no bearing on compliance with Chapter 4D.*

A402 Definitions. Add, omit, or revise the following definitions as follows:
BUILDING CODE. The current San Francisco Building Code.
GROUND FLOOR. A target story, generally a basement story that extends above grade or the first story above grade plane. Alternately, depending on context, GROUND FLOOR might mean the floor level at the base of a target story.

A403.1. Omit the exception and revise the first sentence as follows:
A403.1 General. All modifications required … the building code provisions for new construction, except as modified by this chapter and applicable Administrative Bulletins.

> ***Commentary:*** *The exception is not necessary because Section A404 is omitted. See below.*

A403.2. Omit the exception and revise the provision as follows:
A403.2 Scope of analysis. This chapter requires the alteration, repair, replacement or addition of structural elements and their connections to meet the strength and stiffness requirements herein. The lateral-load-path analysis shall include the resisting elements and connections from the wood diaphragm immediately above any target story to the foundation soil interface. Stories above the uppermost target story shall be considered in the analysis but need not be modified. The lateral-load-path analysis for added structural elements shall also include evaluation of the allowable soil-bearing and lateral pressures in accordance with the building code. Where any portion of a building within the scope of this chapter is constructed on or into a slope, the lateral force-resisting system at and below the first story above grade plane shall be analyzed for the effects of concentrated lateral forces caused by this hillside condition.

A403.3. Correct Δ_0 to Ω_0 in multiple places. Also, add the following sentences at the end of the section:
A403.3 Design base shear and design parameters. … Despite any other requirement of Section A403.3 or A403.4, the total expected strength of retrofit elements added to any target story need not exceed 1.3 times the expected strength of the story immediately above, as long as the retrofit elements are located symmetrically about the center of mass of the story above or so as to minimize torsion in the target story.

> ***Commentary:*** *The added sentence implements the SEAONC recommendation to cap the required strength, consistent with FEMA P-807.*

Add the following subsection:
A403.3.1 Story strength. Calculation of story strength and identification of irregularities in Section A403.3 shall be based on the expected strength of all wall lines, even if sheathed with nonconforming materials. The strength of a wall line may be reduced to account for inadequate load path or overturning resistance.

> ***Commentary:*** *The expected strength of the story above may be calculated using the FEMA P-807 criteria given in Bulletin Section B5.1. The requirement to assume an adequate load path prevents underestimating the upper story strength. It will apply for calculations of weak story or soft story ratio in ASCE 31/41, CEBC A4, and other code-based procedures; application of the 1.3 cap on retrofit strength for ASCE 41 and IEBC A4 retrofits; and calculation of spectral capacity with FEMA P-807.*

A403.5. Revise the subsection heading and the provision as follows:
A403.5. Deformation Compatibility and P ∆ effects. The requirements of the building code shall apply, except as modified herein. All structural framing elements and their connections not required by design to be part of the lateral force-resisting system shall be designed and/or detailed to be adequate to maintain support of expected gravity loads when subjected to the expected deformations caused by seismic forces. Increased demand due to P ∆ effects and story side sway stability shall be considered in retrofit stories that rely on the strength and stiffness of cantilever columns for lateral resistance.

> ***Commentary:*** *This revision is consistent with a change approved for the 2015 IEBC.*

A403.8. Revise the provision as follows:
A403.8 Horizontal diaphragms. The diaphragm immediately above the target story shall be evaluated and/or strengthened as required by Bulletin Section A1.1. Rotational effects shall be accounted for when asymmetric wall stiffness increases shear demands.

> ***Commentary:*** *This revision is consistent with a change approved for the 2015 IEBC.*

A403.9.1 Revise the provision as follows:
A403.9.1 Gypsum or cement plaster products. Gypsum or cement plaster products shall not be used to provide lateral resistance in a target story.

A404. Omit Section A404 entirely.

> ***Commentary:*** *Section A404 applies to two-story buildings only. Two-story buildings are exempt from SFEBC Chapter 4D.*

A405.1. Revise the provision as follows:
A405.1 New materials. New materials shall meet the requirements of the building code, except where allowed by this chapter or applicable Administrative Bulletins.

A407 Quality Control. Omit Section A407 entirely.

> ***Commentary:*** *Bulletin Sections A4 and A5, as well as AB 106, apply instead.*

Part G. GUIDELINES FOR ALTERNATIVE RATIONAL DESIGN BASES

DISCUSSION : Further development of this section is expected as needed to address issues specific to Chapter 4D. Sections to be outlined below will cover broad issues consistent with Chapter 4D. Otherwise, use of this standard is subject to existing Department procedures for implementation of SFBC 104A.2.8, Alternate materials, design, and methods of construction.

Originally signed by:
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