DSA IR 18-4

SUPERSTRUCTURE TO FOUNDATION CONNECTION: 2022 CBC

Disciplines: Structural **History:** Issued 12/12/23 Under 2022 CBC

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PURPOSE

This Interpretation of Regulations (IR) clarifies code requirements relating to the design of the connection of a building's seismic force resisting system (SFRS) superstructure to the foundation on projects under DSA jurisdiction.

SCOPE

This IR applies to the design of SFRS superstructure to foundation connections in new buildings. It addresses both general requirements of the California Building Code (CBC) and system-specific requirements of adopted material design standards and codes. These requirements are presented separately on a construction material and SFRS basis. This IR does not apply to the design of a rehabilitation project utilizing the performance based seismic design approach of California Existing Building Code (CEBC) Section 317.5 in accordance with the American Society of Civil Engineers Standard 41: Seismic Evaluation and Retrofit of Existing Buildings (ASCE 41).

BACKGROUND

CBC Section 1617A.1.15 amends the American Society of Civil Engineers Standard 7: Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE 7), Section 12.13.1. This amendment defines additional requirements for the design strength of the connection of the SFRS to the foundation. By requiring amplified seismic design forces, this code provision intends to prevent inelastic behavior in these connections and thus preserve the assumed ductility of the SFRS upon which the system design and expected building response are based.

Various material specific codes and design standards also include design requirements for these connections that must be complied with in addition to the CBC. These codes and standards include the following:

- American Concrete Institute (ACI) Standard: Building Code Requirements for Structural Concrete (ACI 318).
- American Institute of Steel Construction (AISC) Standard 341: Seismic Provisions for Structural Steel Buildings (AISC 341).
- American Wood Council (AWC): Special Design Provisions for Wind and Seismic (AWC SDPWS).
- American Iron and Steel Institute (AISI) North American Standard for Seismic Design of Cold-Formed Steel Structural Systems (AISI S400).

1. WOOD SYSTEMS

1.1 Light-Frame Shear Walls

Light-frame construction is defined in CBC Chapter 2 as “construction whose vertical and horizontal structural elements are primarily formed by a system of repetitive wood or cold-formed steel framing members”.

1.1.1 Foundation connections for light-framed shear walls are not required to be designed for amplified seismic loads per CBC Section 1617A.1.15, Exception #3.

1.1.2 Concrete anchors used to resist uplift forces delivered by shear wall boundary elements shall comply with the requirements of ACI 318 Section 17.10.5.3. These provisions commonly require some or all of the anchorage limit states to provide strength that exceeds the simple code prescribed earthquake forces.

1.1.3 Sill bolts resisting shear and complying with the requirements of CBC Section 1905A.1.8 need not comply with the strength requirements of ACI 318 Section 17.10.6.3.

1.1.4 Proprietary anchors whose capacities are based on cyclic testing and are documented in an evaluation report in accordance with *IR A-5: Acceptance of Products, Materials and Evaluation Reports* may be used in lieu of design per ACI 318 Chapter 17. Cyclic testing shall be in accordance with International Code Council Evaluation Service (ICC-ES) AC399: Acceptance Criteria for Cast-In-Place Proprietary Bolts in Concrete for Light-Frame Construction. Refer to the Exception in *IR 23-1: Prefabricated Wood Construction Connectors*, Section 3.3.

2. CONCRETE SYSTEMS

2.1 Cast-in-Place Moment Frames

Longitudinal reinforcement for cast-in-place concrete moment frame columns shall be fully developed for tension at the foundation interface per ACI 318 Section 18.13.2.2 with standard hooks near the bottom of the foundation element. See *IR 18-3: Foundation Analysis and Design Forces*, Section 2.4.3 for additional information.

2.1.1 Moment resisting connections between concrete moment frame columns and the supporting foundation elements require inclusion of the foundation flexural stiffness in the drift and deformation compatibility analyses as required by CBC Section 1617A.1.15.

2.1.2 The joint between the concrete column and foundation element shall comply with the requirements of ACI 318 as follows:

2.1.2.1 When the design is based on the amplified seismic loads in accordance with ASCE 7 Section 12.13.1.1 as added by CBC Section 1617A.1.15, the joint shear shall be evaluated per ACI 318 Section 15.4 using a joint area as defined by ACI 318 Section 15.4.2.4.

2.1.2.2 When the design is based on inelastic foundation behavior in accordance with ASCE 7 Section 12.13.1.1, Exception #2 as added by CBC Section 1617A.1.15, the joint shall comply with ACI 318 Section 18.8, including transverse reinforcement per ACI 318 Section 18.8.3 and shear strength per ACI 318 Section 18.8.4. Refer to IR 18-3 Section 2.2 for structural analysis requirements to justify the application of ASCE 7 Section 12.13.1.1, Exception #2.

2.2 Cast-in-Place Shear Walls

Vertical reinforcement for cast-in-place concrete shear walls shall be fully developed for tension at the foundation interface per ACI 318 Section 18.13.2.2 with standard hooks near the bottom of the foundation element. See IR 18-3 Section 2.4.3 for additional information.

2.3 Precast Shear Walls

Precast concrete shear walls include walls constructed by the “tilt-up” method.

2.3.1 Intermediate and special precast concrete shear wall panel connections to the foundation shall be designed for amplified seismic loads per CBC Section 1617A.1.15 as noted in CBC Section 1905A.1.9. When designing the foundation-to-wall panel connection for the amplified seismic loads, the connecting elements (i.e., rebar, headed studs, etc.) embedded into the wall panel shall also comply with the amplified seismic loads and be fully developed into the wall panel.

2.3.2 Yielding in the panel to foundation connection is only permitted when ASCE 7 Section 12.13.1.1, Exception #2 (see CBC Section 1617A.1.15) is applied based on a nonlinear analysis per IR 18-3 Section 2.2. The nonlinear analysis shall capture the nonlinear response of yielding connections at the base of the wall panels and its effect on the building response, including the redistribution of forces throughout the structure.

3. MASONRY SYSTEMS

3.1 Shear Walls

Longitudinal reinforcement for concrete masonry unit (CMU) piers and walls shall be fully developed for tension at the foundation interface per ACI 318 Section 18.13.2.2 with standard hooks near the bottom of the foundation element. See IR 18-3 Section 2.4.3 for additional information.

4. STRUCTURAL STEEL SYSTEMS

In addition to the amplified forces of CBC Section 1617A.1.15, the design of structural steel SFRS connections to the foundation shall comply with the requirements of AISC 341.

4.1 Requirements for All System

Column base connections for all structural steel SFRS shall be designed for the strength required by AISC 341 Section D2.6 as summarized below. Column base connections include all components of the seismic load path, which commonly includes welds, base plates, gusset plates, shear lugs, stiffener plates, anchors rods, welded bar anchors, and other plates and embeds as may be employed by the specific design.

4.1.1 The required axial (vertical) strength shall comply with AISC 341 Section 2.6a.

4.1.2 The required shear (horizontal) strength shall comply with AISC 341 Section 2.6b.

4.1.3 The required flexural strength shall comply with AISC 341 Section 2.6c.

4.1.3.1 Design for load combinations with the overstrength factor per AISC 341 Section 2.6c(b)(2) may only be used when a ductile limit state is provided in the base connection. Ductile limit states include anchor rod yielding and base plate yielding.

4.1.3.2 When the steel column is embedded into the grade beam or other foundation element the connection shall be designed for the expected flexural strength of the column per AISC 341 Section 2.6c(b)(1).

4.1.4 Anchor rods shall be designed for all applicable loads and the limit states and requirements of AISC 341, AISC Standard 360: Specification for Structural Steel Buildings (AISC 360), and ACI 318.

4.1.4.1 Because of the challenges in transferring shear forces through anchor rods, connections designed with an alternate load path for shear forces are recommended. Refer to AISC Design Guide 1: Base Plate and Anchor Rod Design (AISC DG1), Section 3.5.3 and AISC 360 Commentary J9 for further discussion of applicable design considerations.

4.1.4.2 If an alternate load path is not provided, the anchor rods shall be designed for combined shear and tension.

4.1.4.3 When the geometry of the connection results in anchor rod bending, the anchor rods shall be designed for bending in combination with tension and shear. Refer to AISC DG1 Section 3.5.3 and AISC 360 Commentary J9 for more information.

4.1.4.4 When oversized holes are used in the base plate, the design shall comply with CBC Section 2204A.4 and AISC 360 Section J9.

4.1.5 The base connection of columns that are not designated as part of the SFRS shall comply with Sections 4.1.1 and 4.1.2 above. Refer to AISC 341 Section D2.6b, Exception (a) for single story columns with pinned connections at the top and bottom.

4.2 Moment Frames

The connection of moment frame columns to the foundation shall comply with AISC 341 Section D2.6, Section 4.1 above, and this section.

4.2.1 Per AISC 341 Section D2.6b, Exception (b) the columns of ordinary steel moment frames need not comply with D2.6b(c). However, compliance with the amplified seismic loads of CBC Section 1617A.1.15 is still required.

4.2.2 When the connection design is based on the ductile limit state of axial yielding of the steel anchor rods, the following requirements apply.

4.2.2.1 The ductile limit state shall be demonstrated by one of the following:

4.2.2.1.1 Anchor reinforcement shall be provided as required per ACI 318 Section 17.5.2.1 (a). Refer to ACI 318 Figure R17.5.2.1a.

4.2.2.1.2 Anchor embedment shall provide strength sufficient to comply with ACI 318 Section 17.10.5.3(a) subjected to load combinations with the overstrength factor.

4.2.2.2 The base plate flexural capacity and concrete bearing shall be designed with strength to exceed the forces corresponding to the expected tensile strength of the anchor rods. The expected anchor rod strength shall be determined per ACI 318 Section 17.10.5.3(a)(i) and converted into a moment with which to justify the other limit states of the connection.

4.2.2.3 The building structural analysis shall account for increased displacement resulting from anchor rod elongation and demonstrate compliance with code drift limits per ASCE 7 Table 12.12-1 including this effect.

4.2.2.4 Shear shall not be transferred through anchor rods used as the ductile limit state. An alternate load path (e.g., shear lugs per ACI 318 Section 17.11) shall be provided for shear forces.

4.2.2.5 The design shall demonstrate that the anchor rods have sufficient stretch length to achieve the minimum elongation percentage defined by the specified material standard (e.g., ASTM F1554, etc.). Refer to ACI 318 Figure R17.10.5.3 for common detailing methods for achieving sufficient stretch length. Provide anchor rod stretch length complying with one of the following:

4.2.2.5.1 Eight times the anchor rod diameter.

4.2.2.5.2 Length corresponding to the applicable joint rotation:

4.2.2.5.2.1 Special moment resisting frames: 0.04 radians.

4.2.2.5.2.2 Intermediate moment resisting frames: 0.02 radians.

4.2.2.5.2.3 Ordinary moment resisting frames: 0.01 radians.

4.2.2.6 Steel anchor rods shall meet the definition of a "ductile steel element" per ACI 318 Chapter 2 (see "steel element, ductile").

4.2.3 When the connection design is based on the ductile limit state of base plate yielding, the following requirements apply.

4.2.3.1 Anchor rods shall be located a sufficient distance from the column face such that rotation and yielding in the plate will not result in fracture.

4.2.3.2 Calculations shall demonstrate that flexural yielding of the base can accommodate the following joint rotations:

4.2.3.2.1 Special moment frames: 0.04 radians.

4.2.3.2.2 Intermediate moment frames: 0.02 radians.

4.2.3.2.3 Ordinary moment resisting frames: 0.01 radians.

4.2.3.3 The base plate design shall be within the elongation limits defined by the specified material standard (i.e., ASTM standard).

4.2.3.4 The anchor rod capacity shall be designed with strength to exceed the forces corresponding to the expected flexural capacity of the base plate.

4.2.4 When the moment frame column is embedded into the grade beam or other foundation element, the following requirements apply.

4.2.4.1 The maximum effective width of the foundation element considered in the design of the connection to transfer loads from the column shall not exceed the 2.5 times the column width.

4.2.4.2 The design of embedded columns may be based on compliance with the provisions of AISC 341 Section H5.5c for steel coupling beams embedded into composite special shear walls. Other rational design approaches based on accepted engineering principles may be accepted subject to DSA approval.

4.2.4.2.1 The embedment length of the steel column into the foundation shall be sufficient to provide the shear strength required by AISC 341 Equation H5-1.

4.2.4.2.2 The minimum amount of transfer steel shall be per AISC 341 Section H5.5c(d).

4.2.4.3 Steel columns embedded in concrete grade beams shall satisfy the panel zone requirements of AISC 341.

4.2.4.4 The design shall provide sufficient capacity to transfer the shear demand in the foundation element through the joint while accounting for the interruption created by the embedded column. This can typically be achieved by transferring the shear demand through the steel column, which requires a positive shear connection (e.g., welded headed studs on both column flanges) between the column and foundation element.

4.2.5 Moment resisting connections between steel moment frame columns and the supporting foundation elements require the inclusion of the foundation flexural stiffness in the drift and deformation compatibility analyses as required by CBC Section 1617A.1.15.

4.2.6 The column base connection detail shall be coordinated with the structural analysis assumptions upon which the building design is based, including the seismic base level, the interaction of foundation elements, and the influence of the slab-on-grade. The detailing shall not introduce stiffness or flexibility that is unaccounted for in the structural analysis and results in an underestimation of seismic forces or drift.

4.3 Braced Frames

The connection of braced frame columns and braces to the foundation shall comply with AISC 341 Section D2.6 and Section 4.1 above. Per AISC 341 Section D2.6b, Exception (b), the columns of ordinary steel braced frames need not comply with D2.6b(c). However, compliance with the amplified seismic loads of CBC Section 1617A.1.15 is still required.

5. COLD-FORMED STEEL (CFS) SYSTEMS

5.1 Light-Frame Shear Walls

Light-frame construction is defined in CBC Chapter 2 as “construction whose vertical and horizontal structural elements are primarily formed by a system of repetitive wood or cold-formed steel framing members”.

5.1.1 Foundation connections for light framed CFS shear walls are required to comply with AISI S400.

5.1.2 AISI S400 Sections E1.2.1 and E1.4.1.2 define sill bolts, hold-downs, and hold-down anchors as capacity protected components. AISI S400 Section B3 requires capacity protected components to be designed for the lesser of the following:

5.1.2.1 Expected strength of the SFRS.

5.1.2.2 Seismic load combinations including the overstrength factor.

5.1.3 In addition to Section 5.1.2 above, concrete hold-down anchors shall comply with the requirements of ACI 318 Section 17.10.5.3.

5.1.4 Sill bolts resisting shear and complying with the requirements of CBC Section 1905A.1.8 need not comply with the strength requirements of ACI 318 Section 17.10.6.3.

REFERENCES:

2022 California Code of Regulations (CCR) Title 24
Part 2: California Building Code (CBC), Sections 1617A.1.15, 1905A.1.8, 1905A.1.9, 2204A.4.