
BUCKLING-RESTRAINED BRACED FRAMES: 2022 CBC

Disciplines: Structural**History:** Revised 10/22/24 Under 2022 CBCIssued 04/01/21 Under 2019 CBC

Division of the State Architect (DSA) documents referenced within this publication are available on the [DSA Forms](#) or [DSA Publications](#) webpages.

PURPOSE

This Interpretation of Regulations (IR) clarifies DSA project approval, testing, and inspection of buckling-restrained braced frame (BRBF) systems.

SCOPE

This IR provides clarification of building code requirements for buckling-restrained brace (BRB) design, testing, inspection, and construction observation. Design of BRBF systems, structural products and materials shall comply with the applicable sections in the California Building Code (CBC), *American Institute of Steel Construction Specification for Structural Steel Buildings* (AISC 360), *American Institute of Steel Construction Seismic Provisions for Structural Steel Buildings* (AISC 341), and the requirements specified in this IR.

BACKGROUND

BRB systems consist of specially designed and tested braces that prevent overall buckling of a slender steel core by encasing it in a buckling-restraining system. Since the performance is not limited by overall buckling, as seen with conventional braces, the brace achieves near equal strength and ductile behavior in both compression and tension. Because BRBs achieve a high level of ductility and exhibit stable, repeatable hysteresis loops, BRBs can absorb a significant amount of energy during cyclic loading. As a result, building codes allow the use of a response modification factor comparable to special moment resisting frames. BRBs used in a project structure must be similar to the tested BRBs to ensure their anticipated structural behavior.

1. DESIGN REQUIREMENTS**1.1 Design Responsibility and Documentation**

Complete qualification test data, design calculations, and detailing of the brace system shall be submitted to DSA for review and approval with the project application construction documents. See Sections 1.2 through 1.7 below for additional information. BRBF systems are not permitted to be a deferred submittal.

The construction documents defining the BRBF system design shall be stamped and signed by a California registered structural engineer. Refer to *IR A-18: Use of Construction Documents Prepared by Other Professionals* and *IR A-19: Design Professional's Signature and Seal (Stamp) on Construction Documents* for further information. It is common for drawings defining the BRBF system to be prepared by a structural engineer retained by the BRB fabricator who is different from the project's structural engineer of record (SEoR) listed on line 24a of the form *DSA 1: Application for Approval of Plans and Specifications*. See IR A-18 Section 2.4 for acceptable stamping and signing options in this case.

1.2 Drawings

At a minimum, each BRB in the project shall have the following information clearly identified on the drawings:

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1.2.1 Core

- $F_{ysc,min}$ = minimum axial yield stress of the steel core (for use in designing the required core area), ksi
- $F_{ysc,max}$ = maximum axial yield stress of the steel core (for use in calculating the adjusted brace strength), ksi
- A_{sc} = cross-sectional area of the yield segment of the steel core, in²
- L_{ysc} = length of the yield segment of the steel core, in
- β = compression strength adjustment factor
- ω = strain hardening adjustment factor
- KF = stiffness modification factor

1.2.2 Casing and Collar

- Member size. If the casing or collar is not a standard AISC shape, at a minimum, provide the following dimensions and properties for all shapes and plates that make up the restraining and end force transfer system:
 - b_c = width, in
 - d_c = depth, in
 - t_c = wall thickness, in
 - I_c = moment of inertia about both principal axes of casing and/or collar, in⁴
- Material properties.
 - When grout is anticipated to be integral to the buckling-restraining mechanism, a note that the f'_c must meet the manufacturer's specified grout strength (which must meet or exceed that used in the qualifying tests).
 - Exception:** f'_c need not be stated for accepted fabrication shops (reference Section 2.3 below).
 - If the casing or collar is not specified by a standard ASTM specification and grade, at a minimum, provide the following properties for all shapes and plates that make up the restraining and end force transfer system:
 - F_y = specified minimum yield stress, ksi
 - L_c = length of the casing and/or collar, in
 - L_g = length of brace from tip of gusset to tip of gusset, in

1.2.3 Connections

Each BRB connection shall be fully detailed on the construction documents in accordance with AISC 360 and AISC 341 standards. Project-specific conceptual detailing for varying and unique conditions (e.g., shallow or steep brace angles, sloping frame beams, etc.) shall be provided to scale. In cases where unique conditions exist, generic detailing and connection scheduling alone will not be accepted.

1.3 Specifications

BRBF project specifications shall define the BRB manufacturer used as the basis-of-design.

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For each brace in the project, provide qualification testing per AISC 341 Section F4.5b.3. Each qualifying test used must have the following project-specific information clearly identified:

- All test data required in accordance with AISC 341 Section K3.7 and verification of acceptance criteria per AISC 341 Section K3.8.
- Type of qualifying test: subassemblage or uniaxial.
- Project brace(s) to which each test applies.
- Verification that project brace core strength ($P_{y_{sc}}$) is within the test specimen's core strength qualification range specified in AISC 341 Sections K3.2(b) and K3.3c(b).

1.5 Calculations

Each BRBF shall be fully designed in accordance with AISC 360 and AISC 341 standards.

1.5.1 Analysis

- The SEoR shall provide complete BRBF designs in coordination with the BRB manufacturer to ensure the frame analysis matches the final design (e.g., BRB end condition type). The BRB manufacturer may provide design for the BRB and connection only; however, all BRBF columns, beams, struts and connections shall be designed for the capacity-limited seismic load effects per AISC 341 Sections F4.3 and F4.6.
- Values for the adjustment factors β and ω shall be determined in accordance with AISC 341 Section F4.2b. The trendline for backbone curves used to determine β and ω shall be a rational best fit trendline (linear or polynomial) free of irregular inflection points, dips, or change of curvature that may significantly underestimate the predicted values from the hysteresis at strains corresponding to the applicable design story drifts.
- The values for β , ω , and the stiffness modification factor, KF, used in analysis and design shall be within 10 percent of the values calculated by the BRB manufacturer. If the β or ω values used in analysis and design are less than those calculated by the BRB manufacturer, the demand-to-capacity ratios for the BRB adjacent connections and members shall be adjusted to account for the differences. Demand-to-capacity ratios shall not exceed 1.0.
- Loading effects including the actual weight of the BRB shall be considered for the global gravity and in-plane lateral analysis, as well as any out-of-plane component analyses.

1.5.2 Buckling-Restraining System

In order to satisfy the requirements of AISC 341 Sections F4.5b.1(b), K3.2(e) and K3.3a(a) the project BRB shall meet the following minimum stability requirements.

1.5.2.1 Overall Buckling Stability

The SEoR or BRBSE shall demonstrate that the buckling-restraining assembly, including the casing, collar and core extension has an equivalent or greater factor-of-safety than that of the qualifying test BRB. Overall buckling stability shall be demonstrated using rational engineering methods and must be justified through testing and/or calculations.

1.5.2.2 Beam-to-Column Connection

The SEoR shall clearly identify which beam-to-column connection design methodology is used in accordance with AISC 341 Section F4.6b and consistently utilize this methodology throughout the individual BRBF connection design and detailing.

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1.5.3 Foundations

BRBF base connections shall be designed for the capacity-limited seismic load effects per AISC 341 Sections D2.6, F4.3, and F4.6. Furthermore, foundation elements supporting the BRBF shall comply with CBC Section 1617A.1.15.

1.6 Protected Zones

The protected zones, as defined in AISC 341 Section F4.5c, shall be maintained and permanently marked in accordance with AISC 303 Section 1.11.

1.6.1 Attachments to casing

Connections not detailed on the BRB manufacturer's drawings nor fabricated in their fabrication shop require prior approval. Connections with tack welds, fillet welds less than 1/4" thick, puddle welds 3/4" diameter and smaller, shot pins or screws having penetrations not exceeding the casing thickness may be attached to the casing with written approval from the BRBSE. With prior DSA acceptance of a testing protocol and acceptance criteria, welds, shot pins or screws exceeding these limits may be allowed if written approval from the BRBSE and testing documentation is provided demonstrating no detrimental brace performance.

1.7 Non-Bearing Partition Support

BRBs shall not be used to resist gravity, in-plane, or out-of-plane loads applicable to interior or exterior walls.

Exception: BRB may be permitted to resist gravity, in-plane, or out-of-plane interior wall loads provided loading effects on the BRB are considered, expected building drift can be accommodated, and BRB behavior is not restricted. The BRBSE shall provide written approval of the final conditions.

2. TESTING AND SHOP INSPECTION REQUIREMENTS

2.1 Form DSA 103: List of Required Structural Tests and Special Inspections

The BRB section of the form DSA 103 shall be selected.

2.2 DSA Acceptance of BRB Fabrication Shops

To qualify for DSA acceptance, the fabrication shop shall comply with the following:

2.2.1 Certification/Accreditation

Obtain and maintain accreditation from any of the following organizations:

- The International Accreditation Service (IAS).
- The American Welding Society (AWS) per AWS QC17.
- The Canadian Welding Bureau (CWB) per CSA Standard W47.1, Division 1.
- American Institute of Steel Construction (AISC) Certification – Building Fabricator (minimum).
- Other nationally recognized evaluation services or accreditation/certification bodies, equivalent to those indicated above, may be accepted by DSA with prior approval.

2.2.2 Experience

BRB fabrication shops shall have a minimum of three years of documented continuous experience in the design, testing and fabrication of BRBs.

BUCKLING-RESTRAINED BRACED FRAMES: 2022 CBC**2.2.3 Accreditation and Experience Documentation**

Documentation showing evidence of valid accreditation and experience shall be submitted to DSA upon initial acceptance and upon subsequent renewals of the accreditation noted above. Send the required documentation to DSA Headquarters at the following address:

ATTN: Laboratory Evaluations & Acceptance (LEA) Program
DSA Headquarters
1102 Q Street, Suite 5100
Sacramento, CA 95811

2.3 Fabrication of BRB in Shops with DSA Acceptance

BRB fabricated in shops with DSA acceptance per Section 2.2 above are exempt from the special inspection and testing requirements of CBC Section 1705A.

2.3.1 Fabrication Shop Documentation

At the conclusion of all BRB fabrication and any associated material testing, the fabricator's design engineer (or SEoR if the fabricator's BRB construction documents are over-stamped by the SEoR) responsible for the BRB design and testing shall sign and submit a Certificate of Compliance (C of C) to the steel fabricator and SEoR. The SEoR shall review the C of C and verify it meets the requirements of this Section. Any deficiencies in the C of C shall be brought to the attention of DSA, the owner, BRBSE, the design professional in responsible charge, and the Project Inspector (PI). The SEoR shall provide a copy of his/her reviewed, accepted without exception, and identified accordingly C of C to the PI and Laboratory of Record (LOR). In all cases, the C of C shall be transmitted prior to concealing any installed brace. The PI shall upload the SEoR accepted C of C to DSAbbox in the *BRB Certificate of Compliance* folder. The C of C shall cite and be based on the fabricator's quality control records and shall include the following:

- Material identification.
- Core plate material tension tests confirming compliance with brace design criteria, AISC 341 Section K3.6, and specified material ranges indicated on the DSA-approved construction documents.
- Welding inspection by an AWS-certified welding inspector (CWI) or AWS-senior certified welding inspector (SCWI).
- Core installation and debonding material application.
- Grout placement and strength conformance to manufacturer's specification when grout is integral to the buckling-restraining mechanism.
- Any additional project conformance requirements specified in DSA-approved construction documents (e.g., material surface cleaning, finish material application, etc.).

The C of C shall also include the following:

- Project information:
 - DSA file and application numbers.
 - DSA project name.
 - School district.
- Brace fabricator information:
 - Fabricator's address.

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- Signature of brace fabricator's quality control manager.
- Compliance statement:
 - All materials, fabrication and inspection records indicate all braces meet the requirements of the DSA-approved project documents and applicable reference standards.

The C of C shall be a required document for project certification.

Failure to provide documentation may be cause for DSA to withdraw fabrication shop acceptance and reject project BRB lacking documentation.

2.4 Fabrication of BRB in Shops without DSA Acceptance

BRB fabricated in shops without DSA acceptance require special inspection per CBC Section 1705A.

2.4.1 Special Inspector

The special inspector shall be employed by the LOR or school district per California Administrative Code (CAC) Section 4-335(f)1. Special inspectors employed individually and directly by the school district shall be approved by DSA prior to commencing work in accordance with CAC Sections 4-333(c) and 4-335(f)1.B. Refer to Procedure (PR) 13-01: *Construction Oversight Process* for additional requirements applicable to special inspection and IR 17-12: *Special Inspection Reporting Requirements* for daily inspection report content requirements. See form DSA 250: *Special Inspection Report* for an acceptable format.

2.4.2 Material Certification

The special inspector is responsible for ensuring all materials are identifiable and/or traceable to the compliance documentation (e.g., mill certificates for steel and fasteners). The special inspector shall attach copies of the certificates to the daily inspection report(s) required by CAC Section 4-335(f)4.A. Refer to PR 13-01 for additional requirements applicable to special inspection.

2.4.3 Material Testing

If any material testing is required (e.g., unidentifiable steel), the testing must be performed by a test laboratory employed by the school district and acceptable to DSA. A list of LEA accepted test laboratories can be found on DSA's website. For remotely located fabricators, refer to IR A-15: *Testing and Inspection of Remotely Fabricated Structural Elements*.

Test reports shall be submitted by the laboratory per CAC Section 4-335(d), and a final verified report (i.e., form DSA 291: *Laboratory of Record Verified Report*) shall be submitted at the conclusion of the fabrication. Refer to PR 13-01 for additional requirements applicable to the testing laboratory.

2.4.4 Welding

If welding is required in the fabrication shop, a CWI or SCWI shall inspect the welding, provide distinguishing marks/tags/etc., prepare and submit detailed daily inspection reports in accordance with CAC Section 4-335(f)4.A, CBC Section 1705A.2.5 and IR 17-3: *Structural Welding Inspection*. When the special inspector is employed individually and directly by the school district, he/she shall also submit a final verified report (i.e., form DSA 292: *Special Inspectors Employed Directly by the District Verified Report*) per CAC Section 4-335(f)4.B. Refer to PR 13-01 for additional requirements applicable to special inspection.

BUCKLING-RESTRAINED BRACED FRAMES: 2022 CBC**2.4.5 Fabrication Shop Documentation**

At the completion of BRB fabrication and any associated material testing, the fabricator's design engineer (or SEoR if the fabricator's BRB construction documents are over-stamped by the SEoR) responsible for the BRB design and testing shall submit all quality control documentation records associated with material identification, testing, and special inspection noted in Section 2.3.1 above to the steel fabricator and SEoR. The SEoR shall review the documentation and verify it meets the requirements of this Section. If any deficiencies are identified, the SEOR shall notify DSA, the owner, BRBSE, the design professional in responsible charge, and the PI. The SEoR shall provide a copy of his/her reviewed, accepted without exception, and identified accordingly documentation to the PI and LOR. In all cases, the documentation shall be transmitted prior to concealing any installed brace.

Prior to brace concealment, the following documentation shall be provided to the PI:

- Form(s) DSA 291 for applicable completed shop special inspections and testing.
- For special inspectors contracted individually and directly with the school district, form DSA 292 for each such special inspector for applicable completed shop special inspections.

3. INSPECTION AND CONSTRUCTION OBSERVATION IN THE FIELD**3.1 Project Inspector inspection of BRB**

When BRBs are delivered to the jobsite, the PI shall be responsible for, but not limited to, the following:

- Inspect the BRB for compliance with DSA-approved construction documents.
- Inspect the field installation.

Prior to concealing any installed brace:

- Ensure all the required documents per Sections 2.3 or 2.4 above are submitted and, when applicable, upload the C of C to DSAbox in accordance with Section 2.3.1.
- Review the submitted documents for compliance with DSA-approved construction documents.

3.2 Special Inspection of Field Welding

If welding is required in the field, a CWI or SCWI shall inspect welding in accordance with the CBC Section 1705A.2.5 and IR 17-3. Refer to PR 13-01 for additional special inspection requirements.

3.3 Special Inspection of High-Strength Bolting

If high-strength bolting is required in the field, an International Code Council certified Structural Steel and Bolting Special Inspector (S1) shall inspect bolting in accordance with the CBC Section 1705A.2.6 and *IR 17-9: High-Strength Structural Bolting Inspection*. Refer to PR 13-01 for additional special inspection requirements.

3.4 Construction Observation

Project site construction observations and verified reports in accordance with CAC Section 4-341 and 4-336, respectively, provided by design professional(s) shall include project BRBs based on the applicable option in IR A-18. Refer to PR 13-01 for additional design professional responsibility requirements.

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REFERENCES:

2022 California Code of Regulations (CCR) Title 24
Part 2, California Building Code, Section 2205A

This IR is intended for use by DSA staff and by design professionals to promote statewide consistency for review and approval of plans and specifications as well as construction oversight of projects within the jurisdiction of DSA, which includes State of California public schools (K-12), community colleges and state-owned or state-leased essential services buildings. This IR indicates an acceptable method for achieving compliance with applicable codes and regulations, although other methods proposed by design professionals may be considered by DSA.

This IR is subject to revision at any time. Please check DSA's website for currently effective IRs. Only IRs listed on the webpage at www.dgs.ca.gov/dsa/publications at the time of project application submittal to DSA are considered applicable.