
BUCKLING-RESTRAINED BRACED FRAMES: 2019 CBC

Disciplines: Structural**History:** Issued 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, and inspection. 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 up to eight (8) which is comparable to special moment resisting frames. Braces used in a project structure must be similar to the tested braces to ensure their anticipated structural behavior.

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1. DESIGN REQUIREMENTS**1.1 Design Submittal**

The BRB design and construction documents shall be stamped and signed by a California registered structural engineer. 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. Deferred submittals are not permitted.

1.1.1 Drawings

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

1.1.1.1 Core

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

1.1.1.2 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 of casing and/or collar, in
 - d_c = depth of casing and/or collar, in
 - t_c = wall thickness of casing and/or collar, in
 - I_c = moment of inertia about both principal axes of casing and/or collar, in⁴
- F_y = specified minimum yield stress of the steel casing and/or collar, 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
- f'_c = specified minimum grout strength, psi (must meet or exceed the specified strength used for the qualifying test)

1.1.1.3 Connections

Each BRB connection shall be fully detailed in accordance with AISC 360 and 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.

1.1.2 Specifications

BRBF project specifications shall include the following:

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- BRB manufacturer used as the basis-of-design.

1.1.3 Qualification Testing

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).

1.1.4 Calculations

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

1.1.4.1 Analysis

- The Structural Engineer of Record (SEOR) shall provide complete BRBF designs in coordination with the BRB manufacturer to ensure the frame analysis matches the final design (e.g. fixed vs. pinned BRB end condition assumptions). 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 Section F.4.3 and F4.6.
- 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 underestimate the predicted values from the hysteresis.
- 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. The β and ω values shall be based on AISC 341 qualification testing.
- 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.

1.1.4.2 Buckling-Restraining System

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

1.1.4.2.1 Overall Buckling Stability

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

1.1.4.3 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 BRB connection design and detailing.

1.1.4.4 Foundations

BRB 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

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shall comply with CBC 1617A.1.16.

1.2 Protected Zones

In addition to the protected zones defined in AISC 341 Section F4.5c, welded connections, shot pins and any other attachment to the BRB casing are not permitted.

Exception: Welds less than ¼" fillet or ¾" puddle welds shall be allowed to the casing with written approval from the BRB manufacturer's design professional. With prior DSA acceptance of a testing protocol and acceptance criteria, welds exceeding these limits may be allowed if written approval from the BRB manufacturer and testing documentation is provided demonstrating no detrimental brace performance.

1.3 Non-Bearing Partition Support

BRB's shall not be used to support interior or exterior out-of-plane wall loading.

Exception: BRB may be permitted to support interior walls provided loading effects on the BRB are considered, expected building drift can be accommodated, and BRB behavior is not restricted. The BRB manufacturer's design professional shall provide written approval of the final conditions.

2. TESTING AND INSPECTION REQUIREMENTS**2.1 Acceptance of Buckling Restrained Brace Fabrication Shops**

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

2.1.1 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.
- Other nationally recognized evaluation services or accreditation/certification bodies, equivalent to those indicated above, may be accepted by DSA with prior approval.

2.1.2 Experience

Fabricators of buckling restrained braces shall have a minimum of three years of documented continuous experience in the design, testing, and fabrication of buckling restrained braces.

2.1.3 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

2.2 Fabrication of Buckling Restrained Braces in Shops with DSA Acceptance

Buckling restrained braces fabricated in shops with DSA acceptance per Section 2.1 above are exempt from the special inspection requirements of CBC Section 1705A.

BUCKLING RESTRAINED BRACED FRAMES: 2019 CBC**2.2.1 Fabrication Documentation**

At the completion of fabrication, the fabricator's design engineer responsible for the buckling restrained brace design and testing shall submit a certificate of conformance to the project inspector and laboratory of record. The certificate of conformance shall include the following records, but not limited to:

- Material identification
- Core tension tests in accordance with AISC 341 K3.6. Heat number of the tension test specimen (which must match that used for the project braces in accordance with AISC 341 Section K3.6a and Section 1.1.1.1 above of this IR)
- Welding inspection
- Grout placement and strength conformance
- Core installation and debonding material application
- Any additional project conformance requirements specified in DSA-approved construction documents (e.g., material surface cleaning, finish material application, etc.)

Failure to provide documentation may be cause for DSA to withdraw fabricator acceptance and reject project braces lacking documentation.

2.3 Fabrication of Buckling Restrained Braces in Shops without DSA Acceptance

Buckling restrained braces fabricated in shops without DSA acceptance will require special inspection per CBC, Section 1705A.

2.3.1 Special Inspector

The special inspector shall be employed by the laboratory of record or school district per Title 24, Part 1, Section 4-335(f)1. Special inspectors employed individually and directly by the school district shall be approved prior to commencing work by DSA in accordance with Title 24, Part 1, Section 4-333(c) and 4-335(f)1.B. Refer to DSA 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 (*DSA 250: Special Inspection Report*) content requirements.

2.3.2 Material Certification

The special inspector is responsible for ensuring all materials are identifiable and/or traceable to the certificates of compliance (e.g. mill certificates for steel and fasteners). The special inspector shall attach copies of the certificates to the daily inspection report(s) (DSA 250) per Title 24, Part 1, Section 4-335(f)4.A. Refer to PR 13-01 for additional requirements applicable to special inspection.

2.3.3 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 acceptable test laboratories can be found on the DSA 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 Title 24, Part 1, Section 4-335(d), and a final verified report (*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.

2.3.4 Welding

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If welding is required in the fabrication shop, an AWS-certified welding inspector (CWI) or AWS-senior certified welding inspector (SCWI) shall inspect the welding and provide distinguishing marks/tags/etc. in accordance with the CBC Section 1705A.2.5 and *IR 17-3: Structural Welding Inspection*. The welding inspector shall provide daily inspection reports (DSA 250) per Title 24, Part 1, Section 4-335(f)4.A. When the special inspector is employed directly by the school, he/she shall submit a final verified report (*DSA 292: Special Inspectors Employed Directly by the District Verified Report*) per Title 24, Part 1, Section 4-335(f)4.B. Refer to PR 13-01 for additional requirements applicable to special inspection.

2.3.5 Fabrication Documentation

At the completion of fabrication, the fabricator's design engineer responsible for the buckling restrained brace design and testing shall submit the following brace fabrication records, a certificate of conformance to the project inspector, and laboratory of record. The certificate of conformance shall include the following records, but not limited to:

- All records noted in Section 2.2.1 above.

Prior to brace installation, the following documentation shall be provided to the project inspector:

- Laboratory of Record's (LOR) form(s) DSA 291.
- For special inspectors independently contracted with the school, form DSA 292 for each such special inspector.

3. INSPECTION IN THE FIELD

When the Buckling Restrained Brace is delivered to the jobsite; the project inspector shall be responsible for, but not limited to, the following:

- Ensure all the required documents per Sections 2.2 or 2.3 above are submitted by the fabricator.
- Review the fabricator's submitted documents for compliance with DSA approved construction documents.
- Inspect the Buckling Restrained Brace for defects and compliance with DSA approved construction documents.
- Inspect the field installation.

3.1 Special Inspection of Field Welding

If welding is required in the field, an AWS-certified welding inspector (CWI) or AWS-senior certified welding inspector (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.

3.2 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.

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REFERENCES:

2019 California Code of Regulations (CCR) Title 24
Part 2, California Building Code, Section 2205A
AISC 341, Sections F4 and K3

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.