



City of Long Beach
Department of Development Services
Building and Safety Bureau

Information
Bulletin

BU-024

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Design Guidelines for Steel Moment-Resisting Frames

A. PURPOSE

The purpose of this Information Bulletin is to alert designers to the specific design guidelines for steel moment-resisting frames utilized in buildings and structures to resist the effects of lateral seismic forces. Recently developed recommendations by the Structural Engineers Association of Southern California's (SEAOSC) Steel Committee, which combine the knowledge gained from research and testing by various private organizations into the problems associated with steel moment-resisting frames damaged during the 1994 Northridge Earthquake, and previous investigations, particularly by the American Institute of Steel Construction (AISC) and the Federal Emergency Management Agency (FEMA), has lead the ICC Los Angeles Basin Chapter's Structural Committee and the Department, to adopt a more comprehensive design, construction, and inspection requirements intended to improve the performance of steel moment-resisting frames.

With the prevalent use of steel moment-resisting frame systems in light-frame low-rise construction or non-building structures and the limited selection of prequalified or prescriptive steel moment-resisting frame configurations recognized in the code, it is the intent and objective of this Bulletin to provide design guidelines to facilitate the appropriate use and reasonable acceptance of certain FEMA-350 connections and other connection configurations not specifically prequalified in AISC 341-05 or AISC 358-05 standards. With the appropriate limitations applied as summarized and clarified in this Bulletin, these steel moment-resisting frames can be used with reasonable confidence.

B. SPECIFICATIONS, CODES AND STANDARDS

ANSI/AISC 341-05, Seismic Provisions for Structural Steel Buildings, including Supplement No. 1 dated November 16, 2005.

ANSI/AISC 358-05, Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications.

ASCE/SEI 7-05, Minimum Design Loads for Buildings and Other Structures including Supplement No. 1 and excluding Chapter 14 and Appendix 11A.

AWS D1.8/D1.8M-2005, Structural Welding Code – Seismic Supplement, dated 2005.

CBC 2007, California Building Code, Volume 2.

FEMA-350, Recommended Seismic Design Criteria for New Steel Moment Frame Buildings, including Errata dated March 16, 2001.

C. PREQUALIFIED CONNECTION TYPES

AISC 358-05 currently provides three prequalified configurations of steel special (SMF) and intermediate moment-resisting frames (IMF). The reduced beam section (RBS), bolted unstiffened extended end-plate (BUEEP) and bolted stiffened extended end-plate (BSEEP) connections are considered as prequalified for SMF and IMF applications, subject to the limitations of design and construction as described in AISC 358-05. Use of any prequalified configuration of steel SMF and IMF in future AISC 358 supplements shall be subject to up to the approval of the Department.

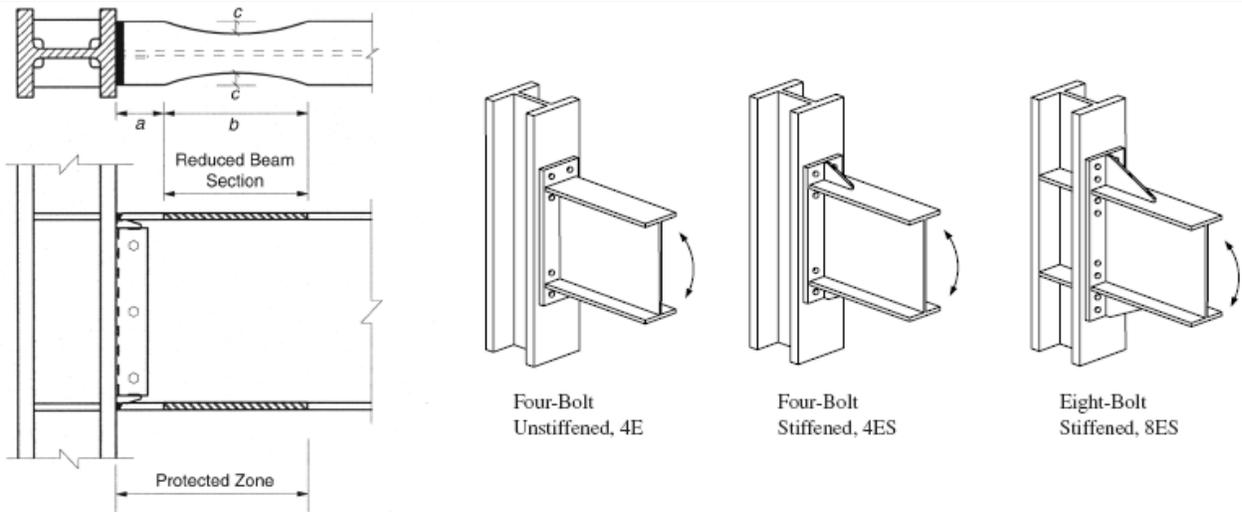


Figure 1. RBS, BUEEP and BSEEP Connections

FEMA-350 provide various prequalified configurations for steel moment-resisting frames. However, only the welded flange plate (WFP), bolted flange plate (BFP) and welded unreinforced flange-welded web (WUF-W) connections are permitted to be prequalified for use as an IMF, subject to the limitations of design and construction as described in FEMA-350 and Section 10 of AISC 341-05. To determine the appropriate design parameters for the selected FEMA-350 connection, use the criteria outlined for ordinary moment-resisting frame (OMF) in the FEMA-350 document (the term IMF was not in use at the time of FEMA-350's publication).

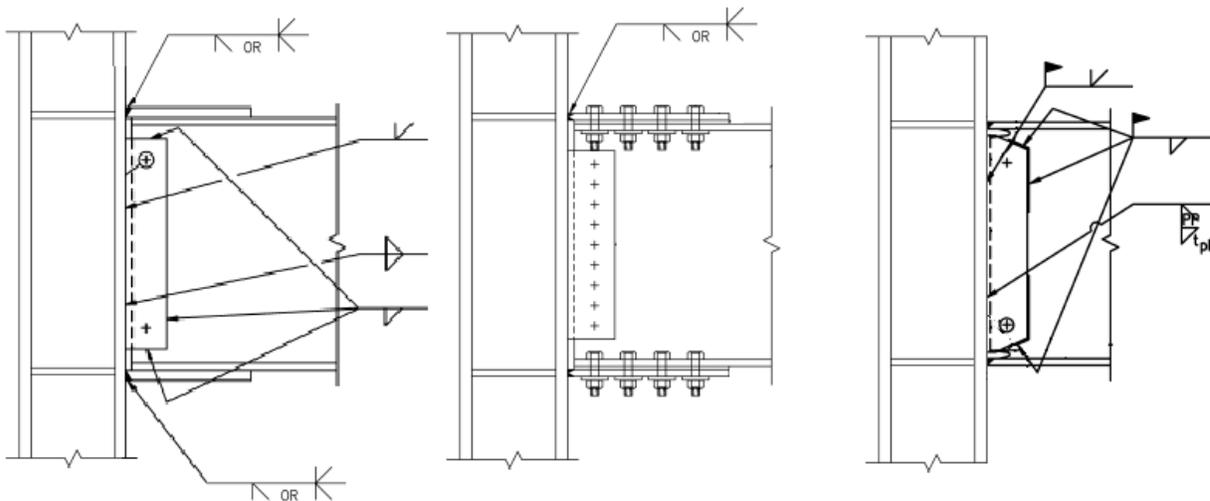


Figure 2. WFP, BFP, and WUF-W Connections

D. NON-PREQUALIFIED CONNECTION TYPES

Connections not prequalified by AISC 358-05 or FEMA-350 as described above, including proprietary connection systems, must be tested in accordance with Appendix S of AISC 341-05. Where connection configurations are based on previously tested special or intermediate moment frames, limit the extrapolation of tests to only those connections that are within the size and weight variation for beams and columns as specified in Appendix S of AISC 341-05.

When variations of any connection systems from the tested configuration that is being used as the basis for prequalification are proposed such as the addition of haunches or cover plates, additional welding, variations from the allowed configuration of the weld access hole at moment connections, moment connections in the weak axis direction of the column (e.g., moment connections to the column web), skewed or dual axis moment connections, project specific tests complying with Appendix S of AISC 341-05 shall be required to qualify their use.

Notwithstanding Appendix S, the Department may consider alternate procedures and acceptance criteria for the evaluation and qualification of a given connection or frame design.

E. STRUCTURAL DESIGN CRITERIA

For SMF and IMF designed and prequalified in accordance with Appendix S of AISC 341-05 or AISC 358-05 (i.e., RBS, BUERP and BSEEP connections) or OMF designed to the prescriptive configuration in accordance with AISC 341 Seismic Provisions for rolled or built-up I-shaped sections (i.e., wide flange shapes), the appropriate design coefficient factors, structural system limitations and building height limits, and allowable story drift indicated in Table 12.2-1 of ASCE 7-05 shall be used in determining the structural system, base shear, element design forces, and design story drift.

For IMF designed and prequalified in accordance with FEMA-350 (i.e., WUF-W, WFP and BFP connections) or OMF designed in accordance with AISC 341-05 for other symmetrical structural shapes such as, but not limited to, channels, built-up sections (non I-shaped), or hollow structural sections (HSS), the appropriate design coefficient factors, structural system limitations and building height limits, and allowable story drift indicated in Table 1, 2 or 3 of this Bulletin shall be used in determining the structural system, base shear, element design forces, and design story drift.

***Exception:** A greater allowable story drift may be permitted if it can be demonstrated from tests, conforming to Appendix S of AISC 341-05, that the connections provides a drift capacity of 1.6 times the proposed allowable story drift. The allowable story drift shall not exceed that permitted by Table 12.2-1 of ASCE 7-05 for any story.*

F. OTHER DESIGN CONSIDERATIONS

Column base connection elements, including but not limited to, anchor bolts, base plate welds and any elements transferring shear, moment and tension mechanism shall be designed using the overstrength factor, Ω_o , in accordance with Section 12.4.3.2 of ASCE 7-05. Load combinations with overstrength factor should apply to elevated structural slabs or beams supporting moment-resisting frame systems. The overstrength factor, Ω_o , need not be applied to the foundation or grade beam supporting columns; provided however that the grade beams are designed and detailed to develop ductility in accordance with the provisions of Chapter 21 of ACI-318-05.

The region at each end of the beam subject to inelastic straining shall be designated as a protected zone and shall meet the requirements of Section 7.4 of AISC 341-05. Unless determined as part of a connection prequalification in accordance with Appendix P of AISC 341-05, determined in a program of qualification testing in accordance with Appendix S of AISC 341-05 or designated in AISC 358-05, the extent of the plastic hinging zone should extend from the face of the column to one half of the beam depth beyond the plastic hinge point. Section 7.4 of AISC 341-05 prohibits discontinuities created by fabrication or erection operations and attachments or penetrations within the protected zones, unless specified otherwise in Section 7.4. Clearly identify this requirement on the structural drawings. See

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figure below for recommended details to prohibit attachments or penetrations in the protected zones. Furthermore, it is recommended that this detail be shown on other appropriate construction documents, including the architectural, mechanical, electrical or plumbing drawings. The importance of avoiding attachments or penetrations within the protected zones should be discussed during the preconstruction meeting with the various contractors and subcontractors prior to commencement of construction work.

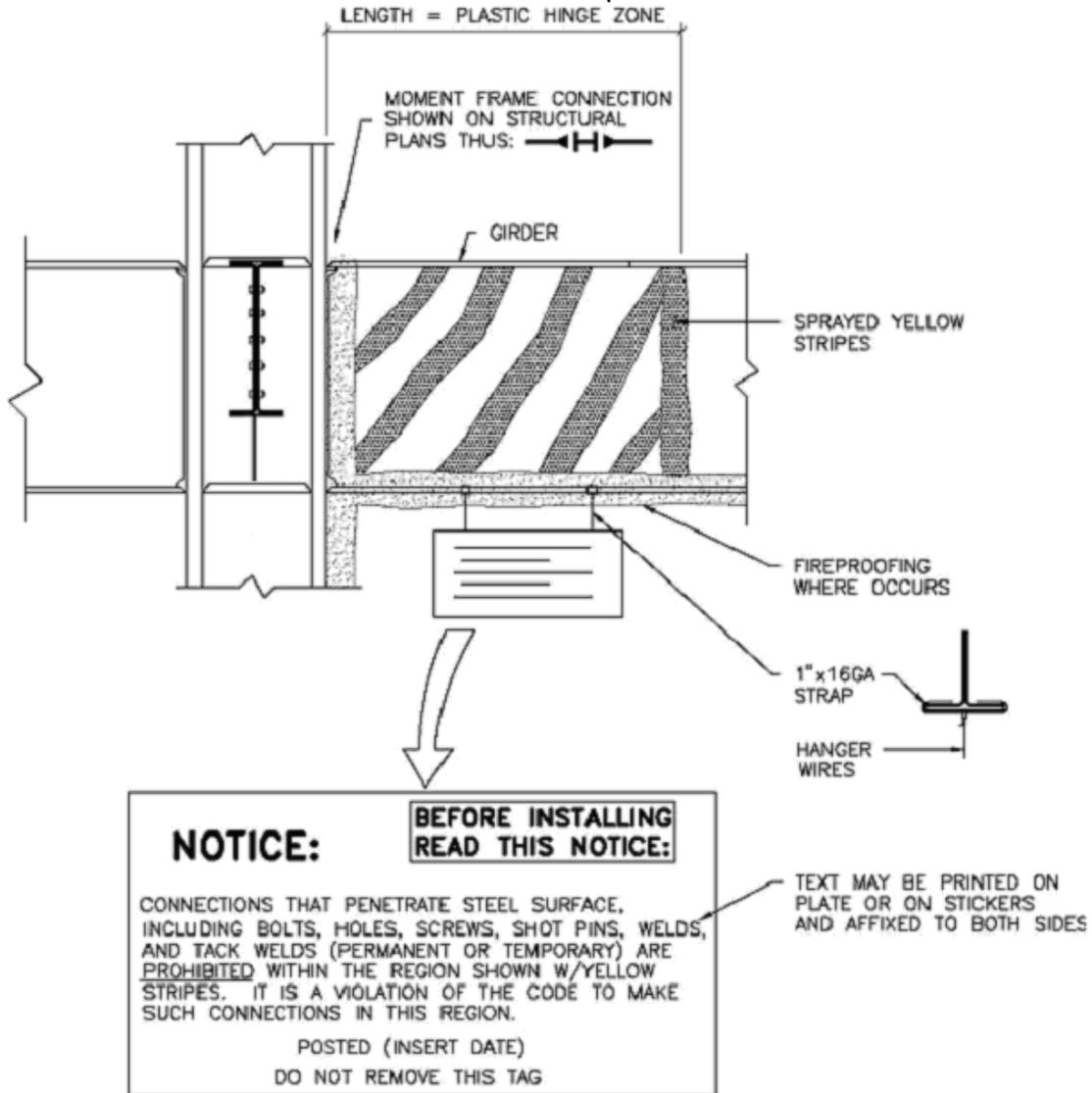


Figure 3. Protected Zone

NOTE: While the AISC 341-05 does not require protected zones for OMF connections, it is good practice to minimize or limit, whenever possible, attachments within this defined area.

G. QUALITY CONTROL AND QUALITY ASSURANCE

Quality control and quality assurance shall be in accordance with Appendix Q of AISC 341-05. Details regarding welding and welding inspection shall be in accordance with AWS D1.8-2005 Structural Welding Code – Seismic Supplement and Appendix W of AISC 341-05 or Chapter 3 of AISC 358-05.

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TABLE 1

**SUMMARY OF DESIGN COEFFICIENTS, FACTORS AND DEFORMATION FOR
STEEL MOMENT-RESISTING FRAMES SYSTEM IN SEISMIC DESIGN CATEGORY D**

LFRS	CONNECTION TYPE	STANDARD	BUILDING AND STRUCTURE TYPES	DESIGN COEFFICIENTS AND FACTORS			SEISMIC DESIGN CATEGORY Structural System Limitations and Building Height Limit ^c				OCCUPANCY CATEGORY Allowable Story Drift Limit ^{e, i}					
				R ^a	Ω_o ^d	C _d ^b	D				≤ 4 Stories			> 4 Stories		
							HT	DL	WDL	Story	I or II	III	IV	I or II	III	IV
SMF ^o	RBS, BUEEP, and BSEEP ^j	AISC-358	Any Building Types	8	3	5.5	NL	NL	NL	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	Connections Qualified by Cyclic Test	AISC-341	Any Building Types	8	3	5.5	NL	NL	NL	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
IMF	RBS, BUEEP, and BSEEP ^{g, h}	AISC-358	Any Building Types	4.5	3	4	35	NL	NL	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	WUF-W, WFP, and BFP ^{g, h}	FEMA-350	Any Building Types	4.5	3	4	35	35	20	NL	0.020h_{sx}	0.015h_{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	Connections Qualified by Cyclic Test ^{g, h}	AISC-341	Any Building Types	4.5	3	4	35	NL	NL	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	Moment Joint Field Connection Constructed of Bolted End Plates ^{f, k, h}	AISC-341	Metal Buildings	4.5	3	4	65	20	20	1	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	NP	NP	NP
OMF	RBS, BUEEP, and BSEEP ^g	AISC-358	Any Building Types	3.5	3	3	35	35	20	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	WUF-W, WFP, and BFP ^g	FEMA-350	Any Building Types	3.5	3	3	35	35	20	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	Beam to Column Connection of Rolled or Built-Up I-Shaped Sections ^{g, k}	AISC-341	Any Building Types	3.5	3	3	35	35	20	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	Moment Joint Field Connection Constructed of Bolted End Plates ^{f, k}	AISC-341	Metal Buildings	3.5	3	3	65	20	20	1	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	NP	NP	NP
	Beam to Column Connection with Other Symmetrical Shapes ^l	AISC-341	Light-Frame Construction or Miscellaneous Structures ^l	1.5	1.5	1.5	35	NL	NL	NL	0.015h_{sx}	NP	NP	0.015h_{sx}	NP	NP

FOOTNOTE:

- a. Response modification coefficient, *R*, for use throughout the standard. Note *R* reduces forces to a strength level, not an allowable stress level.
- b. Reflection amplification factor, *C_d*, for use in ASCE 7-05 Sections 12.8.6, 12.8.7 and 12.9.2.
- c. NL = Not Limited and NP = Not Permitted. For metric units use 30.5 m for 100 ft and use 48.8 m for 160 ft. Heights are measured from the base of the structure as defined in ASCE 7-05 Section 11.2.
- d. The tabulated value of the overstrength factor, Ω_o , is permitted to be reduced by subtracting one-half for structures with flexible diaphragms, but shall not be taken as less than 2.0 for any structure except cantilever column system.
- e. See ASCE 7-05 Section 12.2.5.5 for limitations for steel SMFs in structures assigned to Seismic Design Category D through F.
- f. See ASCE 7-05 Sections 12.2.5.6 and 12.2.5.8 for limitations for single-story steel OMFs and IMFs in structures assigned to Seismic Design Category D through F.
- g. See ASCE 7-05 Section 12.2.5.7 for limitations for steel OMFs and IMFs in structures assigned to Seismic Design Category D through E.
- h. See ASCE 7-05 Section 12.2.5.9 for limitations for steel IMFs in structures assigned to Seismic Design Category F.
- i. See ASCE 7-05 Section 12.12.1.1 for the allowable story drift for seismic force-resisting systems comprised solely of moment frames in Seismic Design Category D through F.
- j. See AISC 358-05 Table 2.1 for limitations for prequalified steel SMFs with concrete structural slabs in direct contact with the steel.
- k. The connection in this table is intended for rolled or built-up I-shaped sections (i.e., wide flange shapes).
- l. Other symmetrical shapes may include, but no limited to, channels, built-up sections (non I-shaped), and hollow structural sections (HSS).
- m. Miscellaneous structures may include, but not limited to, walkways, canopies, penthouse, stairs, towers, and other non-building structures not part of the lateral resisting system of a building.

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TABLE 2

**SUMMARY OF DESIGN COEFFICIENTS, FACTORS AND DEFORMATION FOR
STEEL MOMENT-RESISTING FRAMES SYSTEM IN SEISMIC DESIGN CATEGORY E**

LFRS	CONNECTION TYPE	STANDARD	BUILDING AND STRUCTURE TYPES	DESIGN COEFFICIENTS AND FACTORS			SEISMIC DESIGN CATEGORY Structural System Limitations and Building Height Limit ^c				OCCUPANCY CATEGORY Allowable Story Drift Limit ^{e, i}					
				R ^a	Ω_o ^d	C _d ^b	E				≤ 4 Stories			> 4 Stories		
							HT	DL	WDL	Story	I or II	III	IV	I or II	III	IV
SMF ^o	RBS, BUEEP, and BSEEP ^j	AISC-358	Any Building Types	8	3	5.5	NL	NL	NL	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	Connections Qualified by Cyclic Test	AISC-341	Any Building Types	8	3	5.5	NL	NL	NL	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
IMF	RBS, BUEEP, and BSEEP ^{g, h}	AISC-358	Any Building Types	4.5	3	4	35	35	20	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	WUF-W, WFP, and BFP ^{g, h}	FEMA-350	Any Building Types	4.5	3	4	35	35	20	NL	0.020h_{sx}	0.015h_{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	Connections Qualified by Cyclic Test ^{g, h}	AISC-341	Any Building Types	4.5	3	4	35	35	20	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	Moment Joint Field Connection Constructed of Bolted End Plates ^{f, k, h}	AISC-341	Metal Buildings	4.5	3	4	65	20	20	1	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	NP	NP	NP
OMF	RBS, BUEEP, and BSEEP ^g	AISC-358	Any Building Types	3.5	3	3	35	35	20	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	WUF-W, WFP, and BFP ^g	FEMA-350	Any Building Types	3.5	3	3	35	35	20	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	Beam to Column Connection of Rolled or Built-Up I-Shaped Sections ^{g, k}	AISC-341	Any Building Types	3.5	3	3	35	35	20	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	Moment Joint Field Connection Constructed of Bolted End Plates ^{f, k}	AISC-341	Metal Buildings	3.5	3	3	65	20	20	1	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	NP	NP	NP
	Beam to Column Connection with Other Symmetrical Shapes ^l	AISC-341	Light-Frame Construction or Miscellaneous Structures ^l	1.5	1.5	1.5	35	NL	NL	NL	0.015h_{sx}	NP	NP	0.015h_{sx}	NP	NP

FOOTNOTE:

- a. Response modification coefficient, R, for use throughout the standard. Note R reduces forces to a strength level, not an allowable stress level.
- b. Reflection amplification factor, C_d, for use in ASCE 7-05 Sections 12.8.6, 12.8.7 and 12.9.2.
- c. NL = Not Limited and NP = Not Permitted. For metric units use 30.5 m for 100 ft and use 48.8 m for 160 ft. Heights are measured from the base of the structure as defined in ASCE 7-05 Section 11.2.
- d. The tabulated value of the overstrength factor, Ω_o , is permitted to be reduced by subtracting one-half for structures with flexible diaphragms, but shall not be taken as less than 2.0 for any structure except cantilever column system.
- e. See ASCE 7-05 Section 12.2.5.5 for limitations for steel SMFs in structures assigned to Seismic Design Category D through F.
- f. See ASCE 7-05 Sections 12.2.5.6 and 12.2.5.8 for limitations for single-story steel OMFs and IMFs in structures assigned to Seismic Design Category D through F.
- g. See ASCE 7-05 Section 12.2.5.7 for limitations for steel OMFs and IMFs in structures assigned to Seismic Design Category D through E.
- h. See ASCE 7-05 Section 12.2.5.9 for limitations for steel IMFs in structures assigned to Seismic Design Category F.
- i. See ASCE 7-05 Section 12.12.1.1 for the allowable story drift for seismic force-resisting systems comprised solely of moment frames in Seismic Design Category D through F.
- j. See AISC 358-05 Table 2.1 for limitations for prequalified steel SMFs with concrete structural slabs in direct contact with the steel.
- k. The connection in this table is intended for rolled or built-up I-shaped sections (i.e., wide flange shapes).
- l. Other symmetrical shapes may include, but no limited to, channels, built-up sections (non I-shaped), and hollow structural sections (HSS).
- m. Miscellaneous structures may include, but not limited to, walkways, canopies, penthouse, stairs, towers, and other non-building structures not part of the lateral resisting system of a building.

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TABLE 3

**SUMMARY OF DESIGN COEFFICIENTS, FACTORS AND DEFORMATION FOR
STEEL MOMENT-RESISTING FRAMES SYSTEM IN SEISMIC DESIGN CATEGORY F**

LFRS	CONNECTION TYPE	STANDARD	BUILDING AND STRUCTURE TYPES	DESIGN COEFFICIENTS AND FACTORS			SEISMIC DESIGN CATEGORY Structural System Limitations and Building Height Limit ^c				OCCUPANCY CATEGORY Allowable Story Drift Limit ^{e, i}					
				R ^a	Ω_o ^d	C _d ^b	F				≤ 4 Stories			> 4 Stories		
							HT	DL	WDL	Story	I or II	III	IV	I or II	III	IV
SMF ^o	RBS, BUEEP, and BSEEP ^j	AISC-358	Any Building Types	8	3	5.5	NL	NL	NL	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	Connections Qualified by Cyclic Test	AISC-341	Any Building Types	8	3	5.5	NL	NL	NL	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
IMF	RBS, BUEEP, and BSEEP ^{g, h}	AISC-358	Any Building Types	4.5	3	4	35	35	20	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	WUF-W, WFP, and BFP ^{g, h}	FEMA-350	Any Building Types	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
	Connections Qualified by Cyclic Test ^{g, h}	AISC-341	Any Building Types	4.5	3	4	35	35	20	NL	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	Moment Joint Field Connection Constructed of Bolted End Plates ^{f, k, h}	AISC-341	Metal Buildings	4.5	3	4	65	20	20	1	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	NP	NP	NP
OMF	RBS, BUEEP, and BSEEP ^g	AISC-358	Any Building Types	3.5	3	3	35	20	20	1	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	WUF-W, WFP, and BFP ^g	FEMA-350	Any Building Types	3.5	3	3	35	20	20	1	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	Beam to Column Connection of Rolled or Built-Up I-Shaped Sections ^{g, k}	AISC-341	Any Building Types	3.5	3	3	35	20	20	1	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	0.020h _{sx}	0.015h _{sx}	0.010h _{sx}
	Moment Joint Field Connection Constructed of Bolted End Plates ^{f, k}	AISC-341	Metal Buildings	3.5	3	3	65	20	20	1	0.025h _{sx}	0.020h _{sx}	0.015h _{sx}	NP	NP	NP
	Beam to Column Connection with Other Symmetrical Shapes ^l	AISC-341	Light-Frame Construction or Miscellaneous Structures ^l	1.5	1.5	1.5	35	20	20	1	0.015h _{sx}	NP	NP	0.015h _{sx}	NP	NP

FOOTNOTE:

- a. Response modification coefficient, *R*, for use throughout the standard. Note *R* reduces forces to a strength level, not an allowable stress level.
- b. Reflection amplification factor, *C_d*, for use in ASCE 7-05 Sections 12.8.6, 12.8.7 and 12.9.2.
- c. NL = Not Limited and NP = Not Permitted. For metric units use 30.5 m for 100 ft and use 48.8 m for 160 ft. Heights are measured from the base of the structure as defined in ASCE 7-05 Section 11.2.
- d. The tabulated value of the overstrength factor, Ω_o , is permitted to be reduced by subtracting one-half for structures with flexible diaphragms, but shall not be taken as less than 2.0 for any structure except cantilever column system.
- e. See ASCE 7-05 Section 12.2.5.5 for limitations for steel SMFs in structures assigned to Seismic Design Category D through F.
- f. See ASCE 7-05 Sections 12.2.5.6 and 12.2.5.8 for limitations for single-story steel OMFs and IMFs in structures assigned to Seismic Design Category D through F.
- g. See ASCE 7-05 Section 12.2.5.7 for limitations for steel OMFs and IMFs in structures assigned to Seismic Design Category D through E.
- h. See ASCE 7-05 Section 12.2.5.9 for limitations for steel IMFs in structures assigned to Seismic Design Category F.
- i. See ASCE 7-05 Section 12.12.1.1 for the allowable story drift for seismic force-resisting systems comprised solely of moment frames in Seismic Design Category D through F.
- j. See ASCE 358-05 Table 2.1 for limitations for prequalified steel SMFs with concrete structural slabs in direct contact with the steel.
- k. The connection in this table is intended for rolled or built-up I-shaped sections (i.e., wide flange shapes).
- l. Other symmetrical shapes may include, but not limited to, channels, built-up sections (non I-shaped), and hollow structural sections (HSS).
- m. Miscellaneous structures may include, but not limited to, walkways, canopies, penthouse, stairs, towers, and other non-building structures not part of the lateral resisting system of a building.