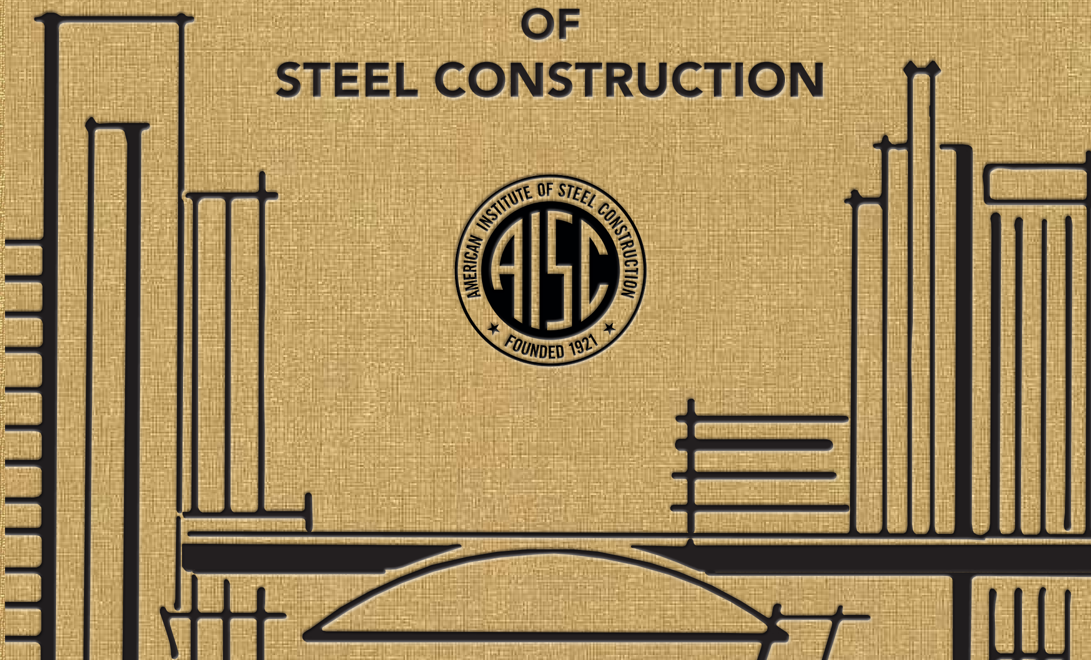
STEEL CONSTRUCTION MANUAL

AMERICAN INSTITUTE OF STEEL CONSTRUCTION



SIXTEENTH EDITION

CONTENTS

STEEL CONSTRUCTION MANUAL

AMERICAN INSTITUTE OF STEEL CONSTRUCTION

SIXTEENTH EDITION

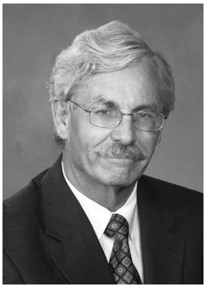
ISBN 978-1-56424-116-0

The information presented in this publication has been prepared following recognized principles of design and construction. While it is believed to be accurate, this information should not be used or relied upon for any specific application without competent professional examination and verification of its accuracy, suitability, and applicability by a licensed engineer or architect. The publication of this information is not a representation or warranty on the part of the American Institute of Steel Construction, its officers, agents, employees or committee members, or of any other person named herein, that this information is suitable for any general or particular use, or of freedom from infringement of any patent or patents. All representations or warranties, express or implied, other than as stated above, are specifically disclaimed. Anyone making use of the information presented in this publication assumes all liability arising from such use.

Caution must be exercised when relying upon standards and guidelines developed by other bodies and incorporated by reference herein since such material may be modified or amended from time to time subsequent to the printing of this edition. The American Institute of Steel Construction bears no responsibility for such material other than to refer to it and incorporate it by reference at the time of the initial publication of this edition.

Printed in the United States of America

DEDICATION



This edition of the AISC *Steel Construction Manual* is dedicated to Dr. William (Bill) A. Thornton, former Chair and long-time member of the AISC Committee on Manuals.

From 1985 until 2011, Bill served as the Chairman of the Committee on Manuals and oversaw the development of numerous Manual editions, including the First Edition LRFD *Steel Construction Manual* and the 14th Edition *Steel Construction Manual*. In addition to Bill's work as the Chair of the Committee on Manuals he authored many articles and publications on the design of steel and specifically on steel connection design. Bill led the Committee by simply being the guy who always seemed to have the answer to the question. His style was direct and relaxed and allowed the Committee to grow into what it is today. All subsequent Chairs will benefit from his leadership and build on the foundation he established.

Bill was formerly President of Cives Engineering Corporation of Roswell, Ga. where he was responsible for all structural design performed by Cives Engineering and a consultant to the seven divisions of Cives Steel Company in matters relating to quality assurance, connection design, and fabrication practices. He has nearly six decades of experience in teaching, research, consulting, and practice in the area of structural analysis and design. He is the winner of the AISC 1995 T.R. Higgins Lectureship Award, the 2003 AISC Lifetime Achievement Award, the 2004 Craftsmanship Award of the General Society of Mechanics and Tradesmen of the City of New York, and was inducted into the National Academy of Engineering in 2013. Bill has also been a longstanding member of the Research Council on Structural Connections, and in 2021 was elected as a Life Member.

All of these accolades show Bill's dedication to the industry, but Bill is best known for his groundbreaking work when he developed the uniform force method (UFM). At the time in the industry's history there was interest in having a direct method to design vertical braced frames. The UFM is now the preferred method given for determining the forces that exist at gusset interfaces. The UFM provides a standardized way to obtain economical, statically admissible force distributions for vertical bracing connections.

Historic connection design practices involved limitations that were intended to account for many simplifying assumptions and unknowns. While these practices generally worked, most engineers who used them did not know why; nor was it obvious whether the limitations were too harsh in some cases or no longer sufficient in others. Bill Thornton changed this and changed the design community and steel construction industry in the process.

Using current and historic research, he developed explanations to justify historic practices where possible, and modifications to them if not. He concatenated several seemingly different techniques of connection design using analysis and testing to show where differences in available approaches could be eliminated. He invented connection analysis and design techniques that answered the challenges for which others had accepted simplifications that required limitations. Bill Thornton's life's work has affected every connection design in a steel building today, and every engineer who designs a steel connection today uses knowledge and understanding that Bill Thornton contributed to the profession.

Bill Thornton has served our profession, our industry, and AISC so significantly and so completely that his wisdom and work changed the way steel connections are understood and designed. No connection or question was too challenging—he could always invent an understandable concept and a rational, practical approach.

FOREWORD

The American Institute of Steel Construction, founded in 1921, is the nonprofit technical standards developer and trade organization for the fabricated structural steel industry in the United States. AISC is headquartered in Chicago and has a long tradition of service to the steel construction industry providing timely and reliable information.

The continuing financial support and active participation of Members in the engineering, research, and development activities of the Institute make possible the publishing of this *Steel Construction Manual.* Those Members include the following: Full Members engaged in the fabrication, production and sale of structural steel; Associate Members, who include erectors, detailers, service consultants, software developers, and steel product manufacturers; Professional Members, who are structural or civil engineers and architects, including architectural and engineering educators; Affiliate Members, who include general contractors, building inspectors and code officials; and Student Members.

The Institute's objective is to make structural steel the material of choice, by being the leader in structural-steel-related technical and market-building activities, including specification and code development, research, education, technical assistance, quality certification, standardization, and market development.

To accomplish this objective, the Institute publishes manuals, design guides, and specifications. Best known and most widely used is the *Steel Construction Manual*, which holds a highly respected position in engineering literature. The Manual is based on the *Specification for Structural Steel Buildings* and the *Code of Standard Practice for Steel Buildings and Bridges*. Both standards are included in the Manual for easy reference.

The Institute also publishes technical information and timely articles in its *Engineering Journal*, Design Guide series, *Modern Steel Construction* magazine, and other design aids and research reports. Nearly all of the information AISC publishes is available for download from the AISC web site at **www.aisc.org**.

PREFACE

This edition commemorates the 100 year anniversary of AISC. This Manual is the 16th Edition of the AISC *Steel Construction Manual*, which was first published in 1927. It replaces the 15th Edition *Manual* originally published in 2017.

The following specifications, codes, and standards are printed in Part 16 of this Manual:

- 2022 AISC *Specification for Structural Steel Buildings*
- 2020 RCSC *Specification for Structural Joints Using High-Strength Bolts*
- 2022 AISC *Code of Standard Practice for Steel Buildings and Bridges*

The following resources supplement the Manual and are available on the AISC web site at **www.aisc.org:**

- AISC *Companion to the AISC Steel Construction Manual* consists of *Volume 1: Design Examples*, which includes design examples that illustrate the application of tables and specification provisions that are included in this Manual, and *Volume 2: Design Tables*, which provides supplementary design tables.
- AISC *Shapes Database V16.0* and the *Historic Shapes Database V16.0H*.
- Background and supporting literature (references) for the Commentary to the AISC *Specification for Structural Steel Buildings* and the AISC *Steel Construction Manual.*

The following major changes and improvements have been made in this edition:

- All tabular information and discussions are updated to comply with the 2022 *Specification for Structural Buildings*, and the standards and other documents referenced therein.
- All tabular information formerly given for 36 ksi material is now provided for 50 ksi or greater material strength for both members and connecting elements.
- Guidance on interpolation within design tables is provided in Part 2 and throughout.
- Shape information is updated to ASTM A6/A6M-19 throughout this Manual.
- A total of 210 new HSS sizes have been added to the Part 1 Dimension and Properties tables reflecting the sizes produced.
- Added new sections on galvanic corrosion in Part 2.
- Solutions for first-order and second-order analyses of two common beam-columns are provided in Part 6.
- Part 8 includes discussion of phased array ultrasonic testing.
- The discussion of the plastic method in Part 8 used as one alternative for designing eccentrically loaded weld groups has been revised and expanded for clarification.
- Part 9 includes a new table of plastic section moduli for coped W-shapes.
- A new section, Biaxial Stresses on Connection Elements, has been incorporated into Part 9.
- The Prying Action discussion in Part 9 has been revised and expanded.
- The procedure used in Tables 10-2 and 10-3 for determining the available weld strength for double-angle connections welded to the supporting member has been changed from the elastic method to the instantaneous center of rotation method.
- Three new design tables are incorporated into Part 10 for determining the available strength of all-bolted double-angle connections.

- Three new design tables are incorporated into Part 10 for determining the available strength of single-plate connections.
- Three new design tables are incorporated into Part 10 for determining the available strength of bolted/welded single-angle connections.
- Three new design tables are incorporated into Part 10 for determining the available strength of bolted/welded shear end-plate connections.
- The information on fully restrained moment connections formerly in Part 12 has been incorporated into Part 11, Design of Moment Connections, and new discussion on Design of Connections Subject to Combined Forces now appears in Part 12.
- A new Special Case 4, Single-Plate-to-Column Web Connection, has been added to the uniform force method discussion in Part 13.
- A new Part 12, Design of Simple Connections for Combined Forces, has been added.
- Part 13 incorporates a new discussion of a design consideration called, “The Chevron Effect,” that may be important for some braced frames.
- Part 13 includes new guidance and a design table for wrap-around gusset plates.
- The discussion on crane rail connections has been updated in Part 15.
- The tabulated information in Part 15 on clevises, turnbuckles, sleeve nuts, recessed-pin nuts, and cotter pins has been removed and the user is referred to the manufacturer.

In addition, many other improvements have been made throughout this Manual.

By the AISC Committee on Manuals,

Mark V. Holland, Chair
William P. Jacobs V, Vice-Chair
Allen Adams
Abbas Aminmansour
Craig J. Archacki
Harry Cole, Emeritus
Brad Davis
Bo Dowswell
Matthew Eatherton
Marshall T. Ferrell, Emeritus
Erica Fischer
Timothy P. Fraser
Louis F. Geschwindner, Emeritus
Christopher Hewitt
Benjamin Kaan
Michael Kempfert
Lawrence F. Kruth
Conner R. Maines
Ronald L. Meng
Thomas M. Murray, Emeritus
James Neary
Kimberly Olson
Davis G. Parsons II, Emeritus
Gian Rassati
Daniel Rocha
John Rolfes
Rafael Sabelli
Brandt Saxey
Thomas J. Schlafly
Clifford W. Schwinger
Victor Shneur
Justin Sikorski
William A. Thornton, Emeritus
Gary C. Violette, Emeritus and Former Vice-Chair
Brian Volpe
Michael A. West, Emeritus
Ronald G. Yeager
Cynthia J. Duncan, Secretary

The committee gratefully acknowledges the contributions made to this Manual by Patrick J. Fortney and William T. Segui who passed away during this cycle, as well as the AISC Committee on Specifications, and the following individuals: Eric Bolin, Mike Gannon, Carlo Lini, Keith Grubb, and Matt Smith and Duff Zimmerman, who both provided AISC Board Oversight.

SCOPE

The 16th Ed. AISC *Steel Construction Manual* is based on the 2022 AISC *Specification for Structural Steel Buildings* (AISC, 2022a), which is printed in Part 16 of the Manual. The AISC *Specification* requirements and other design recommendations and considerations summarized in this Manual apply in general to the design and construction of steel buildings and other structures. Other structures are defined as structures designed, fabricated, and erected in a manner similar to buildings, with building-like vertical and lateral load-resisting elements.

The design recommendations and guidelines in this Manual are intended to demonstrate an approach to the design and are not intended to suggest that the approach presented is the only approach. The committee responsible for the development of the Manual recognizes that designers have alternate approaches that work best for them and their projects. Design approaches that differ from those presented are considered viable as long as they have been prepared following recognized principles of design and construction, follow sound engineering principles, and the AISC *Specification* and project specific requirements are satisfied.

The design of seismic force-resisting systems also must meet the requirements in the AISC *Seismic Provisions for Structural Steel Buildings* (AISC, 2022b), except in the following cases for which use of the AISC *Seismic Provisions* is not required:

- Buildings and other structures in seismic design category (SDC) A
- Buildings and other structures in SDC B or C with $R = 3$ systems [steel systems not specifically detailed for seismic resistance per ASCE/SEI 7, Table 12.2-1 (ASCE, 2022)]
- Nonbuilding structures similar to buildings: braced frame systems with $R = 1\frac{1}{2}$ or moment-frame systems with $R = 1$ (see ASCE/SEI 7, Table 15.4-1)
- Nonbuilding structures not similar to buildings (see ASCE/SEI 7, Table 15.4-2), which are designed to meet the requirements in other standards entirely

Conversely, use of the AISC *Seismic Provisions* is required in the following cases:

- Buildings and other structures in SDC B or C when one of the exemptions for steel seismic force-resisting systems above does not apply
- Buildings and other structures in SDC B or C that use composite seismic force-resisting systems (those containing composite steel-and-concrete members and those composed of steel members in combination with reinforced concrete members)
- Buildings in SDC D, E, or F
- Nonbuilding structures in SDC D, E, or F, when the exemption above does not apply

The AISC *Seismic Design Manual* (AISC, 2018) provides guidance on the use of the AISC *Seismic Provisions*.

The Manual includes tables to aid in the design of members and connections. Tables in the Manual that present available strengths are developed using the geometric conditions indicated and the applicable limit states from the AISC *Specification.* Given the nature of the tables, and the possible governing limit state for each table value, linear interpolation between tabulated values may or may not provide correct strengths. Member design tables in Parts 3, 4, and 5 include member sizes that have been historically used for the type of loading applied; note that there may be other sizes that are appropriate.

The Manual consists of eighteen parts addressing various topics related to steel building design and construction. Part 1 provides the dimensions and properties for structural products commonly used. For proper material specifications for these products, as well as general specification requirements and other design considerations, see Part 2. For the design of members, see Parts 3 through 6. For the design of connections, see Parts 7 through 15. For Specifications and Codes, see Part 16. For other miscellaneous information, see Part 17. For a list of symbols and the index, see Part 18.

REFERENCE

AISC (2018), *Seismic Design Manual*, 3rd Ed., American Institute of Steel Construction, Chicago, III.

AISC (2022a), *Specification for Structural Steel Buildings*, ANSI/AISC 360-22, American Institute of Steel Construction, Chicago, Ill.

AISC (2022b), *Seismic Provisions for Structural Steel Buildings*, ANSI/AISC 341-22, American Institute of Steel Construction, Chicago, Ill.

ASCE (2022), *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, ASCE/SEI 7-22, American Society of Civil Engineers, Reston, Va.

PART 1

DIMENSIONS AND PROPERTIES

SCOPE

The dimensions and properties for structural products commonly used in steel building design and construction are given in this Part. Although the dimensions and properties tabulated in Part 1 reflect "commonly" used structural products, some of the shapes listed are not commonly produced or stocked. These shapes are usually only produced to order and will likely be subject to mill production schedules and minimum order quantities. For availability of shapes, go to **www.aisc.org**. For torsional and flexural-torsional properties of rolled shapes, see AISC Design Guide 9, *Torsional Analysis of Structural Steel Members* (Seaburg and Carter, 1997). For surface areas, box perimeters and areas, *W*/*D* ratios, and *A*/*D* ratios, see AISC Design Guide 19, *Fire Resistance of Structural Steel Framing* (Ruddy et al., 2003).

STRUCTURAL PRODUCTS

W-, M-, S-, and HP-Shapes

Four types of H-shaped (or I-shaped) members are covered in this Manual:

- W-shapes, which have essentially parallel inner and outer flange surfaces.
- M-shapes, which are H-shaped members that are not classified in ASTM A6/A6M as W-, S-, or HP-shapes. M-shapes may have a sloped inside flange face or other cross-section features that do not meet the criteria for W-, S-, or HP-shapes.
- S-shapes (also known as American standard beams), which have a slope of approximately 16⅔% (2 on 12) on the inner flange surfaces.
- HP-shapes (also known as bearing piles), which are similar to W-shapes except their webs and flanges are of equal thickness, and the depth and flange width are nominally equal for a given designation.

These shapes are designated by the mark W, M, S, or HP, nominal depth (in.), and nominal weight (lb/ft). For example, a W24×55 is a W-shape that is nominally 24 in. deep and weighs 55 lb/ft.

The following dimensional and property information is given in this Manual for the W-, M-, S-, and HP-shapes covered in ASTM A6/A6M:

- Design dimensions, detailing dimensions, axial properties, flexural properties, and torsional properties are given in Tables 1-1, 1-2, 1-3, and 1-4 for W-, M-, S-, and HP-shapes, respectively.
- S.I.-equivalent designations are given in Table 17-1 for W-shapes and in Table 17-2 for M-, S-, and HP-shapes.

Tabulated decimal values are appropriate for use in design calculations, whereas fractional values are appropriate for use in detailing. All decimal and fractional values are similar with one exception: Because of the variation in fillet sizes used in shape production, the decimal value, k_{des}, is conservatively presented based on the smallest fillet used in production, and the fractional value, k_{det}, is conservatively presented based on the largest fillet used in production. For the definitions of the tabulated variables, refer to the Symbols list in Part 18.

When appropriate, this Manual presents tabulated values for the workable gage of a section. The term workable gage refers to the gage for fasteners in the flange that provides for entering and tightening clearances, edge distance, and spacing requirements. When the listed value is footnoted, the actual size, combination, and orientation of fastener components should be compared with the geometry of the cross section to ensure compatibility. Other gages that provide for entering and tightening clearances, edge distance, and spacing requirements can also be used. In Table 1-1, for the shapes W14×145 through W14×873, the Workable Gage column contains either 3-7½-3 or 3-8½-3, whereas for the remainder of the tabulated shapes, only a single dimension is given. For these shapes, the three dimensions provide the workable dimension for a row of four holes across the flange. For example, a workable gage of 3-7½-3 indicates that the workable gage for the inner holes is 7½ in., and the workable gage between the inner and outer holes is 3 in.

Channels

Two types of channels are covered in this Manual:

- C-shapes (also known as American standard channels), which have a slope of approximately 16⅔% (2 on 12) on the inner flange surfaces.
- MC-shapes (also known as miscellaneous channels), which have a slope other than 16⅔% (2 on 12) on the inner flange surfaces.

These shapes are designated by the mark C or MC, nominal depth (in.), and nominal weight (lb/ft). For example, a C12×25 is a C-shape that is nominally 12 in. deep and weighs 25 lb/ft.

The following dimensional and property information is given in this Manual for the channels covered in ASTM A6/A6M:

- Design dimensions, detailing dimensions, and axial, flexural, and torsional properties are given in Tables 1-5 and 1-6 for C- and MC-shapes, respectively.
- S.I.-equivalent designations are given in Table 17-3.

The workable gage values are measured from the heel of the channel flange. For the definitions of the tabulated variables, refer to the Symbols list in Part 18.

Angles

Angles (also known as L-shapes) have legs of equal thickness and either equal or unequal leg sizes. Angles are designated by the mark L, leg sizes (in.), and thickness (in.). For example, an L4×3×½ is an angle with one 4 in. leg, one 3 in. leg, and ½ in. thickness.

The following dimensional and property information is given in this Manual for the angles covered in ASTM A6/A6M:

- Design dimensions, detailing dimensions, and axial, flexural, and flexural-torsional properties are given in Table 1-7. The effects of leg-to-leg and toe fillet radii have been considered in the determination of these section properties. The *S* value that is given for the *Z-Z* axis in Table 1-7 is based on the largest perpendicular distance measured from the *Z-Z* axis to the center of the thickness at the tip of the angle toe(s) or heel. Additional properties of single angles are provided in the electronic shapes database available at **www.aisc.org/manualresources**. These properties are used for calculations involving *Z-Z* and *W-W* principal axes. For unequal leg angles, the database includes *I*, and values of *S* at the toe of the short leg, the heel, and the toe of the long leg for the *Z-Z* and *W-W* principal axes. For equal leg angles, the database includes *I*, and values of *S* at the toe of the leg and the heel for *Z-Z* and *W-W* principal axes.

- Workable gages in angle legs are tabulated in Table 1-7A.
- Width-to-thickness criteria for angles are tabulated in Table 1-7B.
- S.I.-equivalent designations are given in Table 17-4.

For the definitions of the tabulated variables, refer to the Symbols list in Part 18.

Structural Tees (WT-, MT-, and ST-Shapes)

Three types of structural tees are covered in this Manual:

- WT-shapes, which are made from W-shapes
- MT-shapes, which are made from M-shapes
- ST-shapes, which are made from S-shapes

These shapes are designated by the mark WT, MT, or ST, nominal depth (in.), and nominal weight (lb/ft). WT-, MT-, and ST-shapes are split (sheared or thermal-cut) from W-, M-, and S-shapes, respectively, and have half the nominal depth and weight of that shape. The kerf that results from splitting is not directly accounted for in the cut shapes. In Table 1-8, 1-9, and 1-10, the kerf is accounted for by rounding down the detailing depths to the nearest ⅛ in. without additional adjustments due to half the kerf dimension. For example, a WT12×27.5 is a structural tee split from a W-shape (W24×55), is nominally 12 in. deep, and weighs 27.5 lb/ft. Although off-center splitting or splitting on two lines can be obtained by special order, the resulting nonstandard shape is not covered in this Manual.

The following dimensional and property information is given in this Manual for the structural tees cut from the W-, M-, and S-shapes covered in ASTM A6/A6M:

- Design dimensions, detailing dimensions, and axial, flexural, and torsional properties are given in Tables 1-8, 1-9, and 1-10 for WT-, MT-, and ST-shapes, respectively.
- S.I.-equivalent designations are given in Table 17-5 for WT-shapes and in Table 17-6 for MT- and ST-shapes.

For the definitions of the tabulated variables, refer to the Symbols list in Part 18.

Hollow Structural Sections (HSS)

Three types of HSS are covered in this Manual:

- Rectangular HSS, which have an essentially rectangular cross section, except for rounded corners, and uniform wall thickness, except at the weld seam(s)
- Square HSS, which have an essentially square cross section, except for rounded corners, and uniform wall thickness, except at the weld seam(s)
- Round HSS, which have an essentially round cross section and uniform wall thickness, except at the weld seam(s)

In each case, ASTM A500/A500M covers electric-resistance-welded (ERW) HSS and seamless HSS with a maximum periphery of 88 in. The coverage of HSS in this Manual is similarly limited.

Rectangular and square HSS are designated by the mark HSS, overall outside dimensions (in.), and wall thickness (in.), with all dimensions expressed as fractional numbers. For example, an HSS10×10×½ is nominally 10 in. by 10 in. with a ½ in. wall thickness. Round HSS are designated by the term HSS, nominal outside diameter (in.), and wall thickness (in.) with both dimensions expressed to three decimal places. For example, an HSS10.000×0.500 is nominally 10 in. in diameter with a ½ in. nominal wall thickness.

Per AISC *Specification* Section B4.2, the wall thickness used in design, t_{des}, is taken as 0.93 times the nominal wall thickness for HSS conforming to ASTM A500/A500M. The rationale for this requirement is explained in the corresponding AISC *Specification* Commentary Section B4.2.

In calculating the b/t and h/t ratios in Tables 1-11 and 1-12, each outside corner radius is taken as $1.5t_{des}$ for rectangular and square HSS. This is in conformity with AISC *Specification* Section B4.1b(d). In Table 1-11, b is the lesser value, and h is the greater value of the outside dimensions. When using AISC *Specification* Table B4.1a, Case 6, with Table 1-11, b/t should be taken from the h/t column in the table. In other tabulated properties, each corner radius is taken as $2t_{des}$. In the tabulated workable flat dimensions of rectangular (and square) HSS, the outside corner radii are taken as $2.25t_{nom}$. The term workable flat refers to a reasonable flat width or depth of material for use in making connections to HSS. The workable flat dimension is provided as a reflection of current industry practice, although the tolerances of ASTM A500/A500M allow a greater maximum corner radius of $3t_{nom}$.

The following dimensional and property information is given in this Manual for the HSS covered in ASTM A500/A500M, ASTM A501/A501M, ASTM A618/A618M, or ASTM A847/A847M:

- Design dimensions, detailing dimensions, axial properties, flexural properties, torsional properties, and flexural-torsional properties are given in Tables 1-11 and 1-12 for rectangular and square HSS, respectively.
- Design dimensions, detailing dimensions, and axial, flexural, and torsional properties are given in Table 1-13 for round HSS.
- S.I.-equivalent designations are given in Tables 17-7, 17-8, and 17-9, for rectangular, square, and round HSS, respectively.
- Width-to-thickness criteria of rectangular and square HSS are given in Table 1-12A.

AISC *Specification* Chapter A references ASTM A1065/A1065M and ASTM A1085/A1085M for HSS. These specifications differ from the other current specifications for HSS in the controls on thickness and corner radii. Both specifications control wall thickness such that the geometrical properties can be determined based on the nominal wall thickness, t_{nom}. Dimensions and properties for ASTM A1085/A1085M are available at **www.aisc.org/manualresources**. Dimensions and properties for ASTM A1065/1065M are available from the Steel Tube Institute (STI, 2015). ASTM A1065/A1065M retains the upper limit on the corner radius of $3t_{nom}$, as required in ASTM A500/A500M. ASTM A1085/A1085M limits corner radius to a lower and upper limit, depending on nominal wall thickness, as follows:

$$t_{nom} \leq 0.400 \text{ in.} \quad R_{min} = 1.6t_{nom},\ R_{max} = 3t_{nom}$$
$$t_{nom} > 0.400 \text{ in.} \quad R_{min} = 1.8t_{nom},\ R_{max} = 3t_{nom}$$

As was the case previously, due to production variations within specified limits for rectangular (and square) HSS, it is necessary to establish a basis for the calculation of properties affected by the corner radius dimension. The same radii that are used in the Part 1 tables are recommended for the properties of shapes produced to ASTM A1065/A1065M and ASTM A1085/A1085M:

- *b*/*t* and *h*/*t* calculated using a corner radius of $1.5t_{nom}$ per AISC *Specification* Sections B4.1b(d) and B4.2 for HSS produced to ASTM A1065/A1065M and ASTM A1085/A1085M
- Other tabulated properties are calculated using $2t_{nom}$
- Workable flat dimensions are calculated using $2.25t_{nom}$

For the definitions of the tabulated variables, refer to the Symbols list in Part 18.

Pipes

Pipes have an essentially round cross section and uniform thickness, except at the weld seam(s) for welded pipe.

Pipes up to and including nominal pipe size (NPS) 26 are designated by the term Pipe, nominal diameter (in.), and weight class (Std., x-Strong, xx-Strong). NPS stands for nominal pipe size. For example, Pipe 5 Std. denotes a pipe with a 5 in. nominal diameter and a 0.258 in. wall thickness, which corresponds to the standard weight series. Physical properties for these three weight classes are tabulated in the manual. Pipes with wall thicknesses that do not correspond to the foregoing weight classes are designated by the term Pipe, outside diameter (in.), and wall thickness (in.), with both expressed to three decimal places. For example, Pipe 14.000×0.375 and Pipe 5.563×0.500 are proper designations. Physical properties for pipes other than those in the three tabulated weight classes must be obtained from the manufacturer.

Per AISC *Specification* Section B4.2, the wall thickness used in design, t_{des}, is taken as 0.93 times the nominal wall thickness, t_{nom}. The rationale for this requirement is explained in the corresponding AISC *Specification* Commentary Section B4.2.

The following dimensional and property information is given in this Manual for the pipes covered in ASTM A53/A53M:

- Design dimensions, detailing dimensions, and axial, flexural, and torsional properties are given in Table 1-14.
- S.I.-equivalent designations are given in Table 17-9.

For the definitions of the tabulated variables, refer to the Symbols list in Part 18.

Double Angles

Double angles (also known as 2L-shapes) are made with two angles that are interconnected through their back-to-back legs along the length of the member, either in contact for the full length or separated by spacers at the points of interconnection.

These shapes are designated by the mark 2L, the sizes and thickness of their legs (in.), and their orientation when the angle legs are not of equal size (LLBB or SLBB)[1]. For example, a 2L4×3×½ LLBB has two angles with one 4 in. leg and one 3 in. leg, and the 4 in. legs are back-to-back; a 2L4×3×½ SLBB is similar, except the 3 in. legs are back-to-back. In both cases, the legs are ½ in. thick.

[1] LLBB stands for long legs back-to-back. SLBB stands for short legs back-to-back. Alternatively, the orientations LLV and SLV, which stand for long legs vertical and short legs vertical, respectively, can be used.

The following dimensional and property information is given in this Manual for the double angles built-up from the angles covered in ASTM A6/A6M:

- Design dimensions, detailing dimensions, and flexural-torsional properties are given in Table 1-15 for equal-leg, LLBB, and SLBB angles. For angle legs 8 in. or less, angle separations of zero in., ⅜ in., and ¾ in. are covered. For longer angle legs, angle separations of zero, ¾ in., and 1½ in. are covered. The effects of leg-to-leg and toe fillet radii have been considered in the determination of these section properties. For workable gages in legs of angles, see Table 1-7A.

For the definitions of the tabulated variables, refer to the Symbols list in Part 18.

Double Channels

Double channels (also known as 2C- and 2MC-shapes) are made with two channels that are interconnected through their back-to-back webs along the length of the member, either in contact for the full length or separated by spacers at the points of interconnection.

These shapes are designated by the mark 2C or 2MC, nominal depth (in.), and nominal weight per channel (lb/ft). For example, a 2C12×25 is a double channel that consists of two channels that are each nominally 12 in. deep, and each weigh 25 lb/ft.

The following dimensional and property information is given in this Manual for the double channels built-up from the channels covered in ASTM A6/A6M:

- Design dimensions, detailing dimensions, and weak- axis flexural properties are given in Tables 1-16 and 1-17 for 2C- and 2MC-shapes, respectively. In each case, channel separations of zero, ⅜ in., and ¾ in. are covered.

For the definitions of the tabulated variables, refer to the Symbols list in Part 18.

W-Shapes and S-Shapes with Cap Channels

Common combined sections made with W- or S-shapes and channels (C- or MC-shapes) are tabulated in this Manual. In either case, the channel web is interconnected to the W-shape or S-shape top flange, respectively, with the flange toes down. The interconnection of the two elements must be designed for the horizontal shear, q, where

$$q = \frac{VQ}{I} \tag{1-1}$$

where

I = moment of inertia of the combined cross section, in.^{4}
Q = first moment of the channel area about the neutral axis of the combined cross section, in.^{3}
V = vertical shear, kips
q = horizontal shear, kip/in.

The effects of other forces, such as crane horizontal and lateral forces, may also require consideration, when applicable.

The following dimensional and property information is given in this Manual for combined sections built-up from the W-shapes, S-shapes, and cap channels covered in ASTM A6/A6M:

- Design dimensions, detailing dimensions, and axial, strong-axis flexural, and weak-axis flexural properties of W-shapes with cap channels are given in Table 1-19.
- Design dimensions, detailing dimensions, and axial, strong-axis flexural, and weak-axis flexural properties of S-shapes with cap channels are given in Table 1-20.

For the definitions of the tabulated variables, refer to the Symbols list in Part 18.

Plate and Bar Products

Plate products may be ordered as sheet, strip, or bar material. Sheet and strip are distinguished from structural bars and plates by their dimensional characteristics, as outlined in Table 2-3 and Table 2-5.

The historical classification system for structural bars and plates suggests that there is only a physical difference between them based upon size and production procedure. In raw form, flat stock has historically been classified as a bar if it is less than or equal to 8 in. wide and as a plate if it is greater than 8 in. wide. Bars are rolled between horizontal and vertical rolls and trimmed to length by shearing or thermal cutting on the ends only. Plates are generally produced using one of two methods:

1. Sheared plates are rolled between horizontal rolls and trimmed to width and length by shearing or thermal cutting on the edges and ends; or
2. Stripped plates are sheared or thermal cut from wider sheared plates.

There is very little, if any, structural difference between plates and bars. Consequently, the term plate is becoming a universally applied term today, and a PL½×4½×1 ft 3 in., for example, might be fabricated from plate or bar stock.

For structural plates, the preferred practice is to specify thickness in 1⁄16 in. increments up to ⅜ in. thickness, ⅛ in. increments over ⅜ in. to 1 in. thickness, and ¼ in. increments over 1 in. thickness. The current extreme width for sheared plates is 200 in. Because mill practice regarding plate widths vary, individual mills should be consulted to determine preferences.

For bars, the preferred practice for squares and rectangles is to specify width in ¼ in. increments, and thickness in ⅛ in. increments, for rounds, diameter in ⅛ in. increments.

Raised-Pattern Floor Plates

Weights of raised-pattern floor plates are given in Table 1-18. Raised-pattern floor plates are commonly available in widths up to 120 in. For larger plate widths, see literature available from floor plate producers.

Crane Rails

Although crane rails are not listed as structural steel in the AISC *Code of Standard Practice* Section 2.1, this information is provided because some fabricators may choose to provide crane rails. Crane rails are designated by unit weight in lb/yard. Dimensions and properties for a representative sample of commonly used crane rail profiles are given in Table 1-21. Crane rails can be either heat treated or end hardened to reduce wear. For additional information or for profiles and properties of crane rails not listed, manufacturer's catalogs should be consulted. For crane-rail connections, see Part 15.

Other Structural Products

The following other structural products are covered in this Manual as indicated:

- High-strength bolts, common bolts, washers, nuts, and direct-tension-indicator washers are covered in Part 7.
- Welding filler metals and fluxes are covered in Part 8.
- Anchor rods and threaded rods are covered in Part 14.

STANDARD MILL PRACTICES

The production of structural products is subject to unavoidable variations relative to the theoretical dimensions and profiles, due to many factors, including roll wear, roll dressing practices, and temperature effects. Such variations are limited by the dimensional and profile tolerances as summarized below.

Hot-Rolled Structural Shapes

Acceptable dimensional tolerances for hot-rolled structural shapes (W-, M-, S-, and HP-shapes), channels (C- and MC-shapes), structural split tees (WT, MT, and ST-shapes), and angles are given in ASTM A6/A6M, Section 12, and summarized in Tables 1-22 through 1-26. Supplementary information, including permissible variations for sheet and strip and for other grades of steel, can also be found in literature from steel plate producers and the Association for Iron and Steel Technology.

Hollow Structural Sections

Acceptable dimensional tolerances for HSS are given in ASTM A500/A500M, Section 11, ASTM A501/A501M, Section 12, ASTM A618/A618M, Section 8, ASTM A847/A847M, Section 10, ASTM A1065/A1065M, Section 8, or ASTM A1085/A1085M, Section 12, as applicable, and summarized in Tables 1-27 and 1-28, for rectangular and square, and round HSS, respectively. Supplementary information can also be found in literature from HSS producers and the Steel Tube Institute.

Pipes

Acceptable dimensional tolerances for pipes are given in ASTM A53/A53M, Section 10, and summarized in Table 1-28. Supplementary information can also be found in literature from pipe producers.

Plate Products

Acceptable dimensional tolerances for plate products are given in ASTM A6/A6M, Section 12, and summarized in Table 1-29. Note that plate thickness can be specified in inches or by weight per square foot, and separate tolerances apply to each method. No decimal edge thickness can be assured for plate specified by the latter method. Supplementary information, including permissible variations for sheet and strip, and for other grades of steel, can also be found in literature from steel plate producers and the Association of Iron and Steel Technology.

PART 1 REFERENCES

Ruddy, J.L., Marlo, J.P., Ioannides, S.A., and Alfawakhiri, F. (2003), *Fire Resistance of Structural Steel Framing*, Design Guide 19, AISC, Chicago, Ill.

Seaburg, P.A. and Carter, C.J. (1997), *Torsional Analysis of Structural Steel Members*, Design Guide 9, AISC, Chicago, Ill.

STI (2015), *HSS Design Manual, Volume One: Section Properties & Design Information*, Steel Tube Institute, Glenview, Ill.

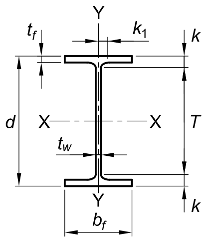
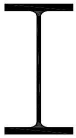


Table 1-1
W-Shapes
Dimensions

Shape	Area, A	Depth, d		Web Thickness, t_w		Web $\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		Distance k k_{des}	Distance k k_{det}	Distance k_1	Distance T	Distance Workable Gage
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W44×408[h]	120	44.8	44 3/4	1.22	1 1/4	5/8	16.1	16 1/8	2.17	2 3/16	2.96	3 3/8	1 13/16	38	3-5 1/2-3
×368	108	44.4	44 3/8	1.10	1 1/8	9/16	16.0	16	1.97	2	2.76	3 3/16	1 3/4		
×335[c]	98.5	44.0	44	1.03	1	1/2	15.9	16	1.77	1 3/4	2.56	3	1 3/4		
×290[c]	85.4	43.6	43 5/8	0.865	7/8	7/16	15.8	15 7/8	1.58	1 9/16	2.36	2 13/16	1 5/8		
×262[c]	77.2	43.3	43 1/4	0.785	13/16	7/16	15.8	15 3/4	1.42	1 7/16	2.20	2 5/8	1 5/8		
×230[c],[v]	67.8	42.9	42 7/8	0.710	11/16	3/8	15.8	15 3/4	1.22	1 1/4	2.01	2 7/16	1 9/16	↓	↓
W40×655[h]	193	43.6	43 5/8	1.97	2	1	16.9	16 7/8	3.54	3 9/16	4.72	4 13/16	2 3/16	34	3-7 1/2-3
×593[h]	174	43.0	43	1.79	1 13/16	15/16	16.7	16 3/4	3.23	3 1/4	4.41	4 1/2	2 1/8		
×503[h]	148	42.1	42	1.54	1 9/16	13/16	16.4	16 3/8	2.76	2 3/4	3.94	4	2		
×431[h]	127	41.3	41 1/4	1.34	1 5/16	11/16	16.2	16 1/4	2.36	2 3/8	3.54	3 5/8	1 7/8		
×397[h]	117	41.0	41	1.22	1 1/4	5/8	16.1	16 1/8	2.20	2 3/16	3.38	3 1/2	1 13/16		
×372[h]	110	40.6	40 5/8	1.16	1 3/16	5/8	16.1	16 1/8	2.05	2 1/16	3.23	3 5/16	1 13/16		
×362[h]	106	40.6	40 1/2	1.12	1 1/8	9/16	16.0	16	2.01	2	3.19	3 1/4	1 3/4		
×324	95.3	40.2	40 1/8	1.00	1	1/2	15.9	15 7/8	1.81	1 13/16	2.99	3 1/16	1 11/16		
×297[c]	87.3	39.8	39 7/8	0.930	15/16	1/2	15.8	15 7/8	1.65	1 5/8	2.83	2 15/16	1 11/16		
×277[c]	81.5	39.7	39 3/4	0.830	13/16	7/16	15.8	15 7/8	1.58	1 9/16	2.76	2 7/8	1 5/8		
×249[c]	73.5	39.4	39 3/8	0.750	3/4	3/8	15.8	15 3/4	1.42	1 7/16	2.60	2 11/16	1 9/16		
×215[c]	63.5	39.0	39	0.650	5/8	5/16	15.8	15 3/4	1.22	1 1/4	2.40	2 1/2	1 9/16		
×199[c]	58.8	38.7	38 5/8	0.650	5/8	5/16	15.8	15 3/4	1.07	1 1/16	2.25	2 5/16	1 9/16	↓	↓
W40×392[h]	116	41.6	41 5/8	1.42	1 7/16	3/4	12.4	12 3/8	2.52	2 1/2	3.70	3 13/16	1 15/16	34	7 1/2
×331[h]	97.7	40.8	40 3/4	1.22	1 1/4	5/8	12.2	12 1/8	2.13	2 1/8	3.31	3 3/8	1 13/16		
×327[h]	95.9	40.8	40 3/4	1.18	1 3/16	5/8	12.1	12 1/8	2.13	2 1/8	3.31	3 3/8	1 13/16		
×294	86.2	40.4	40 3/8	1.06	1 1/16	9/16	12.0	12	1.93	1 15/16	3.11	3 3/16	1 3/4		
×278	82.3	40.2	40 1/8	1.03	1	1/2	12.0	12	1.81	1 13/16	2.99	3 1/16	1 3/4		
×264	77.4	40.0	40	0.960	15/16	1/2	11.9	11 7/8	1.73	1 3/4	2.91	3	1 11/16		
×235[c]	69.1	39.7	39 3/4	0.830	13/16	7/16	11.9	11 7/8	1.58	1 9/16	2.76	2 7/8	1 5/8		
×211[c]	62.1	39.4	39 3/8	0.750	3/4	3/8	11.8	11 3/4	1.42	1 7/16	2.60	2 11/16	1 9/16		
×183[c]	53.3	39.0	39	0.650	5/8	5/16	11.8	11 3/4	1.20	1 3/16	2.38	2 1/2	1 9/16		
×167[c]	49.3	38.6	38 5/8	0.650	5/8	5/16	11.8	11 3/4	1.03	1	2.21	2 5/16	1 9/16		
×149[c],[v]	43.8	38.2	38 1/4	0.630	5/8	5/16	11.8	11 3/4	0.830	13/16	2.01	2 1/8	1 1/2	↓	↓

[c] Shape is slender for compression with $F_y = 50$ ksi.
[h] Flange thickness is greater than 2 in. Special requirements may apply per AISC *Specification* Section A3.1d.
[v] Shape does not meet the h/t_w limit for shear in AISC *Specification* Section G2.1(a) with $F_y = 50$ ksi.

Table 1-1 (continued)
W-Shapes
Properties



W44–W40

Nominal Wt.	Compact Section Criteria		Axis X-X				Axis Y-Y				r_{ts}	h_o	Torsional Properties	
	$\frac{b_f}{2t_f}$	$\frac{h}{t_w}$	I	S	r	Z	I	S	r	Z			J	C_w
lb/ft			in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.^{3}	in.	in.	in.^{4}	in.^{6}
408	3.71	31.9	38700	1730	18.0	2000	1520	189	3.56	297	4.33	42.6	134	691000
368	4.06	35.4	34700	1560	17.9	1800	1350	169	3.54	265	4.28	42.4	100	608000
335	4.50	38.0	31100	1410	17.8	1620	1200	150	3.49	236	4.24	42.2	74.7	535000
290	5.02	45.0	27000	1240	17.8	1410	1040	132	3.49	205	4.20	42.0	50.9	461000
262	5.57	49.6	24100	1110	17.7	1270	923	117	3.47	182	4.17	41.9	37.3	405000
230	6.45	54.8	20800	971	17.5	1100	796	101	3.43	157	4.13	41.7	24.9	346000
655	2.39	17.3	56500	2590	17.1	3080	2870	340	3.86	542	4.71	40.1	589	1150000
593	2.58	19.1	50400	2340	17.0	2760	2520	302	3.80	481	4.63	39.8	445	997000
503	2.98	22.3	41600	1980	16.8	2320	2040	249	3.72	394	4.50	39.3	277	789000
431	3.44	25.5	34800	1690	16.6	1960	1690	208	3.65	328	4.41	38.9	177	638000
397	3.66	28.0	32000	1560	16.6	1800	1540	191	3.64	300	4.38	38.8	142	579000
372	3.93	29.5	29600	1460	16.5	1680	1420	177	3.60	277	4.33	38.6	116	528000
362	3.99	30.5	28900	1420	16.5	1640	1380	173	3.60	270	4.33	38.6	109	513000
324	4.40	34.2	25600	1280	16.4	1460	1220	153	3.58	239	4.27	38.4	79.4	448000
297	4.80	36.8	23200	1170	16.3	1330	1090	138	3.54	215	4.22	38.2	61.2	399000
277	5.03	41.2	21900	1100	16.4	1250	1040	132	3.58	204	4.25	38.1	51.5	379000
249	5.55	45.6	19600	993	16.3	1120	926	118	3.55	182	4.21	38.0	38.1	334000
215	6.45	52.6	16700	859	16.2	964	803	101	3.54	156	4.19	37.8	24.8	284000
199	7.39	52.6	14900	770	16.0	869	695	88.2	3.45	137	4.12	37.6	18.3	246000
392	2.45	24.1	29900	1440	16.1	1710	803	130	2.64	212	3.30	39.1	172	306000
331	2.86	28.0	24700	1210	15.9	1430	644	106	2.57	172	3.21	38.7	105	241000
327	2.85	29.0	24500	1200	16.0	1410	640	105	2.58	170	3.21	38.7	103	239000
294	3.11	32.2	21900	1080	15.9	1270	562	93.5	2.55	150	3.16	38.5	76.6	208000
278	3.31	33.3	20500	1020	15.8	1190	521	87.1	2.52	140	3.13	38.4	65.0	192000
264	3.45	35.6	19400	971	15.8	1130	493	82.6	2.52	132	3.12	38.3	56.1	181000
235	3.77	41.2	17400	875	15.9	1010	444	74.6	2.54	118	3.11	38.1	41.3	161000
211	4.17	45.6	15500	786	15.8	906	390	66.1	2.51	105	3.07	38.0	30.4	141000
183	4.92	52.6	13200	675	15.7	774	331	56.0	2.49	88.3	3.04	37.8	19.3	118000
167	5.76	52.6	11600	600	15.3	693	283	47.9	2.40	76.0	2.98	37.6	14.0	99700
149	7.11	54.3	9800	513	15.0	598	229	38.8	2.29	62.2	2.89	37.4	9.36	80000

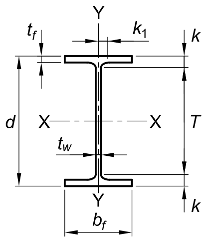


Table 1-1 (continued)
W-Shapes
Dimensions

Shape	Area, A	Depth, d		Web Thickness, t_w		$t_w/2$	Flange Width, b_f		Flange Thickness, t_f		Distance k k_{des}	k k_{det}	k_1	T	Workable Gage
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W36×925[h]	272	43.1	43 1/8	3.02	3	1 1/2	18.6	18 5/8	4.53	4 1/2	5.28	5 3/8	2 5/16	32 3/8	3-7 1/2-3
×853[h]	251	43.1	43 1/8	2.52	2 1/2	1 1/4	18.2	18 1/4	4.53	4 1/2	5.28	5 3/8	2 1/16		
×802[h]	236	42.6	42 5/8	2.38	2 3/8	1 3/16	18.0	18	4.29	4 5/16	5.04	5 1/8	2		
×723[h]	213	41.8	41 3/4	2.17	2 3/16	1 1/8	17.8	17 3/4	3.90	3 7/8	4.65	4 11/16	1 7/8		
×652[h]	192	41.1	41	1.97	2	1	17.6	17 5/8	3.54	3 9/16	4.49	4 13/16	2 3/16	31 3/8	
×529[h]	156	39.8	39 3/4	1.61	1 5/8	13/16	17.2	17 1/4	2.91	2 15/16	3.86	4 3/16	2		
×487[h]	143	39.3	39 3/8	1.50	1 1/2	3/4	17.1	17 1/8	2.68	2 11/16	3.63	4	1 7/8		
×441[h]	130	38.9	38 7/8	1.36	1 3/8	11/16	17.0	17	2.44	2 7/16	3.39	3 3/4	1 7/8		
×395[h]	116	38.4	38 3/8	1.22	1 1/4	5/8	16.8	16 7/8	2.20	2 3/16	3.15	3 7/16	1 13/16		
×361[h]	106	38.0	38	1.12	1 1/8	9/16	16.7	16 3/4	2.01	2	2.96	3 5/16	1 3/4		
×330	96.9	37.7	37 5/8	1.02	1	1/2	16.6	16 5/8	1.85	1 7/8	2.80	3 1/8	1 3/4		
×302	89.0	37.3	37 3/8	0.945	15/16	1/2	16.7	16 5/8	1.68	1 11/16	2.63	3	1 11/16		
×282[c]	82.9	37.1	37 1/8	0.885	7/8	7/16	16.6	16 5/8	1.57	1 9/16	2.52	2 7/8	1 5/8		
×262[c]	77.2	36.9	36 7/8	0.840	13/16	7/16	16.6	16 1/2	1.44	1 7/16	2.39	2 3/4	1 5/8		
×247[c]	72.5	36.7	36 5/8	0.800	13/16	7/16	16.5	16 1/2	1.35	1 3/8	2.30	2 5/8	1 5/8		
×231[c]	68.2	36.5	36 1/2	0.760	3/4	3/8	16.5	16 1/2	1.26	1 1/4	2.21	2 9/16	1 9/16		
W36×387[h]	114	39.1	39 1/8	1.42	1 7/16	3/4	12.7	12 3/4	2.56	2 9/16	3.31	3 13/16	1 15/16	31 1/2	5 1/2
×350[h]	103	38.6	38 5/8	1.30	1 5/16	11/16	12.6	12 5/8	2.32	2 5/16	3.07	3 9/16	1 7/8		
×318[h]	93.4	38.2	38 1/4	1.18	1 3/16	5/8	12.4	12 3/8	2.13	2 1/8	2.88	3 3/8	1 13/16		
×286	83.9	37.8	37 3/4	1.06	1 1/16	9/16	12.3	12 1/4	1.93	1 15/16	2.68	3 1/8	1 3/4		
×256	75.3	37.4	37 3/8	0.960	15/16	1/2	12.2	12 1/4	1.73	1 3/4	2.48	2 15/16	1 11/16		
×232[c]	68.0	37.1	37 1/8	0.870	7/8	7/16	12.1	12 1/8	1.57	1 9/16	2.32	2 13/16	1 5/8		
×210[c]	61.9	36.7	36 3/4	0.830	13/16	7/16	12.2	12 1/8	1.36	1 3/8	2.11	2 5/8	1 5/8		
×194[c]	57.0	36.5	36 1/2	0.765	3/4	3/8	12.1	12 1/8	1.26	1 1/4	2.01	2 1/2	1 9/16		
×182[c]	53.6	36.3	36 3/8	0.725	3/4	3/8	12.1	12 1/8	1.18	1 3/16	1.93	2 3/8	1 9/16		
×170[c]	50.0	36.2	36 1/8	0.680	11/16	3/8	12.0	12	1.10	1 1/8	1.85	2 3/8	1 9/16		
×160[c]	47.0	36.0	36	0.650	5/8	5/16	12.0	12	1.02	1	1.77	2 1/4	1 9/16		
×150[c]	44.3	35.9	35 7/8	0.625	5/8	5/16	12.0	12	0.940	15/16	1.69	2 3/16	1 1/2		
×135[c],[v]	39.9	35.6	35 1/2	0.600	5/8	5/16	12.0	12	0.790	13/16	1.54	2 1/16	1 1/2		

[c] Shape is slender for compression with $F_y = 50$ ksi.
[h] Flange thickness is greater than 2 in. Special requirements may apply per AISC *Specification* Section A3.1d.
[v] Shape does not meet the h/t_w limit for shear in AISC *Specification* Section G2.1(a) with $F_y = 50$ ksi.

Table 1-1 (continued)
W-Shapes
Properties

W36

Nominal Wt.	Compact Section Criteria		Axis X-X				Axis Y-Y				r_{ts}	h_o	Torsional Properties	
	$\frac{b_f}{2t_f}$	$\frac{h}{t_w}$	I	S	r	Z	I	S	r	Z			J	C_w
lb/ft			in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.^{3}	in.	in.	in.^{4}	in.^{6}
925	2.05	10.8	73000	3390	16.4	4130	4940	531	4.26	862	5.30	38.6	1430	1840000
853	2.01	12.9	70000	3250	16.7	3920	4600	505	4.28	805	5.22	38.6	1240	1710000
802	2.10	13.7	64800	3040	16.6	3660	4210	468	4.22	744	5.15	38.3	1050	1540000
723	2.28	15.0	57300	2740	16.4	3270	3700	416	4.17	658	5.06	37.9	785	1330000
652	2.48	16.3	50600	2460	16.2	2910	3230	367	4.10	581	4.96	37.6	593	1130000
529	2.96	19.9	39600	1990	16.0	2330	2490	289	4.00	454	4.80	36.9	327	846000
487	3.19	21.4	36000	1830	15.8	2130	2250	263	3.96	412	4.74	36.6	258	754000
441	3.48	23.6	32100	1650	15.7	1910	1990	235	3.92	368	4.69	36.5	194	661000
395	3.83	26.3	28500	1490	15.7	1710	1750	208	3.88	325	4.61	36.2	142	575000
361	4.16	28.6	25700	1350	15.6	1550	1570	188	3.85	293	4.58	36.0	109	509000
330	4.49	31.4	23300	1240	15.5	1410	1420	171	3.83	265	4.53	35.9	84.3	456000
302	4.96	33.9	21100	1130	15.4	1280	1300	156	3.82	241	4.53	35.6	64.3	412000
282	5.29	36.2	19600	1050	15.4	1190	1200	144	3.80	223	4.50	35.5	52.7	378000
262	5.75	38.2	17900	972	15.3	1100	1090	132	3.76	204	4.46	35.5	41.6	342000
247	6.11	40.1	16700	913	15.2	1030	1010	123	3.74	190	4.42	35.4	34.7	316000
231	6.54	42.2	15600	854	15.1	963	940	114	3.71	176	4.40	35.2	28.7	292000
387	2.48	22.9	26500	1360	15.2	1610	882	139	2.78	224	3.44	36.5	172	294000
350	2.72	25.0	23600	1220	15.1	1440	780	124	2.75	199	3.41	36.3	129	257000
318	2.91	27.5	21200	1110	15.1	1300	682	110	2.70	176	3.33	36.1	98.3	222000
286	3.19	30.6	18900	1000	15.0	1160	602	97.9	2.68	156	3.29	35.9	72.8	194000
256	3.53	33.8	16800	895	14.9	1040	528	86.5	2.65	137	3.24	35.7	52.9	168000
232	3.86	37.3	15000	809	14.8	936	468	77.2	2.62	122	3.21	35.5	39.6	148000
210	4.48	39.1	13200	719	14.6	833	411	67.5	2.58	107	3.18	35.3	28.0	128000
194	4.81	42.4	12100	664	14.6	767	375	61.9	2.56	97.7	3.15	35.2	22.2	116000
182	5.12	44.8	11300	623	14.5	718	347	57.6	2.55	90.7	3.13	35.1	18.5	107000
170	5.47	47.7	10500	581	14.5	668	320	53.2	2.53	83.8	3.11	35.1	15.1	98500
160	5.88	49.9	9760	542	14.4	624	295	49.1	2.50	77.3	3.09	35.0	12.4	90200
150	6.37	51.9	9040	504	14.3	581	270	45.1	2.47	70.9	3.06	35.0	10.1	82200
135	7.56	54.1	7800	439	14.0	509	225	37.7	2.38	59.7	2.99	34.8	7.00	68100

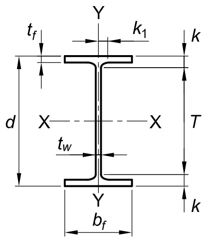


Table 1-1 (continued)
W-Shapes
Dimensions

Shape	Area, A	Depth, d		Web Thickness, t_w		Web $\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		Distance k_{des}	Distance k_{det}	k_1	T	Workable Gage
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W33×387[h]	114	36.0	36	1.26	1¼	⅝	16.2	16¼	2.28	2¼	3.07	3 9/16	1 13/16	28⅞	3-5½-3
×354[h]	104	35.6	35½	1.16	1 3/16	⅝	16.1	16⅛	2.09	2 1/16	2.88	3⅜	1 13/16		
×318	93.7	35.2	35⅛	1.04	1 1/16	9/16	16.0	16	1.89	1⅞	2.68	3 3/16	1¾		
×291	85.6	34.8	34⅞	0.960	15/16	½	15.9	15⅞	1.73	1¾	2.52	2 15/16	1 11/16		
×263	77.4	34.5	34½	0.870	⅞	7/16	15.8	15¾	1.57	1 9/16	2.36	2 13/16	1⅝		
×241[c]	71.1	34.2	34⅛	0.830	13/16	7/16	15.9	15⅞	1.40	1⅜	2.19	2 11/16	1⅝		
×221[c]	65.3	33.9	33⅞	0.775	¾	⅜	15.8	15¾	1.28	1¼	2.06	2½	1⅝		
×201[c]	59.1	33.7	33⅝	0.715	11/16	⅜	15.7	15¾	1.15	1⅛	1.94	2 7/16	1 9/16		
W33×169[c]	49.5	33.8	33⅞	0.670	11/16	⅜	11.5	11½	1.22	1¼	1.92	2 7/16	1 9/16	28⅞	5½
×152[c]	44.9	33.5	33½	0.635	⅝	5/16	11.6	11⅝	1.06	1 1/16	1.76	2 5/16	1½		
×141[c]	41.5	33.3	33¼	0.605	⅝	5/16	11.5	11½	0.960	15/16	1.66	2 3/16	1½		
×130[c]	38.3	33.1	33⅛	0.580	9/16	5/16	11.5	11½	0.855	⅞	1.56	2⅛	1½		
×118[c],[v]	34.7	32.9	32⅞	0.550	9/16	5/16	11.5	11½	0.740	¾	1.44	2	1½		
W30×391[h]	115	33.2	33¼	1.36	1⅜	11/16	15.6	15⅝	2.44	2 7/16	3.23	3¾	1⅞	25¾	3-5½-3
×357[h]	105	32.8	32¾	1.24	1¼	⅝	15.5	15½	2.24	2¼	3.03	3½	1 13/16		
×326[h]	95.9	32.4	32⅜	1.14	1⅛	9/16	15.4	15⅜	2.05	2 1/16	2.84	3 5/16	1¾		
×292	86.0	32.0	32	1.02	1	½	15.3	15¼	1.85	1⅞	2.64	3⅛	1¾		
×261	77.0	31.6	31⅝	0.930	15/16	½	15.2	15⅛	1.65	1⅝	2.44	2 15/16	1 11/16		
×235	69.3	31.3	31¼	0.830	13/16	7/16	15.1	15	1.50	1½	2.29	2¾	1⅝		
×211	62.3	30.9	31	0.775	¾	⅜	15.1	15⅛	1.32	1 5/16	2.10	2 9/16	1⅝		
×191[c]	56.1	30.7	30⅝	0.710	11/16	⅜	15.0	15	1.19	1 3/16	1.97	2½	1 9/16		
×173[c]	50.9	30.4	30½	0.655	⅝	5/16	15.0	15	1.07	1 1/16	1.85	2 5/16	1 9/16		
W30×148[c]	43.6	30.7	30⅝	0.650	⅝	5/16	10.5	10½	1.18	1 3/16	1.83	2½	1 9/16	25¾	5½
×132[c]	38.8	30.3	30¼	0.615	⅝	5/16	10.5	10½	1.00	1	1.65	2¼	1½		
×124[c]	36.5	30.2	30⅛	0.585	9/16	5/16	10.5	10½	0.930	15/16	1.58	2¼	1½		
×116[c]	34.2	30.0	30	0.565	9/16	5/16	10.5	10½	0.850	⅞	1.50	2⅛	1½		
×108[c]	31.7	29.8	29⅞	0.545	9/16	5/16	10.5	10½	0.760	¾	1.41	2	1½		
×99[c]	29.0	29.7	29⅝	0.520	½	¼	10.5	10½	0.670	11/16	1.32	2	1½		
×90[c],[v]	26.3	29.5	29½	0.470	½	¼	10.4	10⅜	0.610	⅝	1.26	1⅞	1 7/16		

[c] Shape is slender for compression with $F_y = 50$ ksi.
[h] Flange thickness is greater than 2 in. Special requirements may apply per AISC *Specification* Section A3.1d.
[v] Shape does not meet the h/t_w limit for shear in AISC *Specification* Section G2.1(a) with $F_y = 50$ ksi.

INDEX

The following list of terms provides reference to items found in the AISC *Steel Construction Manual*, as well as selected supporting references. The locations of supporting references have been abbreviated as follows:

"DG#" is used for items found in AISC's Design Guide series.
"SDM" is used for items found in the AISC *Seismic Design Manual*.
"DSC" is used for items found in AISC's *Detailing for Steel Construction*.

For more information on many of the topics listed, see the *Companion to the AISC Steel Construction Manual—Volume 1: Design Examples* and the *Companion to the AISC Steel Construction Manual—Volume 2: Tables*, posted on the AISC web site at **www.aisc.org**.