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Golden Anniversary of the AISI Specification

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GOLDEN ANNIVERSARY OF THE AISI SPECIFICATION

by

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INTRODUCTION

The use of cold-formed steel members in building construction began in about the 1850's in the United States and Great Britain. However, such thin-walled steel members were not widely used for buildings until after 1946 when the first edition of the *Specification for the Design of Light Gage Steel Structural Members* was published by the American Iron and Steel Institute (AISI, 1946). This first design standard was based primarily on the research work sponsored by the Institute at Cornell University under the direction of Professor George Winter after 1939 (Winter, 1959a and 1959b). It was revised subsequently by the AISI Committees in 1956, 1960, 1962, 1968, 1980, and 1986 to reflect the technical developments and the results of continuing research (Yu, 1991). All the above mentioned seven editions of the AISI Specification adopted the conventional, allowable stress design (ASD) method. In 1991, AISI published the first edition of the *Load and Resistance Factor Design Specification for Cold-Formed Steel Structural Members* (AISI, 1991). Both AISI *allowable stress design* (ASD) and *load and resistance factor design* (LRFD) Specifications were combined into a single document in 1996 (AISI, 1996).

The purpose of this paper is to summarize the historical developments of the AISI Specification during the past 50 years. A review of the past experience and background information will undoubtedly benefit the planning of future research and the development of new design criteria for cold-formed steel structural members and structural systems.

DEVELOPMENTS OF THE AISI SPECIFICATION

(1) *1946 Edition* (AISI, 1946)

During the 1930's the acceptance and the development of cold-formed steel construction in the United States faced difficulties due to the lack of an appropriate design specification. Various building codes made no provision for cold-formed steel construction at that time.

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It became evident that the development of a new design specification for cold-formed steel construction was highly desirable not only because the performance of thin cold-formed structural members under load differs in several significant respects from that of heavy hot-rolled steel sections, but also the forms, shapes, connections, and fabrication practices which have been developed in cold-formed steel construction differ in many ways from those of heavy steel structures. As a result, design specifications for heavy hot-rolled steel construction cannot possibly cover the design features of cold-formed steel construction completely.

Realizing the need of a special design specification and the absence of factual background and research information, the AISI Committee on Building Codes sponsored a research project at Cornell University in February 1939 for the purpose of studying the performance of light-gage, cold-formed steel structural members and of obtaining factual information for the formulation of a design specification. Research projects have been carried out continuously at Cornell University starting under the direction of Professor George Winter. During the first seven years of study (1939-1946), the research program concentrated on the study of beams, studs, roof decks, and connections under the supervision of an AISI Technical Subcommittee. In order to respond to numerous requests from building officials, engineers, architects, and builders for design standards to govern the use of light gage steel members for structural purposes in buildings, the Technical Subcommittee prepared the first edition of the Specification in 1946 under the chairmanship of Milton Male. It was primarily on the basis of the available analytical and experimental results obtained from the Cornell research (Winter, 1940, 1943, 1944, 1946).

The 1946 edition of the Specification contained the following six sections:

Section 1 - General
Section 2 - Design Procedure
Section 3 - Allowable Design Stresses
Section 4 - Connections
Section 5 - Design of Braced Wall Studs
Section 6 - Tests

This first edition of the Specification was applicable only to steel sheet or strip less than 3/16 in. (4.76 mm) in thickness. Two ASTM Specifications (A245 and A246) were listed in Section 1.2 on Material. The yield point of steel ranged from 25 to 33 ksi (172-228 MPa).

For design purposes, the basic design stress was based on a safety factor of 1.85. The *Effective Design Width* approach was used for stiffened compression elements and the *Reduced Working Stress* approach was used for unstiffened compression elements. A form factor "Q" was used for column design to account for the reduction of column strength due to the effect of local buckling of compression elements. For beam design,

the allowable design stresses for lateral buckling and shear buckling of beam webs were based on elastic buckling stresses with a maximum of yield point in tension and shear, respectively.

For connections, design provisions were provided only for welds. The design requirements for wall studs were based on the theoretical and experimental investigations conducted by Green, Winter, and Cuykendall (1947).

Design Manual (AISI, 1949).

In January 1949, AISI published the first *Light Gage Steel Design Manual*, which was prepared by the AISI Manual Subcommittee under the chairmanship of Tappan Collins. The Design Manual included the following five parts and an Appendix:

Part I - Explanatory Comments and Design Charts
Part II - Tables of Properties
Part III - 1946 Edition of the Specification
Part IV - Supplementary Information
Part V - Examples
Appendix - Supplementary Tables

Correlation of the Cornell University Research Investigation with the Specification

Even though most of the findings of the research projects conducted at Cornell University had been published through normal channels, a need was noted as early as 1947 for a systematic discussion of the background of the Specification. This led to the preparation of a document, "Correlation of the Cornell University Research Investigation with the Specification," which was published in mimeographed form by AISI in 1947, and republished in a revised form in 1950.

(2) *1956 Edition*, (AISI, 1956)

Since the publication of the AISI's first design standard in 1946, the Specification has gained both national and international recognition. It was accepted as the design standard for cold-formed steel structural members in the Basic Building Code, the National Building Code, the Southern Building Code, and the Uniform Building Code. Promulgation of the Specification into model national codes, state codes, and local codes has continued throughout the Specification's history. At Cornell University, research projects were continued to study the bending capacities of hat sections, braced and unbraced channels and Z-beams, web crippling strengths, combined axial load and bending, and bolted connections. In keeping with the rapid technical developments and to reflect the results of the continued research at Cornell University (Winter, 1947, 1956a, 1956b), the Specification was rewritten and enlarged in 1956 under the chairmanship of W.D. Moorehead. In this second edition, the order of presentation of

the material was changed and substantive changes and additions were made. The major changes and additions are as follows:

Section 1 - General

ASTM A303 Specification was added.

Section 2 - Design Procedure

The provisions for effective design widths were simplified. The design provisions for multiple-stiffened elements were added. The maximum h/t ratio for beam webs was established.

Section 3 - Allowable Design Stresses

Design provisions were added for angle struts, unbraced channels and Z-beams, bending stress for webs, combined bending and shear stresses in webs, web crippling load for single unreinforced webs, wind and earthquake stresses, and tubular compression members.

Section 4 - Connections

New provisions were added for welds and bolted connections.

Section 5 - Bracing Requirements

Bracing requirements for channels and Z-shaped beams were added.

Design Manual (AISI, 1956)

The second edition of the Specification was published in Part I of the 1956 edition of the AISI *Light Gage Cold-Formed Steel Design Manual.* Other parts of the AISI Design Manual included the following items: II - Supplementary Information, III - Illustrative Examples, and IV - Charts and Tables of Structural Properties.

Commentary (AISI, 1958)

Following the publication of the 1956 edition of the Specification, the mimeographed copy of the "Correlation of the Cornell University Research Investigation with the Specification" was republished in 1956 by adding a Temporary Supplement to discuss the changes made in the second edition of the Specification. At the request of the AISI Committee on Building Research and Technology, Professor George Winter prepared the

first formal Commentary in 1958 to provide a record of the reasoning behind, and justification for the various provisions of the Specification.

(3) *1960 Edition* (AISI, 1960)

The rapidly expanding use of and experience with cold-formed steel construction made it advisable to issue a revised edition of the AISI Specification in 1960 during the chairmanship of Tappan Collins. In this third edition, the basic safety factor was reduced from 1.85 to 1.65. This revision brought the safety factor in line with other specifications for the structural use of steel in buildings, and was considered to be justified by the 14 years of experience since the publication of the first edition of the specification and the enviable safety record established during that time by structures designed according to the AISI Specification. Other major changes were related to the following provisions:

Section 1 - General

Thickness limitation was deleted. Two ASTM Specifications on high strength low alloy steel sheets and strip (A374 and A375) were added.

Section 2 - Design Procedure

Effective design width equations were revised according to the reduced safety factor of 1.65.

Section 3 - Allowable Design Stresses

The basic design stress and the allowable stresses for compression on unstiffened elements and lateral buckling of beams were increased by 12% as a result of using a reduced safety factor of 1.65. In addition, the inelastic buckling behavior was considered for lateral buckling of beams.

The safety factor used for determining the allowable stress for axially loaded compression members was reduced from 2.15 to 1.95.

Section 4 - Connections

Minor changes were made on the allowable shear strengths of resistance welds, built-up compression members, and spacing of connections in compression elements. The design provisions for using high strength bolts were added.

Design Manual (AISI, 1961)

The 1960 Edition of the Specification was published in Part I of the 1961 Edition of the *Light Gage Cold-Formed Steel Design Manual.* Additional illustrative examples and charts and tables were added to Parts III and IV of the Design Manual, respectively.

Commentary (AISI, 1961)

The Commentary on the 1956 Edition of the *Light Gage Cold-Formed Steel Design Manual*, published by the Institute in 1958, was updated in 1961 by Professor Winter to provide the background for the changes made in the 1960 edition of the Specification and the 1961 edition of the Design Manual.

(4) *1962 Edition* (AISI, 1962)

It has long been known that any cold working, such as cold stretching and bending, affects the mechanical properties of steel. Based on the initial research work conducted at Cornell University, the AISI Specification was revised in 1962 during the chairmanship of D.S. Wolford to recognize the possibility of utilizing the added strength due to cold work of forming. Previous editions provided that all design provisions were to be based on the material properties before forming. The 1962 edition of the AISI Specification, for the first time, permitted the use of as-formed strength as a basis for design in those situations where such utilization is safe and justified. In addition to this main change, the interaction equations for combined axial and bending stresses were revised to recognize the secondary moment effect. For frames which depend upon their own bending stiffness for lateral stability, the effective length in the plane of the frame was refined to be not less than the actual unbraced length.

Design Manual (AISI, 1962)

In Part I of the 1962 Edition of the Design Manual, the Specification was revised to reflect recent technical developments and the results of continuing research, particularly those relating to the utilization of as-formed strength.

Part II of the Manual, Supplementary Information, was enlarged to include design procedures for beams having laterally unbraced compression flanges. In Part III, the illustrative examples were revised to conform with the revisions made in the Specification.

Commentary (AISI, 1962)

In order to provide the background for the changes and additions made in the 1962 edition of the Design Manual, the Commentary on the 1962 Edition of the *Light Gage Cold-Formed Steel Design Manual* was revised by Professor Winter and republished by

the Institute in October 1962.

(5) *1968 Edition* (AISI, 1968)

In early 1960's, the AISI sponsored research topics were expanded to include studies of effects of cold-forming, fusion welding, shear diaphragms, bracing of beams and columns with diaphragms, folded plates, hyperbolic paraboloids, torsional-flexural buckling, and cold-formed stainless steel members. The major project on torsional-flexural buckling was initiated by a report of failure in Europe caused by torsional-flexural buckling mode of truss members.

Following the extensive investigations of the above mentioned research topics, a major revision of the Specification was carried out in 1968 during the chairmanship of J.B. Scalzi. The primary expansion was the inclusion of design provisions for compression members which may be subject to torsional-flexural buckling (Pekoz and Winter, 1969). Numerous other revisions were also made throughout the Specification. Prior to the revision of the Specification, special studies were carried out by a joint AISI-AISC Task Force to coordinate the AISC Specification for the design of hot-rolled shapes and the AISI Specification for the design of cold-formed steel structural members.

Specifically, the major revisions made in the 1968 edition of the Specification are outlined as follows:

Section 1 - General steel

ASTM A303 was replaced by ASTM A570 steel.

Section 2 - Design Procedure

Definitions of several new terms were added and the unit for stress was changed from psi to ksi. All design equations were revised for the ksi unit.

Section 3 - Allowable Design Stresses

Design equations for utilizing cold work of forming were added (Karren, 1967; Karren and Winter, 1967; Winter and Uribe, 1968).

Design equations for lateral buckling of beams were revised in terms of (L^2S_{xc}/dI_{yc}) instead of (L/r_y). A bending coefficient C_b was used in the design equation.

The design provisions for shear stress in webs were revised to recognize the inelastic shear buckling and the safety factor used for medium and large h/t ratios was reduced from 2.22 to 1.67. Web crippling equations were changed in terms of F_y instead of the basic design stress.

For compression members, specific design provisions were added for singly-symmetric and nonsymmetric shapes which may be subject to torsional-flexural buckling. For flexural buckling of compact compression members using materials 0.09 inches (2.29 mm) or thicker, the safety factor varies from 1.67 to 1.95. When $L/r > 120$, a slightly higher allowable stress was allowed for bracing and secondary members.

New provisions were added for combined axial and bending stresses to deal with the design of members which may be subject to torsional-flexural buckling.

For cylindrical tubular members, an equation for inelastic local buckling was added.

Section 4 - Connections

The design equation for tension stress on net section of bolted connections was generalized for using multiple bolts.

Section 6 - Tests for special cases

Test requirements for flat elements of formed sections and for mechanical properties of virgin steel were added.

Design Manual (AISI, 1968-1972, 1977)

During the period from 1968 through 1977, several printings of the 1968 edition of the Specification, Commentary, Supplementary Information, Illustrative Examples, and Charts and Tables were published by AISI. In 1977, AISI published a new edition of the *Cold-Formed Steel Design Manual.* It represents a major improvement in format and useability. Since the Manual was in a loose leaf binder, this made the charts and tables much easier to use, and it made possible prompt revisions of portions of the Manual without waiting for republication of the entire Manual.

(6) *1980 Edition* (AISI, 1980)

In 1973, the Advisory Group on the Specification was formed at AISI to handle the

development and modification of the Specification and to supervise the research activity under the AISI sponsorship. The Advisory Group worked under the Specification writing authority of the AISI Committee on Construction Codes and Standards. The Advisory Group was established with a balance among producers, users, and general interest members. This approach has been maintained, and the work of the current Committee on Specifications follows the philosophy established by ASTM and ANSI. The first chairman of the Advisory Group was R.B. Matlock and the second chairman was D.S. Wolford. In 1977, K.H. Klippstein assumed the chairmanship of the Advisory Group (Johnson, 1978).

As far as the Specification was concerned, AISI issued Addendum No. 1 in November 1970 to add ASTM Specifications for A606, A607 and A611 steels.

In February 1977, the AISI Committee approved Addendum No. 2, in which the scope of the Specification was extended to cover cold-formed steel members up to one inch (25.4 mm) in thickness. As a consequence, ASTM Specifications were expanded to include plate and bar steels, as well as sheet steels. This expansion to thicker steels was stimulated by the increased capacity of cold-forming equipment, and was validated by a research project conducted at the University of Missouri-Rolla (Yu, Liu and McKinney, 1974). Also included in Addendum No. 2 was the new requirement covering the delivered minimum thickness. This provision stated that the uncoated minimum steel thickness of the cold-formed product as delivered to the job site shall not at any location be less than 95 percent of thickness used in design. The fourth modification included in Addendum No. 2 was dealing with the reduction of the web crippling load due to the presence of bending moment.

In addition to the modifications included in Addenda Nos. 1 and 2, a number of other important topics were revised in the 1980 edition of the Specification as outlined below (Johnson, 1980).

Section 1 - General

New ductility requirements were added for the minimum elongation and the minimum ratio of tensile strength to yield point. For steels with less ductility (Grade E of A446 and A611), reduced allowable basic design stress was specified in the Specification.

Section 2 - Design Procedure

The maximum h/t ratio for unreinforced webs was increased from 150 to 200. For webs with transverse stiffeners, the maximum h/t ratios were also increased to be consistent with the AISC Specification. New provisions were added for transverse stiffeners attached to beam webs.

Section 3 - Allowable Design Stresses

The provisions for web design were revised extensively on the basis of the research work conducted at the University of Missouri-Rolla: (1) The allowable shear and bending stresses were revised in keeping with the increased maximum h/t ratio. The allowable shear stresses recognized the possible use of transverse stiffeners. The allowable bending stresses were revised for considering the postbuckling strength of beam webs (LaBoube and Yu, 1982). (2) The web crippling provisions were revised and expanded. (3) New interaction equations were added for combined bending and web crippling (Hetrakul and Yu, 1978).

A new section was added to permit the designer to utilize the inelastic reserve capacity of beams under specified limitations. These new provisions were based on Cornell research work (Reck, Pekoz and Winter, 1975; Yener and Pekoz, 1985).

The design equation for determining the allowable compression stress for bracing and secondary members was deleted because of the lack of an accepted definition for that type of member.

A new section was added for the case of torsional buckling of doubly-symmetric and point-symmetric shapes.

Section 4 - Connections

The provisions for arc welds were completely revised based on the Cornell research (Pekoz and McGuire, 1979) and the coordinated effort by AISI and American Welding Society. Of particular importance were design provisions for arc spot welds and arc seam welds. These provisions were applicable for steels with connected parts 0.18 inches (4.57 mm) and less in thickness.

Provisions for bolted connections were completely revised based on research at the University of Missouri-Rolla (Yu, 1982). All design equations were in terms of tensile strength F_u rather than yield point F_y. Criteria for bolted connections without washers were added. The allowable shear stress on bolts was increased and small diameter high strength bolts were covered with listing of ASTM A354 and A449 bolts. The revised design provisions were for connections in which the thickness of the thinnest connected part is less than 3/16 inch (4.76 mm).

Section 5 - Bracing Requirements

Provisions for the design of wall studs which are braced by sheathing were completely revised and expanded. The design was based on the shear stiffness of the sheathing material, rather than on the extensional stiffness formerly used. These revisions were based on research at Cornell University (Simaan and Pekoz, 1976)

As a result of the cooperative effort by the Metal Building Manufacturers Association and AISI, more direct guidance was added to the Specification for bracing channels and Z-sections when one flange is connected to deck or sheathing. In addition, it was specified that no other braces will be required when all loads and reactions on a beam are transmitted through members which frame into the section in such a manner as to effectively restrain the section against rotation and lateral displacement.

Section 6 - Tests for Special Cases

This section was rewritten to improve clarity. Larger load factors were used to determine the load-carrying capacity when limited by connection failure.

Design Manual (AISI, 1983)

The *Cold-Formed Steel Design Manual* based on the 1980 edition of the Specification was published by AISI in 1983. Same as the 1977 edition of the Manual, it included the following five Parts: I - Specification, II - Commentary, III - Supplementary Information, IV - Illustrative Examples, and V - Charts and Tables. Unlike previous editions of the Commentary, which were in a textbook format, the discussions contained in the Commentary on the 1980 edition of the Specification were presented in the same sequence as that in the Specification. This new format was adopted to better facilitate practical use in a well-established field.

(7) *1986 Edition* (AISI, 1986)

The 1980 edition of the Specification was revised in 1986 during the chairmanship of S.J. Errera. It represents six years of intensive effort by the Advisory Group and its 21 subcommittees (Johnson, 1982 and 1986). The Specification was reformatted by using chapters instead of sections in order to simplify the Specification without changing the substance (Pinkham, 1986). The most important change in design procedure was the adoption of the unified approach related to the utilization of postbuckling strength of structural elements, including uniformly compressed stiffened and unstiffened elements, webs of flexural members, stiffened elements with stress gradient and elements with edge

stiffeners. This approach was based on Pekoz's thorough and detailed study of research results (Pekoz, 1986a and 1986b).

The major revisions of the Specification are summarized as follows:

A. General Provisions

Non-dimensional format was adopted to facilitate its use in any compatible system of units.

ASTM Specification A792 for zinc-aluminum sheet was added. Provisions for Grade E steels were clarified, and specific guidance was given for design provisions governed by F_y and F_u.

Guidance on loading conditions were added. A list of reference documents was added. It included related design specifications, as well as the manuals issued by user industries.

B. Elements

The definition of web depth was defined as the flat portion of the web.

Alternative methods for calculating effective widths of uniformly compressed stiffened elements for use in deflection calculations were offered. Provisions for uniformly compressed stiffened elements with circular holes were introduced. Effective widths under stress gradient were considered for webs, stiffened elements, unstiffened elements and edge stiffeners. Allowable stresses for unstiffened elements were replaced by an effective width approach. Design provisions for elements with less than "adequate" edge stiffeners were added.

C. Members

Member strengths were given in terms of force or moment, rather than stress. Safety factors were given explicitly. The unified approach permits numerous simplifications in formulation of design provisions.

New equations were added to determine the critical lateral buckling moment for singly-symmetric sections.

The presentation of web crippling strength was simplified.

The Q factor was eliminated from the design equations for columns. The design provisions for combined axial load and bending were simplified for

singly-symmetric shapes.

The design of cylindrical tubular members was clarified and expanded, with separate treatment for bending and compression.

D. Structural Assemblies

The purpose and requirements for lateral bracing were clearly defined. Detailed provisions for anchorage of bracing for roof systems under gravity load with top flange connected to sheathing were added on the basis of the research work conducted at the University at Oklahoma (Murray and Elhouar, 1985).

Wall stud design provisions for determining the allowable load were revised. A test alternative for determination of wall sheathing parameters was permitted in addition to the use of tabulated values. Design provisions for the interaction of bending and axial load in wall studs were liberalized.

E. Connections and Joints

Allowable shear strengths for resistance spot welds were increased for thinner sheets.

Provisions for oversize and slotted holes were added. Allowable tension stresses for bolts were added. Provisions were introduced for bolts subject to a combination of shear and tension.

Shear rupture was considered at beam-end connections. Connections to other materials were considered, with specific guidance for bearing stresses.

Attention was called to the need for consideration of pull-over of sheet around fastener heads, as well as pull-out of fasteners.

F. Tests for Special Cases

Potential misinterpretation of the test provisions was avoided through rewording definitions and requirements.

Appendices

Three infrequently used sections on cold work of forming, flange curling, and shear lag effects were moved to Appendices to improve the readability of the main text of the Specification.

1989 Addendum

In 1989, AISI issued an Addendum to the 1986 edition of the Specification based on the results of continuing research, advances in design techniques, development of new steels, and the needs of the design profession and consuming industries (Errera, 1990). The major changes are summarized as follows:

A. General Provisions

All ASTM Specifications were updated.

The use of steel with a lower F_u/F_y ratio was permitted for certain flexural members provided that the additional criteria on local and uniform elongation can be satisfied.

The design criteria for cold work of forming were moved from the Appendix to the main text.

The reference documents were updated.

B. Elements

The design provisions for flange curling and shear lag effects were moved from the Appendices to the main text.

C. Members

For lateral buckling strength of flexural members, the sequence of the design provisions was rearranged and clarified.

For beams having one flange through-fastened to deck or sheathing, reduction factors were provided for the calculation of nominal moment (LaBoube and Thompson, 1982; LaBoube et al., 1988; LaBoube and Golovin, 1990).

The allowable moments used for combined bending and shear, combined bending and web crippling, and combined axial load and bending were clarified.

D. Structural Assemblies

For wall studs, the design provisions were improved with a list of limitations. Stub column tests were recognized as a suitable basis for the design of studs with perforations. The effective length factors K_x, K_y, and

K_t were removed from design equations to avoid unconservative designs.

A new section was added for floor, roof or wall steel diaphragm construction. Factors of safety were provided for welded and mechanical connections under various loading conditions (SDI, 1981).

E. Connections and Joints

A new design equation was added to determine the tensile load on arc spot welds. This equation was primarily based on Canadian experimental data (Fung, 1978).

Design Manual (AISI, 1986)

The Design Manual for using the 1986 edition of the Specification was published by AISI in November 1986. It also contained the following seven Parts: I - Specification, II - Commentary, III - Supplementary Information, IV - Illustrative Examples, V - Charts and Tables, VI - Computer Aids, and VII - Test Procedures. The Design Manual was republished in January 1991 to include the 1986 edition of the Specification with December 11, 1989 Addendum. Also included in the 1991 Design Manual was the revised Commentary.

(8) *LRFD Specification*, 1991 Edition (AISI, 1991)

In 1991, the name of the AISI Advisory Group was changed to Committee on Specifications under the chairmanship of R.L. Brockenbrough and the vice chairmanship of J.M. Fisher.

The first edition of the AISI Load and Resistance Factor Design (LRFD) Specification was published in 1991. It was developed from a research project sponsored by AISI at the University of Missouri-Rolla under the direction of Wei-Wen Yu with consultation of T.V. Galambos and initial contribution of M.K. Ravindra (Hsiao, Yu and Galambos, 1990). In this LRFD Specification, separate load and resistance factors were applied to specified loads and nominal resistance to ensure that the probability of reaching a limit state is acceptably small. These factors reflect the uncertainties of analysis, design, loading, material properties and fabrication. They were derived on the basis of the first order probabilistic methodology as used for the development of the AISC Load and Resistance Factor Design Specification for Structural Steel Buildings.

This Specification contained six chapters of the LRFD recommendations for cold-formed steel structural members and connections. The nominal strengths used in the LRFD Specification were the same as that used for the ASD method. The load factors and load combinations were based on ASCE 7 - Load Standard with minor modifications. The background information for the design criteria was discussed in the AISI Commentary

and other related references (AISI, 1991).

LRFD Design Manual (AISI, 1991)

The contents of the AISI *LRFD Cold-Formed Steel Design Manual* are similar as the *ASD Cold-Formed Steel Design Manual* (AISI, 1986), except that Parts I and II are the LRFD Specification and the Commentary thereon. All illustrative examples (Part IV) and Computer Aids (Part VI) were prepared on the basis of the LRFD Specification.

(9) *1996 Edition* (AISI, 1996)

The AISI Allowable Stress Design (ASD) and Load and Resistance Factor Design (LRFD) Specifications were combined into a single document in 1996 during the chairmanship of R.L. Brockenbrough and vice chairmanship of J.W. Larson. In this combined ASD/LRFD specification, the format has been slightly modified. The safety factor, Ω, and the resistance factor, ϕ, are provided in each section along with the nominal strength equation. The detailed revisions and additions of the Specification are summarized by Brockenbrough in a separate conference paper (Brockenbrough, 1996).

Design Manual (AISI, 1996; Kaehler and Seaburg, 1996)

The 1996 edition of the AISI Design Manual has been reorganized and expanded for use with the 1996 edition of the AISI combined ASD/LRFD Specification. The newly revised Design Manual includes the following eight Parts:

Part I - Dimensions and Properties
Part II - Beam Design
Part III - Column Design
Part IV - Connections
Part V - Specification
Part VI - Commentary
Part VII - Supplementary Information
Part VIII - Test Procedures

The contents of the new Design Manual are discussed by Kaehler and Seaburg in a separate conference paper (Kaehler and Seaburg, 1996).

(10) *AISI Staff Support*

During the past 50 years, many AISI staff members have made significant contributions to the development of the AISI Specification. They include B.L. Wood, J.A. Schad, W.G. Kirkland, E.O. Stephenson, J.C. Spence, W.W. Yu, A.L. Johnson, R.A. LaBoube, R.B. Haws, D.F. Boring, K.C. Slaughter, S.P. Bridgewater, and many others. Their tireless effort and technical support provided to the AISI committees proved to be

important factors for the success of the cold-formed steel design technology.

OTHER SPECIFICATIONS AND ORGANIZATIONS

In the past, close liaison has been maintained between the AISI committee and other specification writing committees located in Canada, Europe, Australia and the United States (AISC, ASCE, ACI, etc.) through cross-memberships. The AISI Specification is also used as a reference standard in several specialized structural design standards such as those of MBMA, RMI, SDI, SJI, etc. A collaborative effort among Canadian, Mexican, and United States specification writing groups has recently been initiated (Schuster, 1995). Many members of the AISI committee have been very active in various professional societies, research councils, and trade associations which are concerned with cold-formed steel research and design.

RELATED PUBLICATIONS

1. Translations

Since 1960, the AISI Specification and Design Manual have been translated into German, Spanish, Italian, Chinese, and others. Many other specifications for the design of cold-formed steel structural members have been prepared on the basis of the AISI Specification with modifications to satisfy the national requirements for loads and the design criteria for hot-rolled steel shapes.

2. Stainless Steel Design Specification

Because the mechanical properties of stainless steels are significantly different from those of carbon steel, AISI published the first edition of the *Specification for the Design of Light Gage Cold-Formed Stainless Steel Structural Members* in 1968. The first Specification was prepared on the basis of the extensive research conducted by Johnson and Winter (1966) at Cornell University and the experience accumulated in the design of cold-formed carbon steel structural members. This Specification was revised and published by AISI in 1974 (AISI, 1974) to reflect the results of continuing research conducted by Wang, Errera and Winter (1975) and Errera, Popowich and Winter (1974). This AISI Specification was superseded by the ASCE Standard in 1990 (ASCE, 1991).

3. Automotive Steel Design Manual

In order to provide guidelines for the design of automotive components, AISI developed the first "Guide for Preliminary Design of Sheet Steel Automotive Structural Components," in 1981. It was based on the 1980 edition of the AISI *Specification for the Design of Cold-Formed Steel Structural Members* with the factors of safety removed to provide the automotive engineer with an ultimate strength of the component. In October 1986, AISI published the first edition of the *Automotive Steel Design Manual* (AISI, 1986), which contained five sections. From 1987 through 1996, six revisions have been issued by AISI. A computer software package AISI/CARS

in now available for design use.

4. Textbooks and Design Handbooks

Since the publication of the AISI *Specification for the Design of Light Gage Steel Structural Members* in 1946, the design of cold-formed steel members has been included as a chapter or section in a number of textbooks and engineering handbooks (Yu, 1991). In 1973, a textbook devoted entirely to cold-formed steel structures was published by McGraw-Hill Book Company (Yu, 1973). A revised version of the book was published by John Wiley & Sons in 1985 and 1991 (Yu, 1985 and 1991).

5. Preliminary Design Guide for C- and Z-Members

Preliminary Design Guide for Cold-Formed Steel C- and Z-Members (AISI, 1993) provides a simplified method of preliminary design for these members. The Guide was based on the 1986 edition of the AISI Specification with 1989 Addendum. The design equations have been calibrated by LaBoube to generally yield a conservative load or moment capacity, when compared to the Specification. It can serve as a mechanism for the casual user or code official to quickly verify the adequacy of a cold-formed steel member.

6. Computer-Aided Design, Decision Tables, and Flow Charts

Computer programs have been used extensively for research, design, and preparation of design tables. In 1991, AISI published a document "Cold-Formed Steel Design Computer Programs" for the analysis and design of cold-formed steel structural members. This publication was updated and expended by the Center for Cold-Formed Steel Structures in 1993 and 1996 (CCFSS, 1996).

The decision table formulation of the AISI *Specification* was originally developed by Seaburg (1971) and modified to conform to the 1986 edition of the *Specification* by Midgley-Clauer Associates (AISI, 1988). Since 1986, the AISI Design Manual contains a series of flow charts. These charts are excellent means of helping the user to understand the design provisions and to provide a clear picture of the items that need to be considered in design.

EDUCATIONAL PROGRAMS

1. AISI Programs

Since 1939, AISI has continuously sponsored a large number of research projects to investigate the behavior and structural strength of different types of cold-formed steel members, connections, and systems. In addition, the Institute has been very active to sponsor and to conduct short courses, seminars, and conferences throughout the United States. The Institute also sponsored college professors and established fellowships for graduate students to study cold-formed steel design. Currently, AISI has developed the following programs through it Education

Subcommittee: (1) One-Hour Slide Talk on Cold-Formed Steel Structures, (2) Three-Hour Seminar on Lightweight Steel Framing, (3) Six-Hour Lecture Series on Cold-Formed Structural Steel Design, (4) Cold-Formed Steel Construction Booklet, (5) Manual on Lightweight Steel Framing. Lecture notes for the LRFD seminar are also available from the Center for Cold-Formed Steel Structures.

2. Short Courses and Seminars

The first seminar on the design of light gage cold-formed steel structures was sponsored by AISI at West Virginia University in 1965 (Yu, 1965). Since that time, short courses have been conducted at Cornell University, University of Missouri-Rolla, University of Wisconsin-Madison, University of Wisconsin-Milwaukee, University of Pittsburgh, University of Maryland, and University of Houston, just name a few. In addition, different seminars have been organized and conducted by individual speakers, various professional engineering societies, trade associations, and manufacturing companies.

3. Specialty Conferences

The first Specialty Conference on Cold-Formed Steel Structures was held at the University of Missouri-Rolla in 1971. This year is the Silver Anniversary of the Specialty Conference. During the past 25 years, 12 international specialty conferences were held to review the research findings and the development of design methods. The Golden Anniversary of the AISI Specification will be celebrated at the Thirteenth International Specialty Conference on Cold-Formed Steel Structures on October 17, 1996. Proceedings containing technical papers have been published for all conferences.

4. Center for Cold-Formed Steel Structures

The Center for Cold-Formed Steel Structures was established at the University of Missouri-Rolla in May 1990. The Center's activities focus on four main areas: Research, Engineering Education, Technical Services, and Profession Activity. Currently, the Center is financially supported by the American Iron and Steel Institute, Metal Building Manufacturers Association, Rack Manufacturers Institute, Steel Deck Institute, and the University of Missouri-Rolla.

CONCLUSIONS

The first edition of the *Specification for the Design of Light Gage Steel Structural Members* was prepared and published by American Iron and Steel Institute in 1946. During the past 50 years, numerous important revisions have been made periodically by the AISI Committees to reflect the results of continuing research and the advances in design techniques. This paper summarizes the improvements made in various editions of the Specification to satisfy the needs of the design profession using new materials. Other related publications and activities are also outlined in this presentation.

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