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International Specialty Conference on Cold-  
Formed Steel Structures

(1980) - 5th International Specialty Conference  
on Cold-Formed Steel Structures

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Nov 18th, 12:00 AM - Nov 19th, 12:00 AM

## Fifth International Specialty Conference on Cold-Formed Steel Structures

University of Missouri--Rolla

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FIFTH INTERNATIONAL SPECIALTY  
CONFERENCE ON COLD-FORMED  
STEEL STRUCTURES

RECENT RESEARCH  
AND DEVELOPMENTS IN  
COLD-FORMED STEEL

NOVEMBER 18-19, 1980

**Continuing Education**

**Fifth International Specialty Conference on  
Cold-Formed Steel Structures**

**Recent Research  
and Design Trends in  
Cold-Formed  
Steel Structures**

**November 18-19, 1980**

**University of Missouri-Rolla**

**Fifth International Speciality Conference on  
Cold-Formed Steel Structures**

**RECENT RESEARCH AND DESIGN TRENDS IN  
COLD-FORMED STEEL STRUCTURES**

**Held in St. Louis, Missouri, U.S.A.  
November 18-19, 1980**

**Edited by  
Wei-Wen Yu and Joseph H. Senne**

**Department of Civil Engineering  
University of Missouri-Rolla**

**Presented by**

Department of Civil Engineering  
University of Missouri-Rolla

**Sponsored by**

American Iron and Steel Institute  
Metal Building Manufacturers Association  
University of Missouri-Rolla  
Continuing Education

**In cooperation with**

ASCE Committee on Cold-Formed Members  
Canadian Sheet Steel Building Institute, Canada  
Rack Manufacturer's Institute  
Steel Deck Institute  
Structural Stability Research Council Task Group on  
Thin-Walled Metal Construction  
University of Strathclyde, Scotland

**Conference Directors**

Wei-Wen Yu, Professor of Civil Engineering  
University of Missouri-Rolla;  
Chairman, Structural Stability Research Council Task Group on  
Thin-Walled Metal Construction  
Joseph H. Senne, Chairman and Professor of Civil Engineering  
University of Missouri-Rolla

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S.J. Errera-Bethlehem Steel Corporation;  
Representative of the ASCE  
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D.L. Johnson-Butler Manufacturing Company; Advisor  
H. Klein-Sturdi-Bilt; Representative of RMI  
K.H. Klippstein-United States Steel Corporation;  
Representative of the AISI Building Construction Department  
J. Rhodes-Representative of the University of Strathclyde,  
Scotland  
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Civil Engineering  
D.L. Tarlton-Representative of CSSBI, Canada  
G. Winter-Cornell University; Advisor  
D.S. Wolford-Private Consultant; Advisor  
W.W. Yu-UMR; Representative of the SSRC Task Group on  
Thin-Walled Metal Construction

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# PREFACE

During the past, cold-formed steel members have been used in virtually every area of construction. In order to review the research findings and the design methods developed in this field, four International Specialty Conferences on Cold-Formed Steel Structures were held since 1971.

Since 1978, significant progress has been made in various studies of cold-formed steel members and structural systems throughout the world. The Fifth International Specialty Conference on Cold-Formed Steel Structures was held in St. Louis, Missouri, on November 18-19, 1980. This Conference was sponsored by the American Iron and Steel Institute (AISI), Metal Building Manufacturers Association (MBMA), and the University of Missouri-Rolla (UMR) in cooperation with the American Society of Civil Engineers (ASCE) Committee on Cold-Formed Members, Canadian Sheet Steel Building Institute (CSSBI), Rack Manufacturers Institute (RMI), Steel Deck Institute (SDI), Structural Stability Research Council Task Group on Thin-Walled Metal Construction, and the University of Strathclyde, Scotland.

This publication contains 33 papers presented at the Conference. These papers not only report the results of recent research but also discuss the technical developments in cold-formed steel design and construction.

As Directors of the Conference, we are very grateful to all the sponsors and supporting organizations for their financial and technical support and to all authors for their contributions in the field of cold-formed steel structures. Appreciation is also due to members of the Planning Committee (D.S. Ellifritt, S.J. Errera, N.R. Fleming, R.B. Heagler, A.L. Johnson, D.L. Johnson, H. Klein, K.H. Klippstein, J. Rhodes, D.L. Tarlton, G. Winter and D.S. Wolford) for review and selection of the papers and their advice in preparation of the conference.

We wish to express our sincere thanks to Dr. Robert L. Davis, Dean of the School of Engineering of the University of Missouri-Rolla, for his welcoming remarks.

Appreciation should also be expressed to all Chairmen of the technical sessions listed in the program.

Finally, we wish also to thank the many faculty and staff members of the University of Missouri-Rolla, Dean R.L. Davis, Dean G.E. Lorey, Professor J.B. Heagler, Mrs. N.R. Fleming, Mr. R.A. Blaylock, and many others. Their advice, encouragement and contributions have been of great value to the conference.

Special thanks are extended to Mrs. DeAnne Larson for her assistance in preparing this publication.

Wei-Wen Yu  
Joseph H. Senne

## PROGRAM

### MONDAY, NOVEMBER 17, 1980

6:00 p.m.-9:00 p.m. Registration: Marriott's Pavilion Hotel

### TUESDAY, NOVEMBER 18, 1980

7:00 a.m.-4:00 p.m. Registration

8:00 a.m. **Opening Session**

Presiding: J.H. Senne, Chairman and Professor of  
Civil Engineering, University of  
Missouri-Rolla

"Welcoming Remarks"

R.L. Davis, Dean of the School of  
Engineering, University of Missouri-Rolla

#### **Technical Session No. 1**

##### **DESIGN METHOD DEVELOPMENTS**

Presiding: George Winter, Professor of Structural  
Engineering, Emeritus (Class of 1912  
Chair), Cornell University, Ithaca,  
New York

"AISI's Cold-Formed Steel Design Specification -  
Recent Changes," A.L. Johnson, American Iron and  
Steel Institute, Washington, D.C.

"European Recommendations for Cold-Formed  
Sheet Steel in Building," E.R. Bryan, University of  
Salford, England, U.K.

"Engineering Education on Cold-Formed Steel  
Design," P.A. Seaburg, Armco, Inc., Middletown,  
Ohio

10:00 a.m. Coffee Break

10:30 a.m. **Technical Session No. 2**

##### **BUCKLING BEHAVIOR AND POSTBUCKLING STRENGTH OF FLAT ELEMENTS AND SHELLS**

Presiding: K.H. Klippstein, Chairman, AISI Advisory  
Group on the Specification for the Design  
of Cold-Formed Steel Structural Members;  
Associate Research Consultant, United  
States Steel Corporation Research  
Laboratory, Monroeville, Pennsylvania

"Compressional Behavior of Thick Plate Elements,"  
J. Rhodes, University of Strathclyde, Glasgow,  
Scotland; and I.H. Marshall, Paisley College of  
Technology, Paisley, U.K.

"Post-Buckling Behavior of Bi-Axially Loaded Plates,"  
W.J. Supple and P.J. Wicks, University of Surrey,  
Guildford, Surrey, U.K.

"Intermediate Stiffeners for Thin-Walled Members,"  
T.P. Desmond, Stanford Research Institute, Menlo  
Park, California; T. Pekoz, and G. Winter, Cornell  
University, Ithaca, New York

"Doubly Corrugated Barrel Cold-Formed Steel  
Shells," G. Abdel-Sayed, University of Windsor,  
Windsor, Ontario; G.L. Pierce, Saskatchewan  
Research Council, Saskatoon, Saskatchewan, and

	W.D. Siddall, Fairford Industries Ltd., Moose Jaw, Saskatchewan
12:00 noon	Lunch
1:00 p.m.	<b>Technical Session No. 3</b> <b>STRUCTURAL BEHAVIOR AND ANALYSIS OF FLEXURAL MEMBERS</b> Presiding: S.J. Errera, Chairman, ASCE Committee on Cold-Formed Members; Consulting Engineer, Bethlehem Steel Corporation, Bethlehem, Pennsylvania  "Inelastic Load Carrying Capacity of Cold-Formed Steel Beams," M. Yener and T. Pekoz, Cornell University, Ithaca, New York  "Analysis of Closed Section Thin-Walled Beams Subjected to Partially Restrained Warping," T.H.G. Megson and J. Ergatoudis, University of Leeds, Leeds; and J. Nuttall, PAFEC Ltd., Nottingham, U.K.  "Experimental Study of the Behavior of Cable Trays Used in Nuclear Power Plant Applications," S.G. Pinjarkar, Construction Technology Laboratories, Portland Cement Association, Skokie, Illinois
2:15 p.m.	<b>Technical Session No. 4</b> <b>STRENGTH OF BEAM WEBS</b> Presiding: J. Rhodes, Senior Lecturer, Department of Mechanics of Materials, University of Strathclyde, Glasgow, Scotland, U.K.  "Bending Strength of Cold-Formed Steel Longitudinally Reinforced Beam Webs," P. Nguyen, Black & Veatch Consulting Engineers, Kansas City, Kansas, and W.W. Yu, University of Missouri-Rolla, Rolla, Missouri  "Post-Buckling Shear Strength of a Cold-Formed Steel Joist," G.T. Suter and J.L. Humar, Carleton University, Ottawa, Canada
3:00 p.m.	Coffee Break
3:30 p.m.	<b>Technical Session No. 5</b> <b>COLUMNS AND FRAMES</b> Presiding: A.L. Johnson, Staff Representative, American Iron and Steel Institute, Washington, D.C.  "Simple Design Analysis of Lipped Channel Columns," J. Rhodes, University of Strathclyde, Scotland; and J. Loughlan, Cranfield Institute of Technology, England, U.K.  "Lateral Bracing of Locally Buckled Columns," S.T. Wang, H.Y. Pao, and R. Ekambaram, University of Kentucky, Lexington, Kentucky  "Behavior of Cold-Formed Steel Studs in Fire Tests," K.H. Klippstein, United States Steel Corporation Research Laboratory, Monroeville, Pennsylvania
4:45 p.m.	Adjourn
6:00 p.m.	Social Hour
7:00 p.m.	Banquet - on board the Lt. Robert E. Lee (Mississippi Riverboat)

## WEDNESDAY, NOVEMBER 19, 1980

7:00 a.m.-12:00 noon, Registration

8:00 a.m. **Technical Session No. 6**

### **SHEAR DIAPHRAGMS AND STRUCTURES BRACED BY DIAPHRAGMS**

Presiding: D.S. Ellifritt, Director of Engineering and Research, Metal Building Manufacturers Association, Cleveland, Ohio

"Theoretical and Physical Evaluations of Steel Shear Diaphragms", H.T. Huang, Pittsburgh-Des Moines Steel Company, Pittsburgh, Pennsylvania, and L.D. Luttrell, West Virginia University, Morgantown, West Virginia.

"Shear Resistance of Steel-Stud Wall Panels," T.S. Tarpy, Jr., Vanderbilt University and Stanley D. Lindsey and Associates, Nashville, Tennessee

"Behavior and Design of Continuous Girts and Purlins," D. Polyzois and P.C. Birkemoe, University of Toronto, Toronto, Ontario, Canada

9:15 a.m. **Technical Session No. 7**

### **COMPOSITE DESIGN**

Presiding: R.B. Heagler, Chairman, SDI Floor Deck Technical Committee; Director of Engineering, United Steel Deck, Inc., Summit, New Jersey

"Coating Effects of Cold-Formed Steel Deck Slabs," M.L. Porter and C.E. Ekberg, Iowa State University, Ames, Iowa

"Mechanical Interlocking Capacity of Composite Slabs," R.M. Schuster and W.C. Ling, University of Waterloo, Waterloo, Ontario, Canada

10:00 a.m. Coffee Break

10:30 a.m. **Technical Session No. 8**

### **RACK STRUCTURES**

Presiding: H. Klein, Chief Engineer, Unarco Materials Storage, Unarco Industries, Inc., Chicago, Illinois

"Stability of Unbraced Pallet Racks," J.M. Davies, University of Salford, England, U.K.

"Seismic Response of Industrial Steel Storage Racks," C.K. Chen, R.E. Scholl, and J.A. Blume, URS/John A. Blume and Associates, San Francisco, California

"The Design of Adjustable Storage Shelves," J. Rhodes, W. King, and J.M. Harvey, University of Strathclyde, Scotland, U.K.

"The Effects of Frictional Restraint on the Stability of a Simple Strut," M.H.R. Godley, Oxford Polytechnic, England, U.K.

12:00 noon Lunch

1:00 p.m. **Technical Session No. 9**

### **STEEL BUILDINGS**

Presiding: D.L. Tarlton, General Manager, Canadian Sheet Steel Building Institute, Willowdale, Ontario, Canada

- "Light Gage Space Structures with Prestressing," Lev Zetlin, Zetlin-Argo, Liaison and Guidance Corp. New York, New York
- "Some Important Applications of Cold-Formed Members in Open-Web Joists and Trusses," J.W. Hubler, University of Central Florida, Orlando, Florida
- "Energy Considerations in Low-Rise Steel Buildings," E.W. Machaj and A.S. Zakrzewski, Dominion Foundries and Steel, Limited, Hamilton, Ontario, Canada
- "State of the Art-Cylindrical Cold-Formed Steel Farm Structures," G. Abdel-Sayed, University of Windsor, Windsor, Ontario; C. Fung, Westeel-Rosco Ltd., Toronto, Ontario; and F. Monasa, Michigan Technological University, Houghton, Michigan
- 2:30 p.m. **Technical Session No. 10**  
**CONNECTIONS**  
 Presiding: D.L. Johnson, Senior Research Engineer, Research Center, Butler Manufacturing Company, Kansas City, Missouri
- "Welded Connections in Cold-Formed Sections," J.W.B. Stark and F. Soetens, Institute TNO for Building Materials and Building Structures, Delft, Netherlands
- "Welding of Sheet Steel," T. Pekoz and W. McGuire, Cornell University, Ithaca, New York
- "T-Joints Made of Rectangular Tubes," B. Kato and I. Nishiyama, University of Tokyo, Japan
- 3:40 p.m. **Technical Session No. 11**  
**MECHANICAL PROPERTIES AND SPECIAL DESIGN PROBLEMS**  
 Presiding: D.S. Wolford, Consultant, Middletown, Ohio
- "Fatigue Behavior of Sheet-Steel Fabrication Details," K.H. Klippstein, United States Steel Corporation Research Laboratory, Monroeville, Pennsylvania
- "Elastic Modulus of Cold-Formed Sheet Steel," K.R. Venkataramaiah, Stone and Webster Canda Ltd., Toronto, Ontario, Canada; J. Roorda, University of Waterloo, Waterloo, Ontario, Canada; and K.R. Srinivasaiah, EDS Nuclear Inc., San Francisco, California
- "Design for Manufacturability," G.T. Halmos, Delta Engineering Ltd., Willowdale, Ontario, Canada
- 4:50 p.m. **Closing Remarks**  
 Wei-Wen Yu, Professor of Civil Engineering, University of Missouri-Rolla

# AISI'S COLD-FORMED STEEL DESIGN SPECIFICATION - RECENT CHANGES

by

Albert L. Johnson (1)

## INTRODUCTION

The newly published Edition of AISI's Specification for the Design of Cold-Formed Steel Structural Members represents a major revision, with many changes made to keep the Specification responsive to the needs of users. It reflects the results of research projects and improvements in design techniques.

This paper will highlight the more significant changes since publication of the 1968 Edition of the Specification, including those changes made in Addenda Numbers 1 and 2 published in 1970 and 1977. A description of the change, the reason for making the change with supporting evidence and its significance will be given. There is also an attempt to identify potential future changes to be based on research in progress and to continue to meet the changing needs of the design provision.

A number of editorial clarifications have been made throughout the Specification to lesson ambiguity and to make provisions less subject to misinterpretation. Equations have been numbered for the convenience of the user.

## MAJOR CHANGES

The more significant revisions which appear in the latest Edition of the Specification can be grouped as follows:

Materials

Webs of Flexural Members

Inelastic Reserve Capacity of Flexural Members

Arc Welds

Bolted Connections

Wall Studs

Channel and Z-Sections Used As Beams

Tests For Special Cases

---

(1) Staff Representative, American Iron and Steel Institute, 1000 16th Street, N. W., Washington, D. C. 20036

## MATERIALS

Occasionally there are reasons for using steels which are not listed by ASTM designation. In these cases, one of the most important factors is the ductility. The Specification now defines minimum ductility requirements as a minimum ratio of tensile to yield point and as a minimum elongation, as determined by a Cornell University study.

Steels with less ductility, such as full-hard ASTM A446 and A611, may be used provided the allowable basic design stress does not exceed 45 percent of the specified minimum yield nor 36 ksi. This removes a loop hole wherein there was no specific guidance for full-hard steels and where individual designers and manufacturers used different allowables.

The list of ASTM Specifications has been updated and expanded. The full-hard steels have been deleted from the basic list in keeping with the ductility provisions and new allowables. ASTM A446 Grade F has been added. High strength, low alloy hot rolled steel with improved formability has been added with listing of ASTM A715, Grades 50 and 60.

The thickness maximum of the Specification was increased to one inch in Addendum Number 2. This increase called for a listing of plate and bar steels to go above the thickness range covered by sheet and strip.

Delivered minimum thickness was spelled out in Addendum Number 2. This simply requires that the uncoated minimum thickness of the formed product as delivered be greater than or equal to 95 percent of the design thickness. This will avoid the possibility of capacity significantly less than required, and is particularly important in small thicknesses where rolling tolerances are greater.

## WEBS FOR FLEXURAL MEMBERS

All the provisions which are concerned with web design have been extensively revised.

The maximum depth to thickness ratio of unreinforced webs has been increased to 200. For webs provided with transverse stiffeners, the depth to thickness ratio may be even greater: 260 when bearing stiffeners only are added, and 300 when both bearing stiffeners and intermediate stiffeners are added. Specific provisions for proportioning stiffeners are included.

Provisions for allowable shear and bending stresses in webs or beams have been changed in keeping with the increased maximum depth to thickness ratios. The shear allowables recognize the possible use of transverse stiffeners; the allowable bending stress differentiates between beams with stiffened compression flanges and beams with unstiffened compression flanges. An additional bending-shear interaction equation has been added for webs with transverse stiffeners.

Web crippling provisions have been modified and expanded. A tabular format is used to avoid confusion, with one table giving allowable concentrated loads for shapes with single webs, and another for sections which have a high degree of restraint against rotation of the web. Allowable



concentrated loads now depend on the inclination of the web and whether or not there are opposite concentrated loads, as well as the formerly used parameters of thickness, web depth, length of bearing, and bend radius.

Addendum Number 2 contained a reduction factor intended to avoid potential failure through the combined action of bending and web crippling. This factor was found to be excessively conservative, particularly when used in conjunction with the former allowables for bending moment and concentrated loads. Testing has indicated that a more liberal approach may be taken. In addition, there is an exception for certain cases of continuous beams at interior supports under specified conditions of lateral support and web spacing.

All of the changes on web limits, allowable stresses, and interaction are based on an extensive research project at the University of Missouri-Rolla. We may anticipate further refinement in the case of interaction of bending and crippling as additional tests sponsored by the Steel Deck Institute, AISI, and H. H. Robertson are completed and evaluated.

#### INELASTIC RESERVE CAPACITY OF FLEXURAL MEMBERS

A completely new section has been added to permit the designer to utilize a portion of the inelastic reserve under fairly tight restrictions. The member may not be subject to buckling, cold-forming may not be considered, and the member must be relatively compact. However, in those cases which qualify, the design moment may be as much as 75 percent of the yield moment or 60 percent of the ultimate moment. This new section is based on research at Cornell University.

#### ARC WELDS

The provisions for arc welds have been completely revised, based on a coordinated effort by AISI and American Welding Society. AWS D1.3, Specification for Welding Sheet Steel in Structures, is referred to for welding procedures, qualification, and inspection. Allowable stresses on welds made in accordance with the AWS Specification are given by AISI. These provisions apply for steel with connected parts 0.18 inches and less in thickness, with reference made to AISC for larger thicknesses. Of particular importance are design provisions for determining the carrying capacity of arc spot welds ("puddle welds"), and arc seam welds.

The coordinated AISI/AWS work involved cooperation among structural engineers and welding specialists. All of the welds now listed in the Specification were made under varying conditions, and their load carrying capacities evaluated by tests.

We do anticipate that further study will permit reduction or elimination of the pre-heat requirements for attaching deck to rolled structural shapes. Tension on arc spot welds is the next priority for future study; the Specification is silent on that loading mode at present.

### BOLTED CONNECTIONS

Provisions for design of bolted connections have been completely revised, based on research at the University of Missouri-Rolla. All allowables are now based on ultimate strength rather than yield point. Criteria for bolted connections without washers have been added. The allowable shear stress on bolts has been increased, and small diameter high strength bolts are now covered with listing of ASTM A354 and A449.

The AISI provisions are for connections in which the thickness of the thinnest connected part is less than  $3/16$  inch. For greater thicknesses, reference is made to the AISI Specification.

Research in progress may provide additional information on bolt installation procedures. Because of the short grip length encountered in cold-formed construction, and the fact that friction joints are not permitted, the installation procedures used in heavier steel connections are not applicable.

### WALL STUDS

Provisions for the design of wall studs which are braced by sheathing have been completely revised and expanded. The design is now based on the shear stiffness of the sheathing material, rather than on the extensional stiffness formerly used. The sheathing need not be identical on both sides of the stud; in fact, the provisions anticipate the possible use of sheathing on one side only. These revisions are based on research at Cornell University, and make reference to a computer program developed in conjunction with that research. Wall board parameters are given for common types of sheathing material, with reference to small specimen test procedures for determination of the parameters for other types of sheathing.

### CHANNEL AND Z-SECTIONS USED AS BEAMS

For many years, the designer has been cautioned that "bracing may or may not be required" when only one flange is connected to deck or sheathing. More direct guidance to the designer has been given as a result of several areas of cooperative effort by the Metal Building Manufacturers Association and AISI. Tests continue, and there is some possibility that even more specific guidance to the designer can be provided in the future; however, we have made a significant improvement over previous editions.

The requirements for spacing of braces had been modified to relax the requirement of braces at the quarter points for the case when all loads and reactions on a beam are made through members which frame into the beam and thus act as braces. This case is encountered in the end walls of pre-engineered buildings.

### TESTS FOR SPECIAL CASES

This entire section has been arranged to improve clarity. Substantive changes include a clear distinction between performance tests and confirmatory tests. In the case of performance tests, the multipliers for dead and live

load now include a higher multiplier for capacity limited by connection failure, reflecting the higher margin between service load and ultimate load for connections. The provisions for compression yield point determinations, used in determining the influence of cold work, anticipate publication of a stub column test procedure in the near future.

#### OTHER CHANGES

A few other substantive changes warrant attention.

A new section has been added for the case of torsional buckling of point symmetric sections, such as cruciform sections. This is a rare occurrence, but it was believed appropriate to provide specific recommendations.

The section on bracing and secondary members has been deleted. This section permitted a higher compression stress on the gross section of axial loaded bracing and secondary members; it was deleted because of the lack of an accepted definition for that type of member.

#### ANTICIPATED FUTURE REVISIONS

Several areas where further changes are anticipated were noted in the foregoing discussion. Other portions of the Specification where we may expect changes in the future are in the treatment of flange stiffeners, the design approach for unstiffened compression elements, and column design. Research in these areas is complete or is nearing completion, and proposed revisions will be drafted for consideration by the Advisory Group on the Specification.

#### ACKNOWLEDGEMENTS

AISI acknowledges the devoted efforts of the members of the Advisory Group on the Specification for the Design of Cold-Formed Steel Structural Members. This group, comprised of consulting engineers, researchers, designers from companies manufacturing cold-formed steel members, components, assemblies, and complete structures, and specialists from the steel producing industry has met two to three times per year since its establishment in 1973. Its members have made extensive contributions of time and effort in developing and reaching consensus on the changes which have been described above.

All users of the Specification are invited to continue to offer their valuable comments and suggestions. The cooperation of all involved, the users as well as the writers, is needed to continue to keep the Specification up to date and a useful tool for the designer.