The New Guide to Stability Design Criteria for Metal Structures

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THE PURPOSE of this report is to review the 3rd Edition of the "CRC Guide" for readers of the AISC *Engineering Journal.* There has always been a close and special relationship between the American Institute of Steel Construction and the Column Research Council, officially renamed the "Structural Stability Research Council" in March, 1976. The new name reflects the broadened coverage of the Council that has been gradually achieved over the past 32 years of its history. The name of the 3rd Edition of the "CRC Guide", published in April of 1976, has likewise been changed as indicated in the above title of this review.

In 1961 the AISC Advisory Committee on Specifications made major revisions in the AISC *Specification for the Design, Fabrication and Erection of Structural Steel for Buildings.* These included extensive improvements in clauses pertaining to the buckling behavior of laterally unsupported beams, columns, and beam-columns. These changes were needed because of the introduction at that time of higher strength steels and by the corresponding possibility of achieving greater economy and correctness in the design of steel structures. The AISC Advisory Committee on Specifications turned to the Column Research Council to provide backup and substantiation for the new specification it was about to introduce. It was at that time, too, that architectural concepts in the construction of steel buildings were breaking sharply away from the traditional types of the past. Simplified procedures that had evolved through successful past experience were no longer adequate for the new steels and the new, varied shapes of current construction practice.

A major factor in shaping specification clauses pertaining to steel column design was the recognition of the role of internal residual stress as a primary influence affecting buckling behavior, and the resulting research initiated by Column Research Council. In 1908, Howard,[1] discussing tests at the Watertown Arsenal, had cited residual stresses due to cooling of hot-rolled members as a probable cause of reduced column strength in the intermediate slenderness range. Subsequently, the importance of this effect was largely obscured by the ease in explaining column strength deficiencies through the existence of hypothetical initial curvatures and end eccentricities. The coordinated research on residual stress effects that was begun by Column Research Council in the late 1940's[2,3] has since mushroomed into major investigations throughout the world—in Europe, Japan, Canada, and Australia. The AISC deserves much credit for its role in funding much of the initial residual stress research carried out at Lehigh University.

The following summary relates the new 3rd Edition of the guide to its predecessors:

Edition:	1	2	3
Year published:	1960	1966	1976
No. of chapters:	5	7	19
No. of pages:	93	217	616
No. of references:	157	327	902

One may well hesitate to extrapolate the foregoing tabulation to a 4th edition. Nevertheless, plans are now being made regarding a 4th edition and Dr. T. V. Galambos has agreed to be its editor.

The 1st Edition of the Guide, published by the Council, was unique in that it provided for the first time a column-strength curve that was based realistically on the proven effects of residual stresses in steel members. Its scope was largely restricted to the behavior of columns in trusses and building frames, to laterally unsupported beams, and to beam-columns through the use of interaction formulas. As mentioned, it also provided backup for the 1961 AISC Specification revisions.

At the time of publication of the 1st Edition, the Council had research in progress relating to the use of tension-field action in plate girder webs. Results of this research, as published in the 2nd Edition of the Guide, found direct and innovative design application in the AISC Specification. The 2nd Edition also included a new chapter on intermittently supported compression members.

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This paper is based on a talk given at the 1976 AISC National Engineering Conference in Atlanta, Ga.

The 3rd Edition is largely a new book.* It is the result of the combined effort of more than 110 engineers and researchers who have participated in the five year project. Of these, more than 40 have coauthored portions of the manuscript. The book provides a new and up-to-date summary of research results and their application to design, thus continuing the concept of providing design alternatives that leave to the engineer and specification writer the selection of specific design formulas or procedures, together with appropriate load and resistance factors.

SYNOPSIS

Following is a synopsis of the 3rd Edition, chapter by chapter, with brief comment on some of the salient features.

Chapter 1, Introduction, includes a survey of the mechanical properties of the available structural steels, structural aluminum alloys, and stainless steels. A section providing definitions of terms relating to buckling behavior is followed by a closing discussion of the three classes of buckling behavior for which critical load determinations are overconservative, directly usable, or unconservative in design application.

In *Chapter 2, Structural Safety,* load and resistant factor design (limit states design) is summarized. The following excerpt keynotes the chapter: "Realizing that the traditional approach of using factor-of-safety procedures is not entirely adequate, and that the completely probabilistic approach is too idealistic and ultimately too complex, researchers have been turning their efforts to achieve a compromise solution by retaining some of the simplicity of the traditional approach while incorporating probabilistic concepts to a degree." The chapter closes with illustrations of unsafe column design details.

Chapter 3, Centrally Loaded Columns, is a rewrite of the 2nd Edition chapter of the same title. There is much new residual stress information for a broad range of rolled and welded steel structural shapes, including the combined effect on column strength of residual stress and initial out-of-straightness. It is shown that it is now possible to segregate column strength curves into various classes, providing a basis for the "multiple column curve" design concept that has been adopted in a number of European specifications. The pros and cons of the resulting "design procedure alternatives" are discussed. Other topics in the chapter include effects of welding, cold-straightening, and the effective length of trussed or framed members.

Chapter 4, Local Buckling of Plates, provides a summary of formulas that have been developed for the calculation of both the critical load and post-buckling strength of individual plate elements under a variety of boundary and in-plane load conditions. The effective-width concept is used extensively as a means of establishing the post-buckling strength.

Chapter 5, Dynamic Load Effects, provides an introductory insight into this important topic. This new chapter includes a brief summary of parametric excitation and resonance, illustrated by a consideration of an initially straight column subjected to a periodic axial force.

Chapter 6, Laterally Unsupported Beams, similar to its 2nd Edition counterpart but with many new references added, provides information, with design examples, for evaluating the strength of both open and box-section beams and girders that are laterally unsupported. In many special situations, not directly covered by standard specifications, this information can lead to savings in material. Also included is a new section on continuous beams.

Chapter 7, Plate Girders, is a completely new version of the 2nd Edition chapter of the same name. Emphasis continues to be on the utlimate shear strength of the thin web, concerning which many refinements have been developed in recent years. An in-depth statistical study of test results in relation to 10 different mechanisms of web and flange participation is included. There is also increased coverage on the behavior of webs with transverse and longitudinal stiffeners.

Chapter 8, Beam-Columns, is greatly expanded, with more than half of its length now devoted to biaxial bending. As in the 2nd Edition, both maximum stress and ultimate strength procedures are included. This chapter shows that current design procedures for biaxial bending are generally overly conservative and provides information that should substantially improve design economy.

Chapter 9, Thin-Walled Metal Construction, is new, and is devoted to design practice involving the buckling behavior of members made up of thin plate components. Buckling in flexure, compression, and torsion, alone or in combination, are among the topics that are covered.

Chapter 10, Circular Tubes and Shells, although new, is the longest chapter in the guide, covering 68 pages and including 141 references. It has input by a number of specialists in off-shore oil drilling structures and covers the bending, axial, and pressure loads acting on cylindrical shells, alone or in combination. Both stiffened and unstiffened tubes and shells are included in this summary of design and test information.

Chapter 11, Tapered Structural Members, provides new information regarding their stiffness characteristics in frames, as modified by axial load. The buckling behavior of the individual members, acting as beams, columns, or beam-columns, is also treated, and design formulas in a modified AISC Specification format are provided.

Chapter 12, Columns With Lacing, Battens, or Perforated Cover Plates, covers the effects of shear distortion in reducing critical column loads. Design examples are included and the importance of end tie plates in weakly battened columns is demonstrated.

Chapter 13, Mill-Building Columns, is a brief treatment of the stepped mill-building column, showing how the AISC Specification may be modified for application to heavy industrial mill-building bents. A design example is included.

* *Published by Wiley-Interscience, Div. of John Wiley and Sons, Inc., New York, N.Y.*

Chapter 14, Members with Elastic Lateral Restraints, is essentially the same as the 2nd Edition chapter on "Pony Trusses". Application to other structures, such as the laterally unbraced chord of a through plate girder or a guyed tower, is discussed.

Chapter 15, Multistory Frames, covers a subject wherein alternative design procedures and assumptions are under current scrutiny. The use of effective length, the P-Δ design procedure, and the plastic design method are illustrated by design examples. The chapter was scrutinized by a number of tall building design specialists and went through many revisions before finalization.

Chapter 16, Arches, is entirely new, and includes a summary of information on both in-plane and out-of-plane buckling of various types of arches. Both stiffened and tied arches are included, as well as the special problems that arise in the case of very shallow arch construction.

Chapter 17, Stiffened Flat Plates, another new chapter, covers the use of both longitudinal and transverse stiffeners, separately or in combination, with stiffened plates under in-plane, lateral, or combined loads.

Chapter 18, Shells and Shell-Like Structures, also new, covers the buckling behavior and summarizes design procedures pertinent to latticed, stiffened, and other types of "shell-like" structures for which a modified shell theory may be used to determine structural performance.

Chapter 19, Composite Columns, includes coverage of both concrete encased wide-flange shapes and concrete filled tubular columns. It is an entirely new chapter, covering design procedures advocated by a number of specifications.

The Appendices, in addition to general references, historical notes concerning the Council, and acknowledgments, include the Technical Memorandums of the Council: *No. 1: The Basic Column Formula; No. 2: Notes on the Compression Testing of Metals; No. 3: Stub-Column Test Procedure;* and *No. 4: Procedure for Testing Centrally-Loaded Columns.*

Although the guide has been five years in preparation, the chapters have been revised and updated during the period, with critical reviews by engineers and researchers most expert in the particular chapter category. Thus, the guide provides the most authoritative design information available at this time pertinent to structural problems involving buckling behavior.

REFERENCES

1. *Howard, J. E.* Some Results of the Tests of Steel Columns, in Progress at the Watertown Arsenal *Proc. ASTM, Vol. 8, 1908.*
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