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American Society of Civil Engineers

Specification for Structural Steel Beams with Web Openings

This document uses both Système International (SI) units and customary units.

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ABSTRACT

This Specification covers the design of composite and noncomposite beams with web openings. Basic design procedures involve determination of maximum nominal flexural capacity, maximum nominal shear capacity, and interaction of flexure and shear. Section properties are limited to ensure ductile behavior. Rectangular and circular openings, with or without opening reinforcement, are addressed. The specification follows load and resistance factor design philosophy.

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STANDARDS

In April 1980, the Board of Direction approved ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by the Society. All such standards are developed by a consensus standards process managed by the Management Group F (MGF), Codes and Standards. The consensus process includes balloting by the balanced standards committee made up of Society members and nonmembers, balloting by the membership of ASCE as a whole, and balloting by the public. All standards are updated or reaffirmed by the same process at intervals not exceeding 5 years.

The following Standards have been issued.

ANSI/ASCE 1-82 N-725 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures

ANSI/ASCE 2-91 Measurement of Oxygen Transfer in Clean Water

ANSI/ASCE 3-91 Standard for the Structural Design of Composite Slabs and ANSI/ASCE 9-91 Standard Practice for the Construction and Inspection of Composite Slabs

ANSE 4-86 Seismic Analysis of Safety-Related Nuclear Structures

Building Code Requirements for Masonry Structures (ACI530-95/ASCE5-95/TMS402-95) and Specifications for Masonry Structures (ACI530.1-95/ ASCE6-95/TMS602-95)

ANSI/ASCE 7-95 Minimum Design Loads for Buildings and Other Structures

ANSI/ASCE 8-90 Standard Specification for the Design of Cold-Formed Stainless Steel Structural Members

ANSI/ASCE 9-91 listed with ASCE 3-91

ANSI/ASCE 10-97 Design of Latticed Steel Transmission Structures

ANSI/ASCE 11-90 Guideline for Structural Condition Assessment of Existing Buildings

ANSI/ASCE 12-91 Guideline for the Design of Urban Subsurface Drainage

ASCE 13-93 Standard Guidelines for Installation of Urban Subsurface Drainage

ASCE 14-93 Standard Guidelines for Operation and Maintenance of Urban Subsurface Drainage

ANSI/ASCE 15-93 Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD)

ASCE 16-95 Standard for Load and Resistance Factor Design (LRFD) of Engineered Wood Construction

ASCE 17-96 Air-Supported Structures

ASCE 18-96 Standard Guidelines for In-Process Oxygen Transfer Testing

ASCE 19-96 Structural Applications of Steel Cables for Buildings

ASCE 20-96 Standard Guidelines for the Design and Installation of Pile Foundations

ASCE 21-96 Automated People Mover Standards—Part I

ASCE 22-97 Independent Project Peer Review

ASCE 23-97 Specification for Structural Steel Beams with Web Openings

FOREWORD

The material presented in this publication has been prepared in accordance with recognized engineering principles. This Standard and Commentary should not be used without first securing competent advice with respect to their suitability for any given application. The publication of the material contained herein is not intended as a representation or warranty on the part of the American Society of Civil Engineers, or of any other person named herein, that this information is suitable for any general or particular use or promises freedom from infringement of any patent or patents. Anyone making use of this information assumes all liability from such use.

ACKNOWLEDGMENTS

The American Society of Civil Engineers (ASCE) acknowledges the work of the Structural Steel Beams with Web Openings Standards Committee of the Codes and Standards Activities Division of the Structural Engineering Institute of ASCE. This group comprises individuals from many backgrounds including: consulting engineering, research, construction industry, education, goverment, design and private practice.

This Standard was prepared through the consensus standards process by balloting in complince with procedures of ASCE's Codes and Standards Activities Committee.

This Specification and accompanying Commentary cover the design of composite and noncomposite beams with web openings. The specification is written for structural designers for use with the AISC *Load and Resistance Factor Design (LRFD) Specification for Structural Steel Buildings* (1993).

The Specification and Commentary represent the culmination of many years of work and rely heavily on the research efforts of many individuals. These documents were first written by the ASCE Structural Division Task Committee on Design Criteria for Composite Structures in Steel and Concrete and were first published in the *Journal of Structural Engineering* in 1992. The current documents incorporate modifications to the original Specification and Commentary that reflect efforts by the Standards Committee to improve the usability and applicability of the design procedures embodied in these Standards. Those individuals who serve on the Standards Committee are:

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Specification for Structural Steel Beams with Web Openings

1.0 GENERAL

1.1 SCOPE

This *Specification for Structural Steel Beams with Web Openings* supplements the *Load and Resistance Factor Design Specification for Structural Steel Buildings* of the American Institute of Steel Construction. This Specification applies to both composite and noncomposite flexural members in which the steel section meets the requirements of a compact section.

2.0 APPLICABLE DOCUMENT

Load and Resistance Factor Design Specification for Structural Steel Buildings (1993), American Institute of Steel Construction, Chicago, Illinois.

3.0 DESIGN

The strength of a flexural member at a web opening shall be determined based on the interaction of flexure and shear at the opening. Any procedure may be used that results in prediction of strength in substantial agreement with results of comprehensive tests. Unless stated otherwise, the provisions of the American Institute of Steel Construction *Load and Resistance Factor Design Specification for Structural Steel Buildings* apply.

The requirements of this section may be considered satisfied by the procedure described in Section 4.0 in conjunction with the provisions of Section 5.0.

4.0 DESIGN PROCEDURE

4.1 INTERACTION OF FLEXURE AND SHEAR

The interaction of flexure and shear shall be limited by Eq. (1).

$$\left(\frac{M_u}{\phi_o M_m}\right)^3 + \left(\frac{V_u}{\phi_o V_m}\right)^3 \leq 1.0 \qquad (1)$$

where

M_u = Factored moment at centerline of opening
V_u = Factored shear at centerline of opening
M_m = Maximum nominal flexural capacity at opening; occurs when $V_u = 0$
V_m = Maximum nominal shear capacity at opening; occurs when $M_u = 0$ at opening centerline
ϕ_o = Resistance factor for opening design = 0.90 for noncomposite sections and 0.85 for composite sections

4.2 MAXIMUM NOMINAL FLEXURAL CAPACITY

The maximum nominal flexural capacity at an opening M_m shall be determined from the plastic stress distribution on the net section. When an opening is reinforced, M_m shall not exceed the nominal flexural capacity of the unperforated section without reinforcement.

4.3 MAXIMUM NOMINAL SHEAR CAPACITY

The maximum nominal shear capacity at an opening V_m shall equal the sum of the shear capacities of the regions below and above the opening, the bottom, and top tees $V_m = \Sigma V_{mt}$.

4.3.1 General Equations

The shear capacity for an individual tee V_{mt}, including the top tee in composite beams for which $(\sqrt{6} + \mu)/(\nu + \sqrt{3}) \leq 1.0$, is given by

$$V_{mt} = \frac{\sqrt{6} + \mu}{\nu + \sqrt{3}} V_{pt} \leq V_{pt} \qquad (2)$$

where

V_{pt} = Plastic shear capacity of the web of the tee = $F_y t_w s_t/\sqrt{3}$
F_y = Specified minimum yield stress of steel
t_w = Thickness of web
ν = Aspect ratio of tee = a_o/s_t; use $a_o/\overline{s_t}$ when opening is reinforced
a_o = Length of opening
s_t = Depth of tee