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AIJ Design Standard for Steel Structures

—Based on Allowable Stress Concept—

(2005 Edition)

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Architectural Institute of Japan

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Preface to the English Edition

This volume is the English translation of the 2005 edition of the *AIJ Design Standard for Steel Structures — Based on Allowable Stress Concept*, a publication by the Architectural Institute of Japan (AIJ). The *Standard* has long served as the primary design standard for structural steel buildings in Japan incorporating the latest scientific knowledge.

Readers may benefit from a brief account of the *Building Standard Law* and its relationship with AIJ documents including this *Standard*. In Japan, the planning, design, and construction of buildings are legally governed by the *Building Standard Law*. While no significant change has been made to the *Building Standard Law* since its enactment in 1950, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT, formerly the Ministry of Construction), has issued a number of Enforcement Orders, Enforcement Regulations, and Orders and Notifications of the Ministry to supplement the law and thereby, form the building regulations. Today, engineers rely on a reference titled *Manual for Structural Regulations for Building Design*, published by MLIT, which describes the building regulations in an organized fashion and offers extensive commentary. Since 1981, the building regulations have comprised a two-level design procedure requiring allowable stress design for moderate earthquake loads and ultimate strength design for severe earthquake loads.

The AIJ documents stand independent from the building regulations. Historically, much of the allowable stress design rules were derived from the original edition of the *Standard*. However, because the building regulations have not adopted updates to the *Standard*, small discrepancies exist between the building regulations and the *Standard*. The most notable example is the allowable flexural stress for which the *Standard* specifies an equation derived from elasticity theory while the building regulations specify a simple, classic equation. Another example is the standard hole diameter for ordinary bolts, which is limited as the nominal bolt size plus 0.5 mm in the *Standard* although the legal limitation is the nominal bolt size plus 1.0 mm, or plus 1.5 mm in rare cases. Despite the differences, because the *Standard* provides a complete set of design rules for structural steel buildings while the building regulations do not, the *Standard* remains widely in use.

While the translation is faithful to the original Japanese edition, a number of changes have been made to aid readers who are not familiar with the regulations, codes and provisions, or design and construction practice in Japan. In the main body, wording has been changed, table format modified, and description added where direct translation of the Japanese language may not convey what is intended by the original words of the *Standard*. The commentary was reorganized based on the following principles.

(1) The volume should stand alone as a design standard and as a source of information for the design of structural steel buildings in Japan. In other words, the volume should not assume that readers possess basic knowledge of the regulations, codes, or design and construction practice in Japan.

(2) Any mention of the *Building Standard Law*, the building regulations, or earlier editions of the *Standard* should be omitted. Such description is believed to offer little benefit to readers of the English edition.

(3) Descriptions of fundamental structural analysis concepts should be omitted.

(4) Technical background of the provisions and design equations should be omitted. Data in a uniquely Japanese format and literature in the Japanese language is believed to offer limited interest to readers of the English edition.

The changes resulted in the Special Commentary for the English Edition. Unlike the original Japanese edition, where the entire commentary is placed after the main body, in this English edition, commentary is placed immediately following the relevant section of the main body.

The *Standard* owes significantly to the *Specification for the Design, Fabrication and Erection of Structural Steel for Buildings* published by the American Institute of Steel Construction (AISC), in particular the 1963 and 1967 editions. The chapter organization and many provisions of the original *Standard* were taken directly from the AISC *Specification*. We express our sincere gratitude to AISC and US colleagues for their invaluable influence that has helped the establishment of structural steel construction in Japan.

The Managing Committee on Steel Structures intends to make this volume the first of a series of English editions of its numerous technical documents. We are hopeful that the English edition of the *Standard* will prove itself valuable for engineers designing structural steel buildings in Japan or applying Japanese technology outside of Japan.

April, 2017

Architectural Institute of Japan

Preface

The Architectural Institute of Japan (AIJ) published the *Pre-Standard for Structural Calculation of Steel Structures* in 1941, the *Calculation Standard for Building Structures* in 1947, and the *Calculation Standard for Steel Structures* in 1950. The three volumes formed the basis of the *Design Standard for Steel Structures*, hereafter referred to as the *Standard*, published in 1970. Although the design practice for steel buildings had changed significantly since this original edition was published, the *Standard* had not been updated until now. In particular, the major revision of the *Building Standard Law Enforcement Order* in 1981 implemented additional requirements, often referred to as the "new seismic design method," to design buildings to remain safe against large earthquakes. The new requirements involve ultimate strength design and plastic analysis, which is fundamentally different from the conventional, allowable stress design (ASD) that is based on elastic analysis. In order to address the new seismic design method, the AIJ introduced the *Recommendations for the Plastic Design of Steel Structures* and *Recommendation for Limit State Design of Steel Structures* to supplement the *Standard*. The adoption of the SI-unit system by the Japanese Industrial Standard (JIS) motivated a revision of the *Standard* in 2002 which implemented the SI-unit system throughout and introduced editorial modifications. Except for this minor modification, the *Standard* had not been updated because the AIJ judged that the original edition remained adequate in all regards as an ASD standard. On the other hand, many AIJ members had challenged that, because the *Standard* fails to address current design issues and because the content had remained unchanged for over 30 years, the document is no longer deserving of its title of *Design Standard for Steel Structures*.

In order to address the circumstances described above, the Managing Committee on Steel Structures established a workgroup to examine whether and how each element of the *Standard* should be updated. The workgroup concluded that the *Standard* should be reorganized as the authoritative document to address ASD for steel structures, and should be updated according to the following principles:

(1) The *Standard* should define ASD for buildings constructed of structural steel and should be limited to ASD. The overall composition of the original edition should be maintained.
(2) The *Standard* should be updated to address the current design, fabrication, and construction practice.
(3) The *Standard* should be accompanied by a comprehensive commentary. The

commentary should provide scientific background and limitations of the provisions and identify the referenced literature.

(4) The *Standard* should be consistent with the latest JIS and other related standards.

(5) The *Standard* may incorporate new scientific knowledge, but should carefully consider the generality of the new knowledge.

(6) Wherever content is replaced by new content, the former content should be retained in the commentary for future reference.

(7) The *Standard* should be consistent, within the domain of ASD, with AIJ provisions on steel building structures. The *Standard* should follow principle (6) to incorporate any update that is already adopted in other AIJ provisions. Adoption of new scientific knowledge that is not yet adopted in other AIJ provisions should follow principle (5).

(8) Any discrepancy between the *Standard* and the *Building Standard Law of Japan* shall be described and examined in the commentary.

A subcommittee was formed to update the *Standard* according to the above principles. To mention some of the key issues discussed by the subcommittee: Principle (2) raised the suggestion to remove the section on rivets. Opposition was raised on the ground that engineers may encounter rivets when rehabilitating and upgrading existing structures. The committee followed principle (6) to remove any mention of rivets from the main body of the *Standard* but add a discussion in the commentary to guide engineers on the design of rivets. Principle (5) motivated a comprehensive update of fatigue design and a significant change in the allowable flexural stress equations. While the committee acknowledged the benefit of simplicity of the original allowable flexural stress equations, they judged that the equation cannot be associated with a reliable safety factor and that principle (4) demanded update.

The modifications from the 1970 edition of the *Standard* are summarized below for each chapter.

Chapter 1 A statement is added to clarify that the *Standard* is the authoritative AIJ document that describes ASD for structural steel.

Chapter 2 No change is made.

Chapter 3 Description of design loads is removed and referral to the *Recommendations for Loads on Buildings* is added. The Commentary discusses compliance to the *Building Standard Law Enforcement Order* for design loads.

Chapter 4 While the *Standard* maintains its principle to limit its application to structural steel material conforming to JIS specifications, a new commentary is added to Chapter 5 to describe cold-formed square hollow structural sections (HSS)

that are widely used in practice.

Chapter 5 The original equation for allowable flexural stress is replaced by a more accurate equation that is derived from the governing equation for elastic lateral-torsional buckling. The allowable stress of ordinary bolts is modified: while it remains that the allowable stress for high-strength bolts is based on the nominal bolt area, the allowable stress for ordinary bolts is now based on the reduced area accounting for threads; The allowable stress for loading other than shear is introduced for partial-joint-penetration groove welds.

Chapter 6 No change is made.

Chapter 7 The original design method that featured fatigue factors is replaced by a new method that accounts for the type and geometry of the connection subjected to fatigue effects.

Chapter 8 The width-to-thickness limits are rewritten in non-dimensional form that expresses the modulus of elasticity E.

Chapter 9 New sections are added for lateral bracing of beams and beams with web openings.

Chapter 10 Requirements are added on the story drift limit of structural systems.

Chapter 11 The alignment chart to evaluate the effective length factor for flexural buckling, also included in the AIJ *Recommendations for Stability Design of Steel Structures*, is added to the commentary.

Chapter 12 Major revision of the commentary is made.

Chapter 13 Major revision of the commentary is made.

Chapter 14 Requirements for rivets are removed from the *Standard*, while discussion is added to the commentary to guide engineers on the design of rivets. Requirements are added in the commentary for square HSS. The design equations in the commentary for the shear strength of the column panel zone are updated: New equations are added for square HSS, while the equations for split-tee connections and cruciform columns are removed.

Chapter 15 Requirements are added for washers and the maximum hole size for anchor bolts.

Chapter 16 Partial-joint-penetration groove welds are permitted for a wider range of applications.

Chapter 17 Specific requirements are added for each of the general column base types: the exposed, encased, and embedded.

Appendix While the original edition included extensive charts and tables from JIS standards, those charts and tables are removed to comply with copyright requirements of JIS.

As stated repeatedly, the *Standard* describes the ASD and ASD only. Structural safety of buildings may be achieved by checking that the stresses computed from elastic analysis for design loads is within the allowable limits prescribed in the *Standard*. It is noted that the ASD does not evaluate the ultimate state of the structure and, therefore, does not provide information on the excess capacity beyond the required strength. In order to provide safety beyond the minimum design load, an engineer may adopt larger design loads or supply a high degree of redundancy to the system. In general, the ASD is an effective method to design low-rise buildings to remain elastic under wind loads and snow loads. The ASD is expected to enjoy popularity for such applications. An additional design check for ultimate limit states is warranted to address safety against seismic demands.

AIJ provides two other volumes that prescribe the design of structural steel buildings: the *Recommendations for the Plastic Design of Steel Structures* and *Recommendation for Limit State Design of Steel Structures*. The former volume prescribes a strength-based design method, which in some regards may be viewed as akin to the *Standard*, and which evaluates the strength capacity of the structure. It is cautioned that the energy dissipation mechanism predicted by plastic analysis may be attained if and only if the plastic hinges are provided with sufficient ductility. The latter volume, on the other hand, offers a Limit State Design (LSD) procedure to address dual design requirements: the serviceability limit state to addresses concerns that are similar to those addressed by ASD, and the ultimate limit state when the structure forms a plastic collapse mechanism. The LSD, which targets primarily mid- to high-rise buildings, allows the computation of energy dissipation associated with plastic deformation. Needless to say, the engineer is responsible for choosing the design method that best suits his or her pursuit.

We are hopeful that the *Design Standard for Steel Structures — Based on Allowable Stress Concept*, along with the *Recommendations for the Plastic Design of Steel Structures* and *Recommendation for Limit State Design of Steel Structures*, will prove themselves valuable to our community.

September ,2005

Architectural Institute of Japan

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