The Future of Steel Design Standards

Where Are We Going?

By Louis Geschwindner and Cynthia Duncan

Where Have We Been?

On June 1, 1923, the American Institute of Steel Construction introduced its first standard specification for the design, fabrication and erection of structural steel for buildings. The purpose of the standard was to promote uniform practice in an industry that was, at the time, barely 30 years old. Prior to its introduction, design of structural steel for buildings was carried out using one of the many private "specifications" that were available. These included the "General Specification for Steel Frame Mill Buildings" written by Milo S. Ketchum and first published in 1903, which by 1921 in its 4th edition had become the "General Specification for Steel Frame Buildings". Additionally, steel producers, such the Bethlehem Steel Co. and the Carnegie Steel Co., published their own specifications, usually within their handbook of structural shapes. Finally, city building ordinances also provided specific provisions for structural steel building design.

The original specification was written and approved by a committee of five from among the leading talent in the academic, engineering, and architectural professions. It was a mere nine pages. That first specification has undergone numerous revisions over the past 80 years, based on experience and research, both analytical and physical. Today, a consensus body, consisting of 40 industry representatives, educators and consulting engineers, develops the AISC Specification for Structural Steel Buildings. The AISC Committee on Specifications (COS) has been accredited by the American National Standards Institute as a standards writing body since the year 2000. Its 40 members, working with a much larger group of task committee members, assess all new information and formulate necessary new and revised provisions over a period of years before a new specification is finally approved.

> "That first specification has undergone numerous revisions …"

Early steel specifications provided allowable stresses and assumed that the materials of the day behaved elastically. Over time, the approach became known as allowable stress design (ASD). For ASD, a factor of safety is established that provides a desired margin against some perceived measure of failure. This failure may be as simple as the material reaching its yield stress, or it may be as complex as reaching some critical buckling capacity. The ASD approach was the foundation for structural design in all materials for many years.

In 1986, the AISC COS introduced its first load and resistance factor design specification (LRFD). This specification provided an approach to steel design that was consistent with other specifications being developed world wide, as well as that already used for the design of reinforced concrete. The intention was "to provide design criteria for routine use and not to cover infrequently encountered problems which occur in the full range of structural design." The LRFD approach requires the calculation of member nominal strength based on all possible limit states. This nominal strength is then multiplied by a resistance factor to determine the design member capacity.

As with any design approach, member capacities must be compared to the required capacity established through application of the appropriate building code. The ANSI approved standard for loads on buildings is ASCE 7, *Minimum Design Loads for Buildings and Other Structures*. This standard provides load magnitudes and load combinations that must be met for both allowable stress (ASD) and strength (LRFD) design approaches. AISC continues to provide design standards to be used with both of the approved approaches to load combinations set forth in ASCE 7.

The premier edition of the LRFD specification was followed by the most recent revision of the ASD Specification in 1989. Subsequent to 1989, the COS focused on continued development of the LRFD specification and published two revisions to that standard, 1993 and 1999. In 2001 a limited supplement to the 1989 ASD specification was introduced.

Where Are We Going?

After careful consideration of the needs of the design community, and observing how other standards developers have handled the dilemma of promulgating two design philosophies, AISC COS has embarked on the development of a "unified" or single specification, incorporating both the ASD and LRFD methods. The overriding principal of this unified standard is that "steel is steel, and it does not know the method by which it has been designed." This establishes the fundamental formulation of the unified specification where a single resistance is calculated for a given limit state. That resistance is then further cast into either LRFD, with the use of a resistance factor, or ASD, with the use of a safety factor.

Although the current ASD specification is dated 1989, its fundamentals are based on the 1961 edition. Thus, over 40 years of research and knowledge are potentially missing from its provisions. In addition, the 1989 revision was primarily a format revision of the 1978 edition. Therefore, at least 25 years of knowledge have definitely not been incorporated into ASD. Some of the provisions that have been more succinctly included in the LRFD specifications appear to some designers to be missing in the ASD specification. Many users of the ASD specification believe they are permitted to ignore "leaning columns" and others seem to believe that they are not required to address second order effects. Ignoring either of these topics is as unreasonable as ignoring lateral-torsional buckling in unbraced beams. They are behavioral aspects of steel structures and are not design approach specific.

> "…the development of a "unified" or single specification…"

> *"It gives me great pleasure to congratulate you and the members of the American Institute of Steel Construction on your splendid progress in simplification and standardization of your products and practices." Herbert Hoover, Secretary of Commerce, October 8, 1924*

The new generation of the AISC standard will incorporate the most up-to-date knowledge of steel structures' behavior. Combining provisions from the current ASD and LRFD specifications will provide the best of both standards. The final product will be dated and available in the year 2005. In addition to the change in format, some reorganization of the specification will occur, as well as the inclusion of new and revised provisions throughout. Simultaneously, the entire commentary will be evaluated and rewritten as necessary for clarification and conciseness, and *User Notes* will be interspersed throughout the body of the specification to give brief helpful tips, right where they could best be put to use.

"…the most up-to-date knowledge of steel structures' behavior."

Combined Provisions

The chapter organization of the current ASD and LRFD specifications will be retained in the new specification, as much as practicable. Material from the appendices will be brought forward into the main body of the specification, and new appendices written to address selected provisions that experience limited use. Currently, the proposed appendices include provisions for plastic analysis, fatigue, evaluation and repair, and temperature effects.

In all sections of the specification, design may be carried out according to the provisions for LRFD or the provisions for ASD. For LRFD, design will be performed in accordance with the following relation:

$$R_u \leq \phi R_n$$

where R_u *= required strength (LRFD);* R_n *= nominal strength;* ϕ*= resistance factor;* ϕR_n *= design strength.*

For ASD, design will be performed in accordance with the following relation:

$$R_a \leq R_n/\Omega$$

where R_a *= required strength (ASD);* R_n *= nominal strength;* Ω *= safety factor;* R_n/Ω *= allowable strength.*

These formulations are consistent with the principle that a single resistance is calculated for each limit state and that resistance may then be used in either LRFD or ASD. It should also be noted that the specification is not a strength or stress specification but rather a resistance specification. Thus, any provision may be used in a strength or stress format, at the discretion of the engineer.

Within the member oriented chapters, nominal capacity will be specified and the resistance factor and safety factor will be given in a "side-by-side" format. For example, for calculating nominal tensile yield strength, the new specification will read:

$$P_n = F_y A_g$$

$$\phi_t = 0.90 \text{ (LRFD)} \qquad \Omega_t = 1.67 \text{ (ASD)}$$

where the design tensile strength is $\phi_t P_n$ and the allowable tensile strength is P_n / Ω_t. If an allowable tensile stress for the limit state of yielding is desired, it can be taken as $F_t = F_y / \Omega_t = 0.6 F_y$, which results in an allowable tensile strength of $P_a = F_t A_g$.

The existing LRFD specification was originally calibrated so that LRFD and ASD provided the same member strength for a live to dead load ratio of 3, using a load combination of 1.2D + 1.6L. This results in a target effective load factor of 1.5. Therefore, in most cases, the ASD safety factor is calculated as 1.5/ϕ and is given to 3 significant figures. In many cases, use of the current LRFD resistance factors results in safety factors that are the same as currently in use in ASD. The COS believes that this arrangement will result in greater clarity, uniformity and efficiency when applying AISC specifications. In the final analysis, the only difference between the LRFD and ASD methods of design has to do with the required strength, where ASCE 7 provides two different sets of load combinations for design.

Beam Bending

As an example of what the designer might expect with this new specification, the capacity for lateral-torsional buckling of beams is presented in **Figure 1** (See page 19**)**. These results are for a W36x182, 50 ksi steel beam. The provisions for nominal moment capacity of a laterally unsupported beam found in the 1999 LRFD Specification are given in Equations F1-1, F1-2, and F1-13. The comparable equations given in the 1989 ASD Specification are Equations F1-1, F1-5, F1-6, F1-7, and F1-8. The safety factor proposed for beam bending in the 2005 Specification is $\Omega_b = 1.67$.

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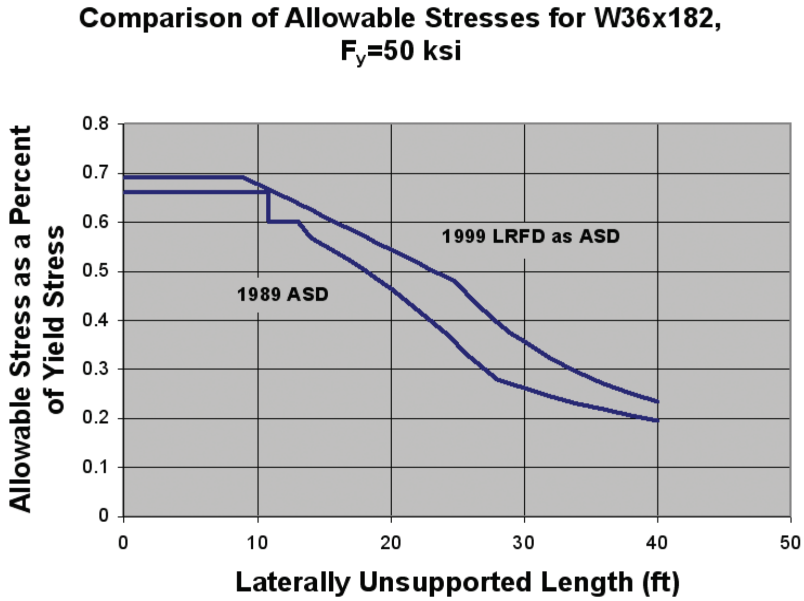
To make a comparison between allowable stresses from the ASD Specification and those that would result if the 1999 LRFD provisions were adopted in the 2005 Specification, the LRFD equations must be divided by 1.67. In addition, since bending resistance calculations use elastic section modulus, S, for ASD and plastic section modulus, Z, for LRFD, this too must be accounted for. First, it should be clear that the LRFD equations could be recast into allowable stress equations. Second, it is seen that the 5 equations from the ASD Specification are replaced by 3 equations from the LRFD Specification. Third, the allowable stresses in all cases for this beam are greater using the 1999 LRFD equations as predictors of beam resistance than they would be using the 1989 ASD equations.

As it is still early in the development process, the actual provisions for the 2005 Specification have not yet been finalized. This comparison is presented to show the possibilities inherent in this new formulation.

Figure 1



How Do We Get There?

Many more topics and much more detail will be discussed after the results of balloting on the first draft of the specification become available in April 2003. The individual task committees under the COS are assigned responsibility for various portions of the Specification, and have submitted their proposed sections for balloting. Several ballot cycles are planned prior to printing in mid 2005. The Committee on Specifications must follow specific ANSI-approved procedures that require all negative votes and comments to be addressed. The required public review period will begin in early 2004, when the draft document will be available to the entire design community. The timeline for completion of the standard continues to be largely dictated by the building codes adoption schedules. The ballot process must be completed by November 2004, in order for the new specification to be adopted by the 2005 NFPA (National Fire Protection Association) Building Code and subsequently the 2006 IBC (International Building Code).

"The required public review period will begin in early 2004…"

Conclusion

Careful forethought and planning have gone into the preliminary preparation of the next generation of the AISC specification: the Standard for the Design, Fabrication, and Erection of Structural Steel for Buildings. Allowance for design using ASD or LRFD are reflected in the new format. Design efficiency will be improved with the reorganization, a rewritten commentary and user notes located within the body of the document; and, we continue to maintain life safety, economical building systems, and predictable behavior and response through revisions and the addition of new provisions. The 2005 AISC Specification is well on its way to being a specification we can all use.

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