Technical Note: Determination of Allowable Strength Design Safety Factors in the 2005 AISC Specification

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The 2005 AISC *Specification for Structural Steel Buildings* (AISC, 2005), hereafter referred to as the 2005 AISC Specification, incorporates both the load and resistance factor design (LRFD) method and the allowable strength design (ASD) method. This is accomplished by placing the resistance factors, ϕ, for LRFD next to the safety factors, Ω, for ASD directly under the nominal strength equation for each limit state. The available strength is then determined for LRFD by multiplying the nominal strength by the resistance factor, ϕR_n, and for ASD by dividing the nominal strength by the safety factor, or R_n/Ω.

The procedure for determining the new ASD safety factors is based on the concept of an effective load factor, originally published in the AISC *Engineering Journal* (Edinger, 1984). This factor is then used together with the resistance factor, ϕ, in the determination of the safety factor for the various limit states.

The effective load factor, γ, is determined by setting the SEI/ASCE 7 (ASCE, 2002) LRFD load combination, for live load, L, and dead load, D, only, equal to a single equivalent load factor times the sum of the dead plus live load. The effective load factor, γ, may then be determined as follows:

$$1.2D + 1.6L = \gamma(L + D) \tag{1}$$

$$\gamma = \frac{(1.2D + 1.6L)}{(D + L)} \tag{2}$$

The AISC *Load and Resistance Factor Design Specification for Structural Steel Buildings* (AISC, 1986) was originally calibrated to the AISC *Specification for the Design, Fabrication and Erection of Structural Steel for Buildings* (AISC, 1978) at a live-to-dead load ratio equal to 3. For $L/D = 3$, Equation 2 becomes

$$\gamma = \frac{[1.2D + 1.6(3D)]}{[D + (3D)]} = \frac{6D}{4D} = 1.5$$

Therefore, with $\gamma = 1.5$ as the effective load factor on the LRFD load combination, and using the LRFD and ASD design basis of the 2005 AISC Specification, the following inequalities can be stated:

For ASD

$$(D + L) \le \frac{R_n}{\Omega} \tag{3}$$

For LRFD

$$1.5(D + L) \le \phi R_n \tag{4}$$

Solving Equations 3 and 4 for R_n and setting them equal permits the determination of a relationship between ϕ and Ω as

$$\Omega(D + L) = \frac{1.5(D + L)}{\phi}$$

and

$$\Omega = \frac{1.5}{\phi}$$

Throughout the 2005 AISC Specification, both ϕ and Ω are rounded to two decimal places.

The 2005 AISC Specification defines the strength of each element by identifying the limit states appropriate to that element. The resistance factors and safety factors corresponding to each structural element and the defined limit states are summarized in Table 1.

REFERENCES

AISC (2005), *Specification for Structural Steel Buildings*, March 9, ANSI/AISC 360-05, American Institute of Steel Construction, Inc., Chicago, IL.

ASCE (2002), *Minimum Design Loads for Buildings and Other Structures*, SEI/ASCE 7-02, American Society of Civil Engineers, Reston, VA.

Edinger, John (1984), "Introduction to the Proposed AISC Load and Resistance Factor Design Specification," *Engineering Journal*, AISC, Vol. 21, No.1, pp. 62–65.

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Table 1. Resistance Factors and Safety Factors in the 2005 AISC Specification				
Resistance Factor, ϕ (LRFD)	**Safety Factor, Ω (ASD)**	**Structural Element**	**Limit State**	**2005 AISC Specification Reference**
1.00	1.50	High-strength bolt	Slip at serviceability limit states	J3
		Connecting element	Shear yielding	J4
		Web of I-shape	Local yielding	J10
		Web of rolled I-shape	Shear yielding	G2
		Web of rolled I-shape	Shear buckling	G2
		Wall of rectangular HSS	Local yielding	K1, K2, K3
		End of rectangular HSS	Local yielding	K1
		Wall of rectangular HSS	Plastification	K1, K2, K3
		Rectangular HSS	Distortional failure	K3
0.95	1.58	Rectangular HSS	Local yielding	K1, K2, K3
		HSS	Shear yielding (punching)	K1, K2, K3
0.90	1.67	Tension member	Tensile yielding	D2
		Compression member	Flexural buckling	E1, E3, E7
		Compression member	Torsional buckling	E1, E4, E7
		Compression member	Flexural-torsional buckling	E1, E4, E7
		Flexural member	Yielding (plastic moment)	F2, F6, F7, F8
		Flexural member	Lateral-torsional buckling	F2, F3, F4, F5
		Compression flange of flexural member	Local buckling	F3, F4, F5, F6, F7, F8
		Compression flange of flexural member	Yielding	F4, F5
		Tension flange of flexural member	Yielding	F4
		Web of flexural member	Local buckling	F7
		Web of flexural member other than rolled I-shape	Shear yielding	G2
		Web of flexural member other than rolled I-shape	Shear buckling	G2
		Web in tension field action	Yielding	G3
		Round HSS	Shear yielding	G6
		Round HSS	Shear buckling	G6
		HSS	Torsional yielding	H3
		HSS	Torsional buckling	H3
		Non-HSS	Torsional yielding	H3
		Non-HSS	Shear yielding	H3
		Non-HSS	Torsional buckling	H3
		Encased composite column	Tensile yielding	I2
		Fillet composite column	Tensile yielding	I2

Table 1. (cont.) Resistance Factors and Safety Factors in the 2005 AISC Specification				
Resistance Factor, ϕ (LRFD)	**Safety Factor, Ω (ASD)**	**Structural Element**	**Limit State**	**2005 AISC Specification Reference**
0.90	1.67	Composite beam with shear connectors	Yielding (plastic moment)	I3
		Composite beam with shear connectors	Yielding (yield moment)	I3
		Concrete-encased and filled beam	Yielding (plastic moment)	I3
		Concrete-encased and filled beam	Yielding (yield moment)	I3
		Weld base material	Tensile rupture	J2
		Weld base material	Yielding	J2
		Connecting element	Tensile yielding	J4
		Connecting element in compression	Yielding	J4
		Connecting element in compression	Buckling	J4
		Flange with concentrated force	Local bending	J10
		Web with concentrated force	Local buckling	J10
		Web with concentrated force	Shear yielding	J10
		Round HSS	Local yielding	K1
		Rectangular HSS	Local buckling	K1
		Round and rectangular HSS	Plastification	K1, K2, K3
		Rectangular HSS	Local crippling	K2
0.85	1.76	Encased and filled flexural member with shear connectors	Yielding (plastic moment)	I3
		High-strength bolt	Slip at required strength level	J3
		Web with concentrated force	Sidesway buckling	J10
0.80	1.88	PJP groove weld	Tension yielding	J2
		PJP groove weld	Compression yielding	J2
0.75	2.00	Tensile member	Tensile rupture	D2
		Pin-connected member	Tensile rupture	D5
		Member in shear	Shear rupture	D5
		Encased composite column	Flexural buckling	I2
		Filled composite column	Flexural buckling	I2
		PJP groove weld	Shear yielding	J2
		Fillet weld	Shear yielding	J2

Table 1. (cont.) Resistance Factors and Safety Factors in the 2005 AISC Specification				
Resistance Factor, ϕ (LRFD)	**Safety Factor, Ω (ASD)**	**Structural Element**	**Limit State**	**2005 AISC Specification Reference**
0.75	2.00	Plug and slot weld	Shear yielding	J2
		Fastener	Tensile rupture	J3
		Fastener	Shear rupture	J3
		Bearing-type connection	Tension and shear rupture	J3
		Bolt hole	Bearing	J3
		Shear element	Shear rupture	J4
		Tension element	Tensile rupture	J4
		Block shear	Block shear rupture	J4
		Surfaces in contact	Bearing (local compressive yielding)	J7
		Web with concentrated force	Local crippling	J10
		Rectangular HSS wall	Local crippling	K1, K2
		End of rectangular HSS	Local crippling	K1
0.65	2.31	Encased and filled composite column	Concrete crushing	I2
0.60	2.50	Column base	Concrete crushing	J8