

Tolerances Illustrated

By understanding and accommodating structural steel production, fabrication, and erection tolerances, you can avoid expensive and time-consuming field fixes.

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AS A YOUNG DESIGNER, IT WAS SURPRISING TO ME HOW A HALF INCH HERE OR THERE COULD HAVE A BIG EFFECT ON THE SUCCESS OF THE CONSTRUCTION OF A LARGE BUILDING. Poor curtain wall fit-up, partition wall problems, finished floor elevation unevenness, and door and opening

installation problems can all be the end result of misunderstanding or neglect of structural steel tolerances. Engineers most often encounter steel tolerances when addressing the interface of the steel frame with another material or system. Problems in these areas are not only time-consuming and expensive to fix, but also they can

taint the owner's, architect's, developer's, or general contractor's view of the project's success—even if the steel frame performs exactly as designed.

Providing adjustable details at system interfaces is the most straightforward solution to accommodate system tolerances. Understanding where adjustable details are needed and providing details with the proper amount of adjustment allows an engineer to provide a structural frame that easily integrates the non-structural elements.

An engineer designing with structural steel must account for three types of tolerance in their design: Mill Tolerance, Fabrication Tolerance, and Erection Tolerance.

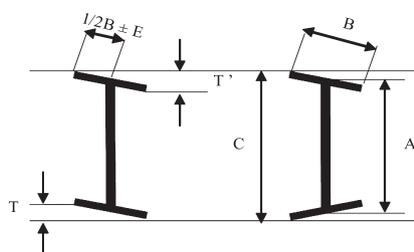
Mills producing hot-rolled structural steel must conform to the ASTM A6 specification as stated in AISC's *Manual of Steel Construction*, 13th Edition. ASTM A6 sets the acceptable variance for member length, straightness, camber, sweep, and cross-section properties. Cross-section properties addressed are overall depth and width, flange and web thickness, and flange out-of-alignment (see Table 1).

ASTM A6 tolerances for member camber and sweep of typical wide flange shapes are shown in Table 2. It should be noted that these tolerances are for incidental mill camber; a different set of tolerances apply for fabricator "induced" camber. Small amounts of incidental mill camber are common and don't typically cause problems in construction. However, if a piece is to be used as a column or a beam in an application that requires it to be flat, one can specify "no camber" on the order.

Fabrication and erection tolerances are specified in the 2005 AISC *Code of Standard Practice* (COSP), included in Part 16 of the *Manual*. Examining the COSP and its com-

Table 1. Mill Cross-Section Tolerances for W Shapes per ASTM A6-05a

Parameter	Over	Under
A depth at web centerline	1/8"	1/8"
B flange width	1/4"	3/16"
T + T' flanges out of square	1/4"*	0"
E web off center	3/16"	3/16"
C max depth	1/4"	0"

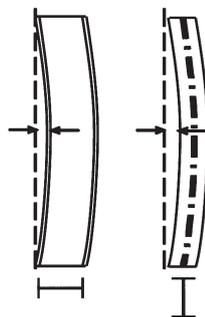


Additional References: Table 1-22, *Manual*; Figure C-5.1, COSP; see also *Manual* Tables 1-23 through 1-29 for other shape types (S, M, WT, MT, ST, Channels, Angles, Rect. HSS, Rnd. HSS, Pipe and Plates).

* increase to 5/16" for nominal depths greater than 12".

Table 2. Mill straightness tolerances for W Shapes in ASTM A6-05a

Sizes	Length, L	Camber	Sweep
$b_f \geq 6$ in.	All	$1/8" \times (L/10)$	$1/8" \times (L/10)$
$b_f < 6$ in.	All	$1/8" \times (L/10)$	$1/8" \times (L/5)$
$b_f \approx d$ "columns"	$L \leq 45'$	$1/8" \times (L/10) \leq 3/8"$	
	$L > 45'$	$3/8" + [1/8" \times (L - 45)/10]$	



Camber Sweep

Additional References: Table 1-22, *Manual*; Figure 1-1, *Manual*; See also *Manual* Tables 1-23 through 1-29 for other shape types (S, M, WT, MT, ST, Channels, Angles, Rect. HSS, Rnd. HSS, Pipe and Plates).

mentary can greatly improve your understanding of how a structural steel building fits together. Fabrication and erection tolerances are addressed specifically in sections 6 and 7 of the COSP. Issues that are addressed are:

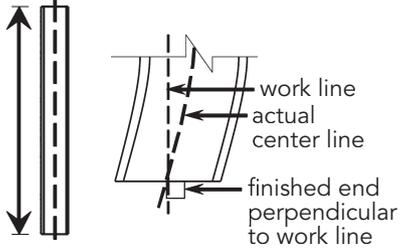
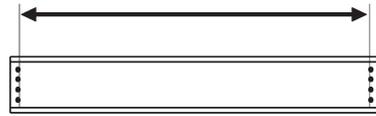
- Location of workpoints.
- Temperature shrinkage and expansion.
- Beam and column out-of-alignment (in elevation and plan).
- Column clearance.
- Erection tolerance at column splices.
- Induced camber tolerance.

Table 3 illustrates fabrication tolerances for column and beam length, respectively.

Table 4 highlights fabrication tolerances for column and beam straightness.

Table 5 shows beam and column erection tolerances.

Table 3. Beam and Column Fabrication Tolerances for Length

Sizes	Length, L	Max. Variation	
Both ends finished for contact bearing (i.e. columns, COSP 6.4.1)	All	$\pm 1/32''$	
Members that frame to other steel members (COSP 6.4.1)	$L \leq 30'$	$\pm 1/16''$	
	$L > 30'$	$\pm 1/8''$	

Additional Information

- Architecturally Exposed Structural Steel (AESS) has its own set of tolerances. These are outlined in section 10 of the COSP.
- Chapter M of the Specification addresses Quality Control issues for Fabrication and Erection.

→ HSS mill tolerances must conform to ASTM A500.

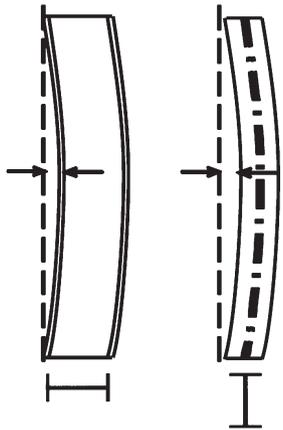
→ Pipe mill tolerances must conform to ASTM A53.

→ Engineering Frequently Asked Questions, free on AISC's web site at www.AISC.org/FAQ.

→ *Modern Steel Construction* SteelWise article, June 2005, "Tolerating Tolerances," by Kurt Gustafson.

Proper knowledge and application of structural steel tolerances will enable you to smoothly navigate the construction process. Time and money will be saved

Table 4. Beam and Column Fabrication Tolerances for Straightness of W Shapes

Concerning	Member Type	Length	Camber	Sweep	
Straightness of structural members without specified camber, COSP 6.4.2	Straight, structural shape or built-up, non-compression	All	See ASTM A6		
	Straight, structural shape or built-up, compression	All	$L/1000$		
	Curved members	All	See ASTM A6	Same sweep as ASTM A6 measured from theoretical curvature	
Beams with Specified Camber, COSP 6.4.4		$L \leq 50$ ft	- 0 in. + 1/2 in.	See ASTM A6	
		$L > 50$ ft	- 0 in. + 1/2 in. + $[1/8 \text{ in.} \times (L - 50)/10]$	See ASTM A6	
All		Free of twists, bends, open joints, sharp kinks or bends.			Camber Sweep

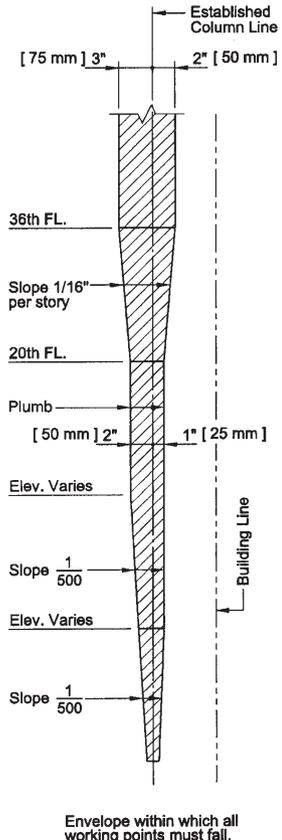
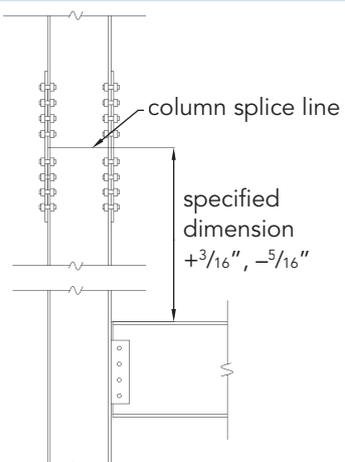
* Except when a smaller variation in straightness is specified in the contract documents

** For the purpose of inspection, camber shall be measured in the fabricators shop

Beams and trusses that are detailed without specified camber shall be fabricated so that, after erection, any incidental camber is upward, COSP Section 6.4.3.

Additional References: *Manual* Tables 1-22 through 1-29; See COSP Section 6.4.5 for camber of trusses.

Table 5. Beam and Column Erection tolerances for Work Points

Member	Location	Tolerance	
Columns (COSP 7.13)	Interior	$L/500^*$	
	Exterior	<p>Perpendicular to building line: 1" toward and 2" away from building line for first 20 stories; increase $\frac{1}{16}$" for each additional story up to max. limit of 2" toward and 3" away from building line.**</p>	
		<p>Paralell to building line (not illustrated) 2" or less from the established column line for first 20 stories; increase $\frac{1}{16}$" for each additional story up to max. limit of 3".</p>	
Members other than columns (COSP 7.13)	Beams connecting to column	plus $\frac{3}{16}$ ", minus $\frac{5}{16}$ " from column splice point	
	All other	"variation acceptable as long as it is caused solely by variations in elevations of supporting members"	

*Stricter limits apply at elevator shafts; see 7.13.1.1.

** Additional limits at column splices; see 7.13.1.1 and figure C-7.6.

Additional References: COSP figure C-7.1 differential column shortening; COSP figure C-7.2, temperature adjustments; COSP figures C-7.3 & C-7.4, column clearances.

by understanding tolerances correctly and communicating expectations clearly. Working closely with the fabricator, erector, and contractor during the design and construction process will help a job run smoothly. Being known for designing projects that run smoothly can earn your

firm a good reputation and put you in a favorable position to win future work. **MSC**

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