BIM and Tolerances

"THE ARCHITECT SAYS YOU DON'T NEED DIMENSIONS ON THE DRAWING WHEN YOU CAN SIMPLY QUERY THE COMPUTER MODEL"
BXP Level of Development

Defines trade specific LOD requirements

CONCRETE CAST-IN-PLACE

LOD 200  LOD 300  LOD 350
STEEL BASE PLATE DESIGN DRAWINGS
BASE PLATE LOD 100

BASE PLATE LOD 200
BASE PLATE LOD 300

BASE PLATE LOD 350
BASE PLATE LOD 400

300 ➔ 350 ➔ 400

PERMIT ➔ TRADE COORD. ➔ PLACEMENT
Scrap Selection → Electric Arc Furnace → Ladle Refining → Finished Product

Rolling Mill → Continuous Casting
Fabrication
Erection & Field

<table>
<thead>
<tr>
<th>Material</th>
<th>Fractional expansion per degree C x10^-6</th>
<th>Fractional expansion per degree F x10^-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass, ordinary</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td><strong>Aluminum</strong></td>
<td>24</td>
<td>13</td>
</tr>
<tr>
<td>Brass</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td><strong>Copper</strong></td>
<td>17</td>
<td>9.4</td>
</tr>
<tr>
<td>Iron</td>
<td>12</td>
<td>6.7</td>
</tr>
<tr>
<td><strong>Steel</strong></td>
<td>13</td>
<td>7.2</td>
</tr>
</tbody>
</table>


REFERENCED SPECIFICATIONS, CODES AND STANDARDS

IMPORTANT TO KNOW:
1. 2018 IBC
2. 2016 ASCE 7
3. 2015 AWS D1.1
4. 2014 RCSC Specification
5. 2014 ACI 318
Architecturally Exposed Structural Steel (AESS)

1. AESS 1: Basic elements
2. AESS 2: Feature elements > 20 ft
3. AESS 3: Feature elements ≤ 20 ft
4. AESS 4: Showcase elements w/special surface & edge treatment
5. AESS C: Custom

Tolerances & Structural Steel
2016 AISC Standards: AISC 303-16

*Tolerances absent from this Code or the contract documents shall not be considered zero by default.*
1. New Shapes.
2. Updates dimensions. Updated fillet radii $k_{det}$, $k_1$, $T$ affected

References

Mill Tolerances for W and HP Shapes

Industry Standards


### Permissible variation in camber and sweep for W and HP shapes

<table>
<thead>
<tr>
<th>Sizes</th>
<th>Permissible variation, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flange width less than 6 in. (150 mm)</td>
<td>( \frac{1}{6} \times \frac{L}{5} \times 6 )</td>
</tr>
<tr>
<td>Flange width equal to or greater than 6 in. (150 mm)</td>
<td>( \frac{1}{8} \times \frac{L}{10} )</td>
</tr>
<tr>
<td>Certain sections used as columns* 45 ft. (14 m) and under</td>
<td>( \frac{1}{4} \times \frac{L}{10} ) with ( \frac{3}{10} ) in. max.</td>
</tr>
<tr>
<td>Over 45 ft. (14 m)</td>
<td>( \frac{3}{10} \times \left( \frac{L}{4} - \frac{45}{10} \right) )</td>
</tr>
</tbody>
</table>


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### Permissible variation in length for W and HP shapes

<table>
<thead>
<tr>
<th>W shapes</th>
<th>30 ft. (9 m) and under</th>
<th>Over 30 ft. (9 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beams 24 in. (610) and under</td>
<td>( % (10) )</td>
<td>( % (10) )</td>
</tr>
<tr>
<td>Beams over 24 in. (610) and all columns</td>
<td>( % (13) )</td>
<td>( % (13) )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>30 ft. (9 m) and under</th>
<th>Over</th>
<th>Under</th>
</tr>
</thead>
<tbody>
<tr>
<td>( % (10) )</td>
<td>( % (10) ) plus ( % (1) ) for each additional 5 ft. (1 m) or fraction thereof</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Over 30 ft. (9 m)</th>
<th>Under</th>
</tr>
</thead>
<tbody>
<tr>
<td>( % (10) )</td>
<td>( % (13) ) plus ( % (13) ) for each additional 5 ft. (1 m) or fraction thereof</td>
</tr>
</tbody>
</table>
Mill Tolerances for S and M channels

Out of Square Tolerance:
1/64 in/in (0.017 mm/mm) of Depth

Camber = 1/8 in x \( \frac{L}{5} \) (for nominal size over 3 in)

(Camber = 2 x L, m for over 75 mm)

Camber = 1/4 in x \( \frac{L}{5} \) (for nominal size under 3 in)

(Camber = 4 x L, m for under 75 mm)

Sweep: Subject to negotiation between manufacturer and purchaser


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Mill Tolerances for Structural Angles & Tees

THIS SECTION INCLUDES INFORMATION FOR ROLLED TEES AND STRUCTURAL-SIZE ANGLES. THERE ARE ADDITIONAL TOLERANCES FOR BAR-SIZE ANGLES, WHICH INCLUDE THOSE WITH LEGS LESS THAN 3” (75 mm). REFER TO ASTM A6/A6M FOR INFORMATION ON THESE SMALLER ANGLES AND FOR TEE SECTIONS.


Angles & T’s

FOR SECTIONS 3” (75) AND OVER:
CAMBER = 1/8” x \( \frac{L}{6} \)
(CAMBER = 2 x L, m)

SWEEP: SUBJECT TO NEGOTIATION BETWEEN MANUFACTURER AND PURCHASER

SWEEP AND CAMBER TOLERANCES

HORIZONTAL SURFACE

POSITION FOR MEASURING CAMBER

Mill Tolerances for Pipe and Tubing

THIS SECTION INCLUDES INFORMATION FOR STRUCTURAL PIPE AND TUBING THAT ARE COMMONLY USED FOR COLUMNS IN RESIDENTIAL AND LIGHT COMMERCIAL CONSTRUCTION. IN MOST CASES, THE ALLOWABLE MILL TOLERANCES ARE SMALL ENOUGH THAT PROBLEMS WITH ARCHITECTURAL DETAILING ARE NOT ENCOUNTERED. THE RELATIVELY LARGE MILL TOLERANCES FOR LENGTH ARE ADJUSTED AT THE FABRICATING PLANT TO MORE PRECISE MEASUREMENTS IF NECESSARY.


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Length tolerances for pipe and tubing

<table>
<thead>
<tr>
<th>Length tolerance for specified lengths, in. (mm)</th>
<th>22 ft. (6.7 m) and under</th>
<th>Over</th>
<th>Under</th>
<th>Over 22 ft. (6.7 m)</th>
<th>Under</th>
</tr>
</thead>
<tbody>
<tr>
<td>{\frac{1}{2}} (12.7)</td>
<td>{\frac{1}{4}} (6.4)</td>
<td>{\frac{3}{4}} (19.0)</td>
<td>{\frac{1}{4}} (6.4)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


## Twist tolerances for square and rectangular tubing

<table>
<thead>
<tr>
<th>Specified dimension of the longest side, in. (mm)</th>
<th>Maximum twist in the first 3 ft. (1 m) and in each additional 3 ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2 (38.1) and under</td>
<td>0.050 in. (1.39)</td>
</tr>
<tr>
<td>Over 1 1/2 (38.1) to 2 1/2 (63.5), incl.</td>
<td>0.062 in. (1.72)</td>
</tr>
<tr>
<td>Over 2 1/2 (63.5) to 4 (101.6), incl.</td>
<td>0.075 in. (2.09)</td>
</tr>
<tr>
<td>Over 4 (101.6) to 6 (152.4), incl.</td>
<td>0.087 in. (2.24)</td>
</tr>
<tr>
<td>Over 6 (152.4) to 8 (203.2), incl.</td>
<td>0.100 in. (2.78)</td>
</tr>
<tr>
<td>Over 8 (203.2)</td>
<td>0.112 in. (3.11)</td>
</tr>
</tbody>
</table>


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## HSS ROUND

**A618:**

0 = 2’’ (50) AND OVER: ±1%

D = 1/16’’ (38) AND UNDER:

+ 1/64’’ (0.4), -1/32’’ (0.8)

A500: ±0.75%

A500: -10% MAX

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**HSS ROUND**

Pipe 2’’ (50.8) dia. and over

1/8’’ (10.4 mm) x \( \frac{L \text{ ft. (m)}}{5} \)

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HSS

R = 3 x T (MAX)

±0.01 TIMES A FOR A OVER 5 1/2” (139.7)
T = ±10% FOR A500 ONLY

1/8” (10.4 mm) x L. ft (m)


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- Vertical
- Horizontal
- Field Welding
Steel Column Erection Tolerances

INDUSTRY STANDARDS

AISC 303-05, CODE OF STANDARD PRACTICE FOR STEEL BUILDINGS AND BRIDGES (CHICAGO: AMERICAN INSTITUTE OF STEEL CONSTRUCTION, INC., 2005).

• A COLUMN IS CONSIDERED PLUMB IF THE DEVIATION OF THE WORKING LINE OF THE COLUMN FROM TRUE PLUMB DOES NOT EXCEED 1:500.

• HOWEVER, FOR INDIVIDUAL EXTERIOR COLUMNS, AISC STANDARD PRACTICES LIMIT THE TOTAL VARIATION TO 1” (25 mm) TOWARD THE BUILDING LINE AND 2” (50 mm) AWAY FROM THE BUILDING LINE UP TO THE TWENTIETH FLOOR AND A MAXIMUM DEVIATION OF 1/16” (2 mm) PER FLOOR ABOVE THE TWENTIETH FLOOR UP TO A MAXIMUM OF 2 IN. (50 MM) TOWARD AND 3” (75 mm) AWAY FROM THE BUILDING LINE.

• ALTHOUGH TOLERANCES FOR ANCHOR BOLT PLACEMENT ARE NOT THE RESPONSIBILITY OF THE FABRICATOR OR THE ERECTOR, THE AISC CODE REQUIRES THAT THE CENTER-TO-CENTER DIMENSION BETWEEN ADJACENT ANCHOR BOLT GROUPS AND FROM THE ESTABLISHED COLUMN LINE NOT VARY BY MORE THAN ¼” (6 mm). THE CENTER-TO-CENTER DISTANCE BETWEEN ANY TWO BOLTS WITHIN AN ANCHOR BOLT GROUP CAN NOT VARY BY MORE THAN ¼” (3 mm).
Location of Exterior Steel Columns in Plan

**Industry Standards**
TOLERANCES: COL. CONT. INTERMED. BEAMS

max height (T₀) and max deflection (Tₜ)

column plumbness tolerances,  
T₀ = Tₜ

maximum envelope for working points for all columns at any given elevation; must fall within the limits of T₀ and Tₜ

1-1/2" (38)

TOLERANCES FOR MEMBERS WITH FIELD SPLICES

field splice  
support point

500 maximum

1

500 maximum
Steel Beam/Column Connections

Industry Standards

ARCHITECTURALLY EXPOSED STRUCTURAL STEEL

\[ L = \text{see Tables 3-2 and 3-3} \]

Camber, sweep, and length:

ARCHITECTURALLY EXPOSED STRUCTURAL STEEL

1/8 in (3) if open joint

JOINTS

WELDING

maximum 1/16 in. (2) above exposed surface

ERECTION

one half the distances permitted for structural steel


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Elevator Shaft Tolerances

Industry Standards
Building Transportation Standards and Guidelines (Salem, NY: National Elevator Industry, Inc.)
ACCUMULATED FRAME TOLERANCE EXAMPLE


DIFFERENTIAL COLUMN SHORTENING

ADJUSTABLE ITEMS


CANTILEVERED MEMBERS

FIELD-ASSEMBLED MEMBERS


Precast on steel

Brick on steel


https://csengineermag.com/article/structural-detailing-solutions-to-avoid-thermal-bridging/
- Window Wall
- Concrete
- Reinforcing
- Masonry
- Embed
- Structural Steel
- Cold Formed Metal Framing
- Thermal Break
Stone

Handbook of Construction Tolerances, 2nd Edition, by David Kent Ballast, FAIA, CSIC

Curtain Walls

Handbook of Construction Tolerances, 2nd Edition, by David Kent Ballast, FAIA, CSIC
Masonry joint tolerances


CONCRETE MASONRY JOINTS
PT TENDONS

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Plant Examples
Laser Data
Understanding Existing Fit-up
Memorial Herman
Tolerances, Complex Geometry