BRACING FOR STABILITY

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Sponsored by: Structural Stability Research Council
American Institute of Steel Construction

PURPOSES OF BRACING

- Reduce Effective Length
- Reduce Unbraced Length
- Provide Overall Stability

TYPES OF BRACING

IDEAL BRACE STIFFNESS

GENERAL BRACE REQUIREMENTS

- **STIFFNESS**
  CONNECTION DETAILS CAN BE DETRIMENTAL

- **STRENGTH**
  BRACE FORCES ARE DIRECTLY RELATED TO THE MAGNITUDE OF INITIAL OUT-OF-Straightness
**SIMPLE RULE**

- Use brace system stiffness at least twice the ideal value.
- Design the brace and its connections for 0.4% of the compressive force.

**RELATIVE BRACE DESIGN**

<table>
<thead>
<tr>
<th>ASD F.S. = 2.0</th>
<th>Brace Stiffness ( \frac{2P}{L} )</th>
<th>Brace Strength ( 0.004P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta = \frac{4P}{L} )</td>
<td>( F_{br} = 0.004P )</td>
<td></td>
</tr>
<tr>
<td>( \beta = \frac{2P}{\phi L} )</td>
<td>( F_{br} = 0.004P )</td>
<td></td>
</tr>
</tbody>
</table>

**FRAMES**

**EXAMPLE - RELATIVE BRACE - TENSION SYSTEM**

- Typical brace must stabilize three bents. Factored load each bent = 150 + 250 + 100 = 500 kips.
- Design recommendations assume \( F_{br} \) and \( \Delta \) are perpendicular to the column.

**EXAMPLE PROBLEM - Combined Loads**

- Type 2 construction ASD.
- Bracing every third bent.
- Wind shear at level (per bent) = 6.5 K.
- Bracing must be designed to support:
  - Wind shear = 6.5 x 3 = 19.5 K.
  - Stability effects (gravity) = 3 x 300 = 900 K.
**GRAVITY**

Stiffness: $\beta_{\text{reqd}} = \frac{4 \times 600}{11} = 286 \text{ kft}$

$\beta = \frac{A_{\text{br}}} {L_{b}} \cos^{2} \theta = 328 \quad A_{\text{br}} = 0.451 \text{ in}^{2}$

Strength: $F_{\text{br}} = 0.004 \times 600 = 3.6 \text{ k}$

Brace force $= 3.6 / \cos \theta = 3.8 \text{ k}$

$F_{g} = 22 \text{ kalm} \times 36 \quad A_{\text{br}} = 3.8 / 22 = 0.173 \text{ in}^{2}$

**GRAVITY plus WIND**

$P = 900 \text{ k}, \quad V_{w} = 19.5 \text{ k}$

Stiffness: same as gravity load

Strength: $A_{\text{br}} = 19.5 / (1.33 \times 22 \cos \theta) = 0.700 \text{ in}^{2}$

$A_{\text{br}} = 0.173 / 1.33 = 0.130 \text{ in}^{2}$

**EXAMPLE PROBLEM - System Stiffness**

Stiffness of Rods:

$A = 0.44 \text{ in}^{2} \quad \beta_{\text{rod}} = \frac{A}{L_{b}} \cos^{2} \theta = \frac{0.44 	imes 29000}{25 \times 12} = 27 \text{ k/in}$

Stiffness of Connection:

Idealize connection area as a square plate with dimensions $T \times T$

$\frac{1}{\beta_{\text{system}}} = \frac{1}{\beta_{\text{brace}}} + \frac{1}{\beta_{\text{connection}}}$

$\frac{1}{\beta_{B}} = \frac{1}{19.4} + \frac{1}{19.4} \quad \beta = 7.1 \text{ k/in}$

System Stiffness is only 26% of rod stiffness!\

$\Delta_{L} = C \times \left(1 + \mu \right) \frac{F}{E} \frac{T}{I}$

$C = 0.138 \text{ for S.S.} - \text{use } 0.67 \text{ for flanged}$

$\Delta_{L} = 0.138 \times (0.91) \frac{13625}{29000} \times 25 \times 12 \times 25 = 27 \text{ k/in}$

$\Delta_{L} = 19.4 \text{ k/in}$

$\Delta_{L} = 19.4 \times 27 \quad \beta = 7.1 \text{ k/in}$
**BRACING FUNDAMENTALS**

![Diagram showing bracing fundamentals](image)

**SIMPLE RULE**

- Use brace system stiffness at least twice the ideal value.
- Design the brace and its connections for 1% of the compressive force.

**COLUMN BRACING RECOMMENDATIONS**

<table>
<thead>
<tr>
<th>Relative Bracing</th>
<th>LRFD Factored Loads - $P_u$</th>
<th>ASD Service Loads - $P_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p_{req'd} = \frac{2 \sum P_i}{\phi L}$</td>
<td>$\beta_{req'd} = \frac{4 \sum P_i}{L}$</td>
<td>$\beta_{req'd} = N_i \frac{4 P_i}{L}$</td>
</tr>
<tr>
<td>$F_{br} = 0.004 P_u$</td>
<td>$F_{br} = 0.004 P_s$</td>
<td>$F_{br} = 0.01 P_u$</td>
</tr>
</tbody>
</table>

**DISCRETE BRACING**

$N_i = 4 - \left( \frac{2}{n} \right)$

$F_{br} = 0.01 P_u$

**IDEAL BRACE STIFFNESS REQUIREMENTS**

- More braces require more stiffness!

![Ideal brace stiffness requirements](image)
INEFFECTIVE TORSIONAL BRACE

EFFECT OF LOAD AND BRACE POSITION
TORSIONAL BRACING SYSTEMS

SECTION IS FULLY BRACED AT A LOCATION IF TWIST IS PREVENTED
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