APPENDIX 6

STABILITY BRACING FOR COLUMNS AND BEAMS

This appendix addresses the minimum brace strength and *stiffness* necessary to provide member *strengths* based on the *unbraced length* between braces with an *effective length factor*, K, equal to 1.0.

The appendix is organized as follows:

6.1. General Provisions
6.2. Columns
6.3. Beams

User Note: The requirements for the stability of braced-frame systems are provided in Chapter C. The provisions in this appendix apply to bracing, intended to stabilize individual members.

6.1. GENERAL PROVISIONS

Bracing is assumed to be perpendicular to the members to be braced; for inclined or *diagonal bracing*, the brace strength (*force* or moment) and *stiffness* (force per unit displacement or moment per unit rotation) shall be adjusted for the angle of inclination. The evaluation of the stiffness furnished by a brace shall include its member and geometric properties, as well as the effects of *connections* and anchoring details.

Two general types of bracing systems are considered, relative and nodal. A *relative brace* controls the movement of the brace point with respect to adjacent braced points. A *nodal brace* controls the movement at the braced point without direct interaction with adjacent braced points. The *available strength* and stiffness of the bracing shall equal or exceed the required limits unless analysis indicates that smaller values are justified by analysis.

A *second-order analysis* that includes an initial out-of-straightness of the member to obtain brace strength and stiffness is permitted in lieu of the requirements of this appendix.

6.2. COLUMNS

It is permitted to brace an individual *column* at end and intermediate points along its length by either relative or nodal bracing systems. It is assumed that *nodal braces* are equally spaced along the column.

1. Relative Bracing

The required brace strength is

$$P_{br} = 0.004 P_r \qquad \text{(A-6-1)}$$

The required brace *stiffness* is

$$\beta_{br} = \frac{1}{\phi}\left(\frac{2P_r}{L_b}\right) \text{(LRFD)} \qquad \beta_{br} = \Omega\left(\frac{2P_r}{L_b}\right) \text{(ASD)} \qquad \text{(A-6-2)}$$

where

$$\phi = 0.75 \text{ (LRFD)} \qquad \Omega = 2.00 \text{ (ASD)}$$

L_b = distance between braces, in. (mm)

For design according to Section B3.3 (LRFD)

P_r = *required axial compressive strength* using *LRFD load combinations*, kips (N)

For design according to Section B3.4 (ASD)

P_r = required axial compressive strength using *ASD load combinations*, kips (N)

2. Nodal Bracing

The required brace strength is

$$P_{br} = 0.01 P_r \qquad \text{(A-6-3)}$$

The required brace stiffness is

$$\beta_{br} = \frac{1}{\phi}\left(\frac{8P_r}{L_b}\right) \text{(LRFD)} \qquad \beta_{br} = \Omega\left(\frac{8P_r}{L_b}\right) \text{(ASD)} \qquad \text{(A-6-4)}$$

where

$$\phi = 0.75 \text{ (LRFD)} \qquad \Omega = 2.00 \text{ (ASD)}$$

For design according to Section B3.3 (LRFD)

P_r = *required axial compressive strength* using *LRFD load combinations*, kips (N)

For design according to Section B3.4 (ASD)

P_r = required axial compressive strength using *ASD load combinations*, kips (N)

When L_b is less than L_q, where L_q is the maximum *unbraced length* for the required *column force* with K equal to 1.0, then L_b in Equation A-6-4 is permitted to be taken equal to L_q.

6.3. BEAMS

At points of support for *beams*, girders and tr
their longitudinal axis shall be provided. Be
displacement of the top and bottom flanges,
Lateral *stability* of beams shall be provided b
or a combination of the two. In members sub
the inflection point shall not be considered a

1. Lateral Bracing

Bracing shall be attached near the compressi
member, where an end brace shall be attached
bracing shall be attached to both flanges at t
point for beams subjected to double curvat
braced.

1a. Relative Bracing

The required brace strength is

$$P_{br} = 0.008 M_r C_d /$$

The required brace *stiffness* is

$$\beta_{br} = \frac{1}{\phi}\left(\frac{4M_rC_d}{L_bh_o}\right) \text{(LRFD)} \qquad \beta_{br} =$$

where

$$\phi = 0.75 \text{ (LRFD)}$$

h_o = distance between flange centroids, in
C_d = 1.0 for bending in *single curvature*; 2
only applies to the brace closest to th
L_b = laterally *unbraced length*, in. (mm)

For design according to Section B3.3 (LRF

M_r = *required flexural strength* using *L*
(N-mm)

For design according to Section B3.4 (ASD

M_r = required flexural strength using *ASD l*

1b. Nodal Bracing

The required brace strength is

$$P_{br} = 0.02 M_r C_d / h$$

The required brace *stiffness* is

$$\beta_{br} = \frac{1}{\phi}\left(\frac{10M_rC_d}{L_bh_o}\right) \text{(LRFD)} \qquad \beta_{br} =$$

6.3. BEAMS

At points of support for *beams*, girders and trusses, restraint against rotation about their longitudinal axis shall be provided. Beam bracing shall prevent the relative displacement of the top and bottom flanges, in other words, twist of the section. Lateral *stability* of beams shall be provided by *lateral bracing*, *torsional bracing* or a combination of the two. In members subjected to *double curvature* bending, the inflection point shall not be considered a brace point.

1. Lateral Bracing

Bracing shall be attached near the compression flange, except for a cantilevered member, where an end brace shall be attached near the top (tension) flange. Lateral bracing shall be attached to both flanges at the brace point nearest the inflection point for beams subjected to double curvature bending along the length to be braced.

1a. Relative Bracing

The required brace strength is

$$P_{br} = 0.008 M_r C_d / h_o \qquad \text{(A-6-5)}$$

The required brace *stiffness* is

$$\beta_{br} = \frac{1}{\phi}\left(\frac{4M_r C_d}{L_b h_o}\right) \text{(LRFD)} \qquad \beta_{br} = \Omega\left(\frac{4M_r C_d}{L_b h_o}\right) \text{(ASD)} \qquad \text{(A-6-6)}$$

where

$$\phi = 0.75 \text{ (LRFD)} \qquad \Omega = 2.00 \text{ (ASD)}$$

h_o = distance between flange centroids, in. (mm)
C_d = 1.0 for bending in *single curvature*; 2.0 for double curvature; $C_d = 2.0$ only applies to the brace closest to the inflection point
L_b = laterally *unbraced length*, in. (mm)

For design according to Section B3.3 (LRFD)

M_r = *required flexural strength* using *LRFD load combinations*, kip-in. (N-mm)

For design according to Section B3.4 (ASD)

M_r = required flexural strength using *ASD load combinations*, kip-in. (N-mm)

1b. Nodal Bracing

The required brace strength is

$$P_{br} = 0.02 M_r C_d / h_o \qquad \text{(A-6-7)}$$

The required brace *stiffness* is

$$\beta_{br} = \frac{1}{\phi}\left(\frac{10M_r C_d}{L_b h_o}\right) \text{(LRFD)} \qquad \beta_{br} = \Omega\left(\frac{10M_r C_d}{L_b h_o}\right) \text{(ASD)} \qquad \text{(A-6-8)}$$

where

$$\phi = 0.75 \text{ (LRFD)} \qquad \Omega = 2.00 \text{ (ASD)}$$

For design according to Section B3.3 (LRFD)

M_r = required flexural strength using LRFD load combinations, kip-in. (N-mm)

For design according to Section B3.4 (ASD)

M_r = required flexural strength using ASD load combinations, kip-in. (N-mm)

When L_b is less than L_q, the maximum unbraced length for M_r, then L_b in Equation A-6-8 shall be permitted to be taken equal to L_q.

2. Torsional Bracing

It is permitted to provide either nodal or continuous *torsional bracing* along the *beam* length. It is permitted to attach the bracing at any cross-sectional location and it need not be attached near the compression flange. The *connection* between a torsional brace and the beam shall be able to support the required moment given below.

2a. Nodal Bracing

The required bracing moment is

$$M_{br} = \frac{0.024 M_r L}{n C_b L_b} \tag{A-6-9}$$

The required cross-frame or *diaphragm* bracing *stiffness* is

$$\beta_{Tb} = \frac{\beta_T}{\left(1 - \dfrac{\beta_T}{\beta_{sec}}\right)} \tag{A-6-10}$$

where

$$\beta_T = \frac{1}{\phi}\left(\frac{2.4 L M_r^2}{n E I_y C_b^2}\right) \text{(LRFD)} \qquad \beta_T = \Omega\left(\frac{2.4 L M_r^2}{n E I_y C_b^2}\right) \text{(ASD)} \tag{A-6-11}$$

$$\beta_{sec} = \frac{3.3E}{h_o}\left(\frac{1.5 h_o t_w^3}{12} + \frac{t_s b_s^3}{12}\right) \tag{A-6-12}$$

where

$$\phi = 0.75 \text{ (LRFD)} \qquad \Omega = 3.00 \text{ (ASD)}$$

User Note: $\Omega = 1.5^2/\phi = 3.00$ in Equation A-6-11 because the moment term is squared.

L = span length, in. (mm)
n = number of *nodal braced* points within the span
E = modulus of elasticity of steel = 29,000 ksi (200 000 MPa)

I_y = out-of-plane moment of inertia, ir
C_b = modification factor defined in Ch
t_w = *beam* web thickness, in. (mm)
t_s = web *stiffener* thickness, in. (mm)
b_s = stiffener width for one-sided stiffe width for pairs of stiffeners), in. (
β_T = brace *stiffness* excluding web dist
β_{sec} = web *distortional stiffness*, includir *ers*, if any, kip-in./radian (N-mm/r

For design according to Section B3.3 (LF

M_r = *required flexural strength* using L (N-mm)

For design according to Section B3.4 (AS

M_r = required flexural strength using A (N-mm)

If $\beta_{sec} < \beta_T$, Equation A-6-10 is negative, bracing will not be effective due to inadequ

When required, the web stiffener shall exten and shall be attached to the flange if the t flange. Alternatively, it shall be permissible t equal to $4t_w$ from any *beam* flange that is brace. When L_b is less than L_q, then L_b in be taken equal to L_q.

2b. Continuous Torsional Bracing

For continuous bracing, use Equations A-6- as 1.0 and L_b taken as L_q; the bracing mo span length. The distortional stiffness for a

$$\beta_{sec} = \frac{3.3Et_w^3}{12h_o}$$

I_y = out-of-plane moment of inertia, in.^{4} (mm^4)
C_b = modification factor defined in Chapter F
t_w = *beam* web thickness, in. (mm)
t_s = web *stiffener* thickness, in. (mm)
b_s = stiffener width for one-sided stiffeners (use twice the individual stiffener width for pairs of stiffeners), in. (mm)
β_T = brace *stiffness* excluding web distortion, kip-in./radian (N-mm/radian)
β_{sec} = web *distortional stiffness*, including the effect of web *transverse stiffeners*, if any, kip-in./radian (N-mm/radian)

For design according to Section B3.3 (LRFD)

M_r = *required flexural strength* using *LRFD load combinations*, kip-in. (N-mm)

For design according to Section B3.4 (ASD)

M_r = required flexural strength using *ASD load combinations*, kip-in. (N-mm)

If $\beta_{sec} < \beta_T$, Equation A-6-10 is negative, which indicates that torsional *beam* bracing will not be effective due to inadequate web distortional stiffness.

When required, the web stiffener shall extend the full depth of the braced member and shall be attached to the flange if the torsional brace is also attached to the flange. Alternatively, it shall be permissible to stop the stiffener short by a distance equal to $4t_w$ from any *beam* flange that is not directly attached to the torsional brace. When L_b is less than L_q, then L_b in Equation A-6-9 shall be permitted to be taken equal to L_q.

2b. Continuous Torsional Bracing

For continuous bracing, use Equations A-6-9, A-6-10 and A-6-13 with L/n taken as 1.0 and L_b taken as L_q; the bracing moment and stiffness are given per unit span length. The distortional stiffness for an unstiffened web is

$$\beta_{sec} = \frac{3.3Et_w^3}{12h_o} \qquad \text{(A-6-13)}$$