Example II.C-5 HSS Chevron Brace Connection

Given:

Verify that the chevron brace connection shown in Figure II.C-5-1 is adequate for the loading shown. The ASTM A36, w-in.-thick gusset plate is welded with 70-ksi electrode welds to an ASTM A992 W18×35 beam. The braces are ASTM A500 Grade B HSS6×6× 2.

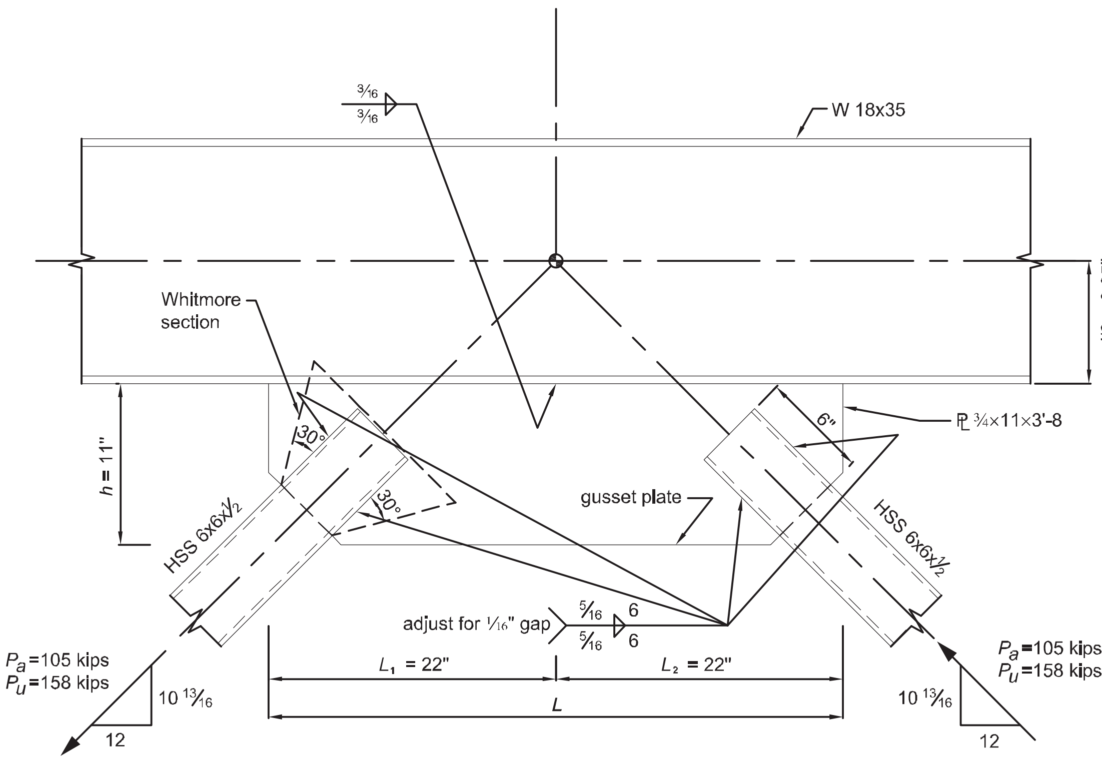

Fig. II.C-5-1. Layout for chevron brace connection.

Solution:

From AISC *Manual* Tables 2-4 and 2-5, the material properties are as follows:

Beam
W18×35
ASTM A992
F_y = 50 ksi
F_u = 65 ksi

Brace
HSS 6×6× 2
ASTM A500 Grade B
F_y = 46 ksi
F_u = 58 ksi

Gusset Plate
ASTM A36
F_y = 36 ksi
F_u = 58 ksi

t_p = w in.

From the AISC *Manual* Tables 1-1 and 1-12, the geometric properties are as follows:

Beam
W18×35
d = 17.7 in.
t_w = 0.300 in.
t_f = 0.425 in.
k_{des}= 0.827 in.

Brace
HSS 6×6×2
$H = B$ = 6.00 in.
A = 9.74 in.^{2}
t = 0.465 in.

Solution:

Calculate the interface forces (at the beam-gusset plate interface).

$\Delta = 2(L_2 - L_1) = 0$ (Note: Δ is negative if $L_2 < L_1$)

The work point is at the concentric location at the beam gravity axis, e_b = 8.85 in. The brace bevels and loads are equal, thus the gusset will be symmetrical and Δ = 0.

Brace forces may both act in tension or compression, but the most common is for one to be in tension and the other to be in compression, as shown for this example.

From Figure II.C-5-1:

$$e_b = \frac{d}{2}$$
$$= \frac{17.7 \text{ in.}}{2}$$
$$= 8.85 \text{ in.}$$
$$\theta = \tan^{-1}\left(\frac{12}{10\ \text{m}}\right)$$
$$= 48.0^\circ$$

L = 44.0 in.
$L_1 = L_2$ = 22.0 in.
h = 11.0 in.

Determine the moments indicated in Figure II.C-5-2.

<table>
<tr><th>LRFD</th><th>ASD</th></tr>
<tr><td>
At Point A:
$P_{u1} = 158\text{ kips}$
$H_{u1} = 158\sin(48.0°)$
$= 117\text{ kips}$
$V_{u1} = 158\cos(48.0°)$
$= 106\text{ kips}$
$P_{u2} = -158\text{ kips}$
$H_{u2} = -117\text{ kips}$
$V_{u2} = -106\text{ kips}$
$M_{u1} = H_{u1}e_b + V_{u1}\Delta$
$= (117\text{ kips})(8.85\text{ in.}) + (106\text{ kips})(0)$
$= 1{,}040\text{ kip-in.}$
$M_{u2} = H_{u2}e_b - V_{u2}\Delta$
$= -1{,}040\text{ kip-in.}$

At Point B:
$M_{u1}' = \frac{1}{8}V_{u1}L - \frac{1}{4}H_{u1}h - \frac{1}{2}M_{u1}$
$= \frac{1}{8}(106\text{ kips})(44.0\text{ in.})$
$-\frac{1}{4}(117\text{ kips})(11.0\text{ in.})$
$-\frac{1}{2}(1{,}040\text{ kip-in.})$
$= -259\text{ kip-in.}$
$M_{u2}' = \frac{1}{8}V_{u2}L - \frac{1}{4}H_{u2}h - \frac{1}{2}M_{u2}$
$= \frac{1}{8}(-106\text{ kips})(44.0\text{ in.})$
$-\frac{1}{4}(-117\text{ kips})(11.0\text{ in.})$
$-\frac{1}{2}(-1{,}040\text{ kip-in.})$
$= 259\text{ kip-in.}$
</td><td>
At Point A:
$P_{a1} = 105\text{ kips}$
$H_{a1} = 105\sin(48.0°)$
$= 78.0\text{ kips}$
$V_{a1} = 105\cos(48.0°)$
$= 70.3\text{ kips}$
$P_{a2} = -105\text{ kips}$
$H_{a2} = -78.0\text{ kips}$
$V_{a2} = -70.3\text{ kips}$
$M_{a1} = H_{a1}e_b - V_{a1}\Delta$
$= (78.0\text{ kips})(8.85\text{ in.}) + (70.3\text{ kips})(0)$
$= 690\text{ kip-in.}$
$M_{a2} = H_{a2}e_b - V_{a2}\Delta$
$= -690\text{ kip-in.}$

At Point B:
$M_{a1}' = \frac{1}{8}V_{a1}L - \frac{1}{4}H_{a1}h - \frac{1}{2}M_{a1}$
$= \frac{1}{8}(70.3\text{ kips})(44.0\text{ in.})$
$-\frac{1}{4}(78.0\text{ kips})(11.0\text{ in.})$
$-\frac{1}{2}(690\text{ kip-in.})$
$= -173\text{ kip-in.}$
$M_{a2}' = \frac{1}{8}V_{a2}L - \frac{1}{4}H_{a2}h - \frac{1}{2}M_{a2}$
$= \frac{1}{8}(-70.3\text{ kips})(44.0\text{ in.})$
$-\frac{1}{4}(-78.0\text{ kips})(11.0\text{ in.})$
$-\frac{1}{2}(-690\text{ kip-in.})$
$= 173\text{ kip-in.}$
</td></tr>
</table>

Note: The signs on the variables are important.

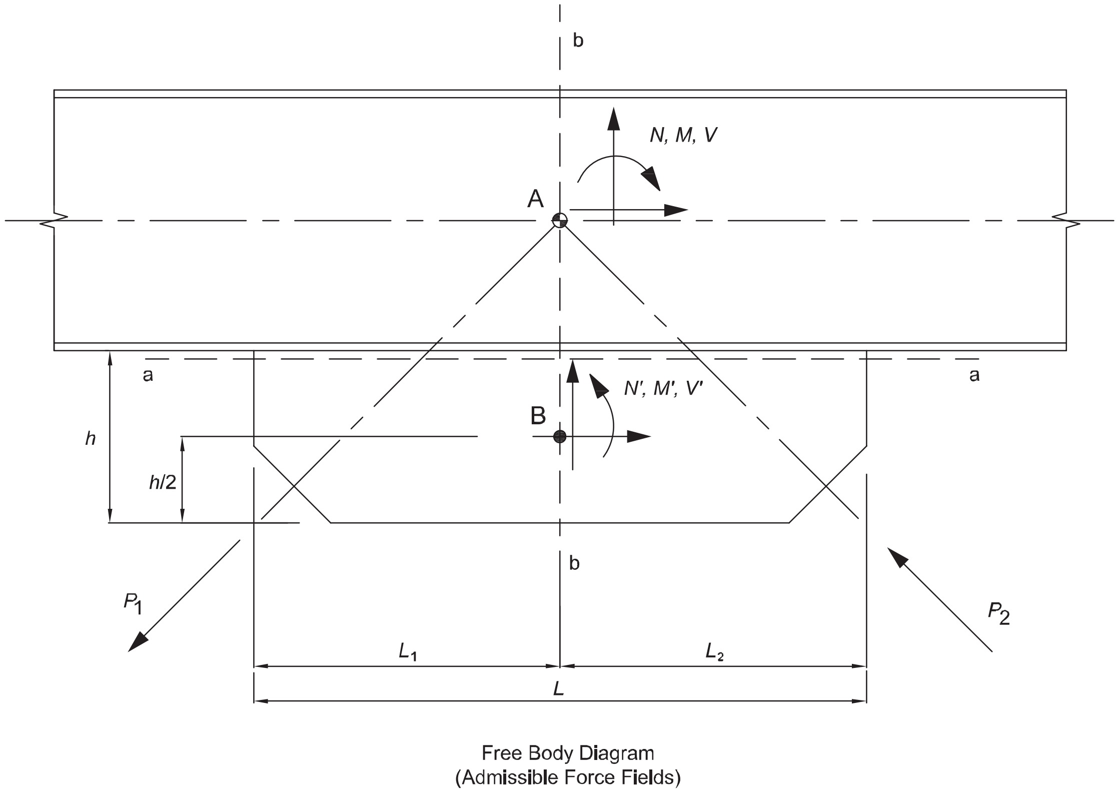

Fig. II.C-5-2. Free body diagrams

Forces for Section a-a (Gusset Internal Forces)

LRFD	ASD
Axial $N_u = V_{u1} + V_{u2}$ $= 106 \text{ kips} + (-106 \text{ kips})$ $= 0 \text{ kips}$	*Axial* $N_a = V_{a1} + V_{a2}$ $= 70.3 \text{ kips} + (-70.3 \text{ kips})$ $= 0 \text{ kips}$
Shear $V_u = H_{u1} - H_{u2}$ $= 117 \text{ kips} - (-117 \text{ kips})$ $= 234 \text{ kips}$	*Shear* $V_a = H_{a1} - H_{a2}$ $= 78.0 \text{ kips} - (-78.0 \text{ kips})$ $= 156 \text{ kips}$
Moment $M_u = M_{u1} - M_{u2}$ $= 1{,}040 \text{ kip-in.} - (-1{,}040 \text{ kip-in.})$ $= 2{,}080 \text{ kip-in.}$	*Moment* $M_a = M_{a1} - M_{a2}$ $= 690 \text{ kip-in.} - (-690 \text{ kip-in.})$ $= 1{,}380 \text{ kip-in.}$

Forces for Section b-b (Gusset Internal Forces)

LRFD	ASD
Axial $N_u' = \frac{1}{2}(H_{u1} + H_{u2})$ $= \frac{1}{2}[117\text{ kips} + (-117\text{ kips})]$ $= 0\text{ kips}$ Shear $V_u' = \frac{1}{2}(V_{u1} - V_{u2}) - \frac{2M_u}{L}$ $= \frac{1}{2}[106\text{ kips} - (-106\text{ kips})]$ $- \frac{2(2{,}080\text{ kip-in.})}{44.0\text{ in.}}$ $= 11.5\text{ kips}$ Moment $M_u' = M_{u1}' + M_{u2}'$ $= -259\text{ kip-in.} + 259\text{ kip-in.}$ $= 0\text{ kip-in.}$	Axial $N_a' = \frac{1}{2}(H_{a1} + H_{a2})$ $= \frac{1}{2}[78.0\text{ kips} + (-78.0\text{ kips})]$ $= 0\text{ kips}$ Shear $V_a' = \frac{1}{2}(V_{a1} - V_{a2}) - \frac{2M_a}{L}$ $= \frac{1}{2}[70.3\text{ kips} - (-70.3\text{ kips})]$ $- \frac{2(1{,}380\text{ kip-in.})}{44.0\text{ in.}}$ $= 7.57\text{ kips}$ Moment $M_a' = M_{a1}' + M_{a2}'$ $= -173\text{ kip-in.} + 173\text{ kip-in.}$ $= 0\text{ kip-in.}$

Design Brace-to-Gusset Connection

This part of the connection should be designed first because it will give a minimum required size of the gusset plate.

Brace Gross Tension Yielding

From AISC *Specification* Equation D2-1, determine the available strength due to tensile yielding in the gross section as follows:

LRFD	ASD
$\phi P_n = \phi F_y A_g$ $= 0.90(46\text{ ksi})(9.74\text{ in.}^2)$ $= 403\text{ kips} > 158\text{ kips}$ **o.k.**	$\frac{P_n}{\Omega} = \frac{F_y A_g}{\Omega}$ $= \frac{(46\text{ ksi})(9.74\text{ in.}^2)}{1.67}$ $= 268\text{ kips} > 105\text{ kips}$ **o.k.**

Brace Shear Rupture

Because net tension rupture involves shear lag, first determine the weld length, *l*, required for shear rupture of the brace.

From the AISC *Specification* Equation J4-4,