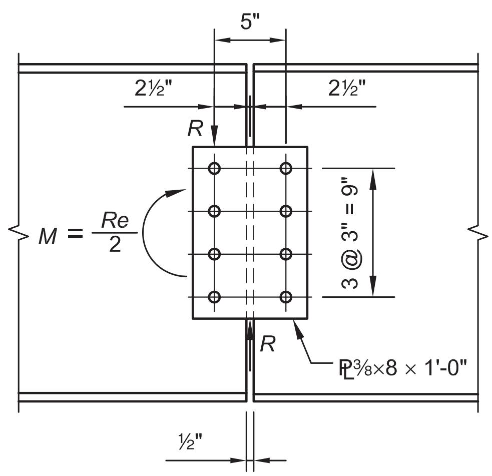
EXAMPLE II.A-20 ALL-BOLTED SINGLE-PLATE SHEAR SPLICE

Given:

Design an all-bolted single-plate shear splice between an ASTM A992 W24×55 beam and an ASTM A992 W24×68 beam.

$R_D = 10$ kips
$R_L = 30$ kips

Use ⅞-in.-diameter ASTM A325-N or F1852-N bolts in standard holes with 5 in. between vertical bolt rows and an ASTM A36 plate.



Solution:

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

Beam
W24×55
ASTM A992
$F_y = 50$ ksi
$F_u = 65$ ksi

Beam
W24×68
ASTM A992
$F_y = 50$ ksi
$F_u = 65$ ksi

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

From AISC *Manual* Table 1-1, the geometric properties are as follows:

Beam
W24×55

t_w = 0.395 in.

Beam
W24×68
t_w = 0.415 in.

Bolt Group Design

Note: When the splice is symmetrical, the eccentricity of the shear to the center of gravity of either bolt group is equal to half the distance between the centroids of the bolt groups. Therefore, each bolt group can be designed for the shear, R_u or R_a, and one-half the eccentric moment, $R_u e$ or $R_a e$.

Using a symmetrical splice, each bolt group will carry one-half the eccentric moment. Thus, the eccentricity on each bolt group, $e/2$ = 2½ in.

From Chapter 2 of ASCE/SEI 7, the required strength is:

LRFD	ASD
$R_u = 1.2(10\text{ kips}) + 1.6(30\text{ kips})$ $= 60.0\text{ kips}$	$R_a = 10\text{ kips} + 30\text{ kips}$ $= 40.0\text{ kips}$

Bolt Shear

From AISC *Manual* Table 7-1:

LRFD	ASD
$\phi r_n = 24.3\text{ kips/bolt}$	$\dfrac{r_n}{\Omega} = 16.2\text{ kips/bolt}$

Bolt Bearing on ⅜-in. Plate

Note: The available bearing strength based on edge distance will conservatively be used for all of the bolts.

$$l_c = 1.50\text{ in.} - \frac{{}^{15}\!/\!_{16}\text{ in.}}{2}$$
$$= 1.03\text{ in.}$$

$$r_n = 1.2 l_c t F_u \le 2.4 d t F_u \qquad (\textit{Spec}.\text{ Eq. J3-6a})$$
$$= 1.2(1.03\text{ in.})(\tfrac{3}{8}\text{ in.})(58\text{ ksi}) \le 2.4(\tfrac{7}{8}\text{ in.})(\tfrac{3}{8}\text{ in.})(58\text{ ksi})$$
$$= 26.9\text{ kips/bolt} \le 45.7\text{ kips/bolt}$$

LRFD	ASD
$\phi = 0.75$ $\phi r_n = 0.75(26.9\text{ kips})$ $= 20.2\text{ kips/bolt}$	$\Omega = 2.00$ $\dfrac{r_n}{\Omega} = \dfrac{26.9\text{ kips}}{2.00}$ $= 13.5\text{ kips/bolt}$

Note: By inspection, bearing on the webs of the W24 beams will not govern.

Since bearing is more critical,

LRFD	ASD
$C_{min} = \dfrac{R_u}{\phi r_n}$ $= \dfrac{60.0 \text{ kips}}{20.2 \text{ kips/bolt}}$ $= 2.97$ By interpolating AISC *Manual* Table 7-6, with $n = 4$, $\theta = 0°$ and $e_x = 2\frac{1}{2}$ in.: $C = 3.07 > 2.97$ **o.k.**	$C_{min} = \dfrac{R_a}{r_n / \Omega}$ $= \dfrac{40.0 \text{ kips}}{13.5 \text{ kips/bolt}}$ $= 2.96$ By interpolating AISC *Manual* Table 7-6, with $n = 4$, $\theta = 0°$ and $e_x = 2\frac{1}{2}$ in.: $C = 3.07 > 2.96$ **o.k.**

Flexural Yielding of Plate

Try PL⅜ in. × 8 in. × 1’-0”.

The required flexural strength is:

LRFD	ASD
$M_u = \dfrac{R_u e}{2}$ $= \dfrac{60.0 \text{ kips}(5.00 \text{ in.})}{2}$ $= 150$ kip-in. $\phi = 0.90$ $\phi M_n = \phi F_y Z_x$ $= 0.90(36 \text{ ksi})\left[\dfrac{3/8 \text{ in.}(12.0 \text{ in.})^2}{4}\right]$ $= 437$ kip-in. > 150 kip-in. **o.k.**	$M_a = \dfrac{R_a e}{2}$ $= \dfrac{40.0 \text{ kips}(5.00 \text{ in.})}{2}$ $= 100$ kip-in. $\Omega = 1.67$ $\dfrac{M_n}{\Omega} = \dfrac{F_y Z_x}{\Omega}$ $= \dfrac{36 \text{ ksi}}{1.67}\left[\dfrac{3/8 \text{ in.}(12.0 \text{ in.})^2}{4}\right]$ $= 291$ kip-in. > 100 kip-in. **o.k.**

Flexural Rupture of Plate

$Z_{net} = 9.00$ in.^{3} from AISC *Manual* Table 15-3

From AISC *Manual* Equation 9-4:

LRFD	ASD
$\phi = 0.75$ $\phi M_n = \phi F_u Z_{net}$ $= 0.75(58 \text{ ksi})(9.00 \text{ in}^3)$ $= 392$ kip-in. > 150 kip-in. **o.k.**	$\Omega = 2.00$ $\dfrac{M_n}{\Omega} = \dfrac{F_u Z_{net}}{\Omega}$ $= \dfrac{58 \text{ ksi}(9.00 \text{ in.}^3)}{2.00}$ $= 261$ kip-in. > 100 kip-in. **o.k.**

Shear Yielding of Plate

From AISC *Specification* Equation J4-3:

LRFD	ASD
$\phi = 1.00$ $\phi R_n = \phi 0.60 F_y A_{gv}$ $= 1.00(0.60)(36 \text{ ksi})(12.0 \text{ in.})(3/8 \text{ in.})$ $= 97.2 \text{ kips} > 60.0 \text{ kips}$ **o.k.**	$\Omega = 1.50$ $\dfrac{R_n}{\Omega} = \dfrac{0.60 F_y A_{gv}}{\Omega}$ $= \dfrac{0.60(36 \text{ ksi})(12.0 \text{ in.})(3/8 \text{ in.})}{1.50}$ $= 64.8 \text{ kips} > 40.0 \text{ kips}$ **o.k.**

Shear Rupture of Plate

$$A_{nv} = 3/8 \text{ in.}[12.0 \text{ in.} - 4(15/16 \text{ in.} + 1/16 \text{ in.})]$$
$$= 3.00 \text{ in.}^2$$

From AISC *Specification* Equation J4-4:

LRFD	ASD
$\phi = 0.75$ $\phi R_n = \phi 0.60 F_u A_{nv}$ $= 0.75(0.60)(58 \text{ ksi})(3.00 \text{ in.}^2)$ $= 78.3 \text{ kips} > 60.0 \text{ kips}$ **o.k.**	$\Omega = 2.00$ $\dfrac{R_n}{\Omega} = \dfrac{0.60 F_u A_{nv}}{\Omega}$ $= \dfrac{0.60(58 \text{ ksi})(3.00 \text{ in.}^2)}{2.00}$ $= 52.2 \text{ kips} > 40.0 \text{ kips}$ **o.k.**

Block Shear Rupture of Plate

$$L_{eh} = L_{ev} = 1\tfrac{1}{2} \text{ in.}$$

From AISC *Specification* Equation J4-5:

LRFD	ASD
$\phi R_n = \phi U_{bs} F_u A_{nt} + \min(\phi 0.60 F_y A_{gv},\ \phi 0.60 F_u A_{nv})$ $U_{bs} = 1.0$ Tension rupture component from AISC *Manual* Table 9-3a: $\phi U_{bs} F_u A_{nt} = 1.0(43.5 \text{ kips/in.})(3/8 \text{ in.})$	$\dfrac{R_n}{\Omega} = \dfrac{U_{bs} F_u A_{nt}}{\Omega} + \min\left(\dfrac{0.60 F_y A_{gv}}{\Omega},\ \dfrac{0.60 F_u A_{nv}}{\Omega}\right)$ $U_{bs} = 1.0$ Tension rupture component from AISC *Manual* Table 9-3a: $\dfrac{U_{bs} F_u A_{nt}}{\Omega} = 1.0(29.0 \text{ kips/in.})(3/8 \text{ in.})$

LRFD	ASD
Shear yielding component from AISC *Manual* Table 9-3b: $\phi 0.60F_y A_{gv} = 170$ kips/in.(⅜ in.)	Shear yielding component from AISC *Manual* Table 9-3b: $\dfrac{0.60F_y A_{gv}}{\Omega} = 113$ kips/in.(⅜ in.)
Shear rupture component from AISC *Manual* Table 9-3c: $\phi 0.60F_u A_{nv} = 183$ kips/in.(⅜ in.) $\phi R_n = (43.5\text{ kips/in.} + 170\text{ kips/in.})(⅜\text{ in.})$ $= 80.1\text{ kips} > 60.0\text{ kips}$ **o.k.**	Shear rupture component from AISC *Manual* Table 9-3c: $\dfrac{0.60F_u A_{nv}}{\Omega} = 122$ kips/in.(⅜ in.) $\dfrac{R_n}{\Omega} = (29.0\text{ kips/in.} + 113\text{ kips/in.})(⅜\text{ in.})$ $= 53.3\text{ kips} > 40.0\text{ kips}$ **o.k.**

Use PL⅜ in. × 8 in. × 1 ft 0 in.