

### Example 7.6.1 Joist Seat Rollover Resistance

Determine the resistance to rollover of the seat shown below.

1. Calculate the resistance based on first yielding.
2. Calculate the resistance based on ultimate strength.

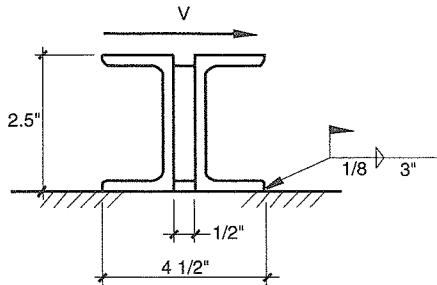


Fig. 7.6.1 Joist Seat

- a. The seat is made from 2"x2"x1/8" angle with a yield strength of 50 ksi.
- b. The seat has sufficient internal strength (based on Vulcraft's fabrication procedures) to force the failure to be a field weld failure or a failure associated with bending of the seat angle.
- c. The resisting forces are assumed as shown:

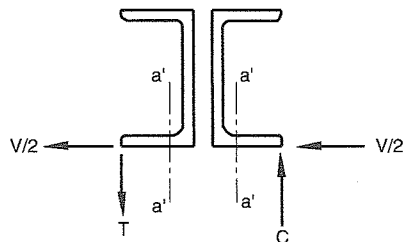


Fig. 7.6.2 Resisting Forces on Joist Seat

#### Solution:

1. Resistance based on first yield:

The yield moment can be determined from the section modulus of the seat angle. The seat angles section modulus,  $S = bt^2/6$ , where  $b$  at  $a'-a'$  is determined as shown in Fig. 7.6.3.

$$\begin{aligned}
 b &= \text{weld length} + (2-k) \\
 b &= 3 + (2 - 7/16) = 4.56 \text{ in.} \\
 S &= (4.56)(0.125)^2/6 = 0.0119 \text{ in.}^3 \\
 M_y &= SF_b \\
 F_b &= 0.75 F_y = (0.75)(50) = 37.5 \text{ ksi.} \\
 M_y &= (0.0119)(37.5) = 0.446 \text{ in. - kips}
 \end{aligned}$$

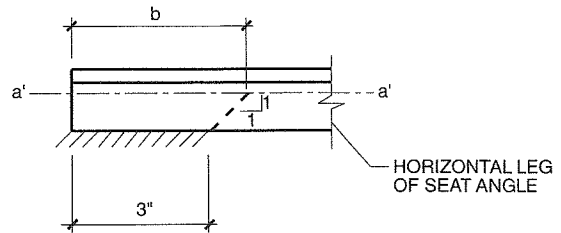


Fig. 7.6.3 Effective Angle Width

The maximum force  $T$  or  $C$  equals  $M_y / (2 - 7/16)$   
 $= 0.286 \text{ kips}$

$$T = C = (2.5V)/4.5 = 0.56V$$

$$\therefore V \approx 510 \text{ pounds}$$

It can be seen that the strength is controlled by yielding in the seat angle rather than the strength of the field weld.

2. Resistance based on ultimate strength:  
 At failure the seat is assumed to be deformed as shown Fig. 7.6.4.

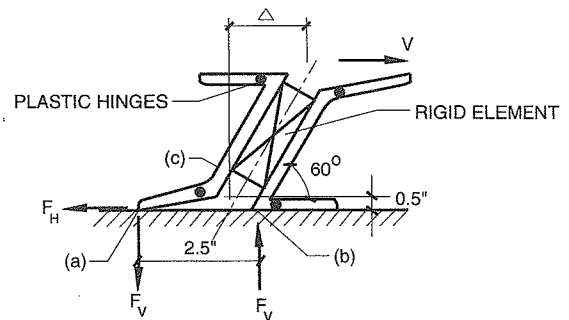


Fig. 7.6.4 Seat Failure Mode

It is assumed that the primary resistance to overturning is provided by the weld at point (a) and by a couple formed by the forces  $F_V$ . Plastic hinges are assumed to have formed in the seat angles. The seat leg which lifts from the base is assumed to hinge approximately 1/2 inch above the base. This assumption is based upon the location of the rigid end diagonal which is welded between the angles.

The ultimate weld resistance can be determined as follows:

Weld strength:

Taking moments about point (b),

$$2.5 F_V = 2.5 V, \text{ thus } F_V = V$$

$\Sigma$  Forces in the horizontal direction,

$$F_H = V$$

The total force at (a) =  $\sqrt{F_H^2 + F_V^2} = 1.414V$

The resisting force in the weld at point (a) equals  $R = 1.414V$ .

The design strength of the weld, based on the AISC LRFD Specification (using Appendix J) equals:

$$\begin{aligned}\phi R &= \phi F_w A_w \\ F_w &= 0.60 F_{EXX} (1.0 + 0.5 \sin^{1.5} \theta) \\ &= 63 \text{ ksi} \\ A_w &= (0.125)(0.707)(3) = 0.265 \text{ in.}^2 \\ \phi R &= (0.75)(63)(0.265) = 12.52 \text{ kips} \\ V &= \phi R / 1.414 = 8.85 \text{ kips}\end{aligned}$$

Seat angle strength:

The maximum strength of the seat angle equals the shear yield strength of the seat angle times the shear area at point (c). Using the von Mises yield criteria:

$$V = (50/\sqrt{3})(0.125)(4.56) = 16.45 \text{ kips}$$

Thus, the design strength is 8.85 kips.

Using a factor of safety of 2.0 the allowable shear force equals 4.42 kips.

As can be seen from the deformed shape, the seat assembly would displace laterally a significant amount at the ultimate load. Based upon the geometry assumed in Fig. 7.6.4, the lateral deflection would be approximately 1.15 inches. It is suggested that the deflection at service loads be limited to 0.25 inches. It should be noted that even at this limit there would be some yielding of the connection.

Thus by proportioning, the allowable shear equals  $(0.25)(8.85)/1.15 = 1.92 \text{ kips}$ .

The allowable lateral force capacity for any given joist seat can be based upon the ultimate strength procedure shown above, provided the basic assumptions as given are not violated. The assumption relative to the internal strength of the seat assembly is beyond the control of the building designer. This strength cannot be easily calculated. Some upper bound is required.

An upper bound on the internal seat strength can be based on tests which were performed by Vulcraft.

ALLOWABLE  
FORCE IS  
PROPORTIONAL  
TO SEAT  
DEPTH.

## Summary of Test Results

Ten tests were conducted on three different seat angle thicknesses. All the seats in these ten tests were fabricated from clipped angles to form a 2-1/2 inch seat. The top chord consisted of 1-1/2 inch angles in each case. The end diagonal of the joist was welded between the seat angles using Vulcraft's standard fabrication practice for H and K joists. Four tests were conducted on seats for 8H3 joists, four tests on seats for 24H6 joists, and two tests for 26H8 seats. The typical seat configurations are shown in Figure 7.6.5 and 7.6.6.

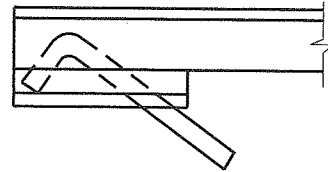


Fig. 7.6.5 8H3 and 24H6 Seats

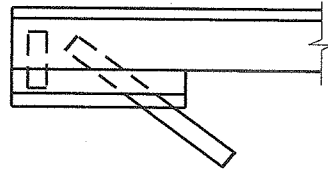


Fig. 7.6.6 26H8 Seats

The tests were conducted by welding the seats to a fixed support. Design vertical loading was applied to the joist prior to the lateral force being applied. Shown in Figure 7.6.7 is the welding and lateral load arrangement:

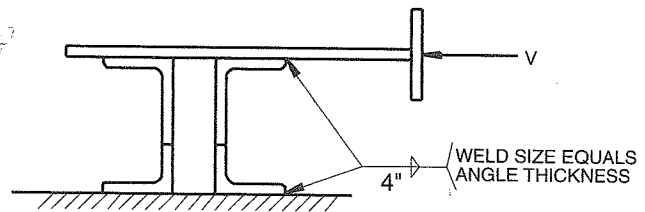


Fig. 7.6.7 Load Arrangement

The fillet weld size was equal to the seat angle thickness. Summarized below are the results of the ten tests.

Seat Type	Bearing $\angle$ size	Ave. Failure Load, lbs.
8H3	1-1/2x1x.109	8940
24H6	1-1/2x1x.145	13500
26H8	1-1/2x1x.163	15630*

\* Test discontinued.

For the 8H3 and 24H6 seats, the failure mode was that of weld failure at the base of the seat angle or between the loading plate and the top chord. Failure load on the 26H8 joist was not reached due to the capacity of the loading system. Internal weld failure did not occur on any of these tests. Significant lateral distortion was noted at failure loads on all ten tests.

Two additional tests were conducted using lapped bearings on 26H8 seats. The seat configuration is shown in Figure 7.6.8. The average ultimate load for these two tests was 14,630 pounds. The failure mode was that of weld failure between the seat angle and the support.

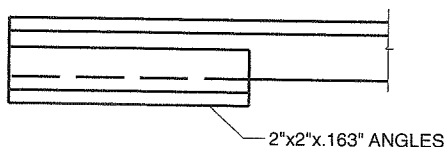


Fig. 7.6.8 Lapped Bearing

Based on the results of these tests, a conservative internal strength values for lateral load is 9000 pounds. Thus, if the ultimate analysis procedure as given here is used to predict the rollover capacity, an upper bound on the strength limit should be taken as 9000 pounds. For most welding configurations it would appear that the capacity will be controlled by lateral deflections.

It is interesting to compare computed ultimate strength values with experimental values. For the 8H3 seats, the computed ultimate strength using the method presented herein is 8,808 pounds, and for the 24H6 seats is 11,717 pounds, as compared to test values of 8,940 and 13,500 pounds respectively.