1007 – Beam in Axial Compression According to ADM

Description

Utulizing the 2020 Aluminum Design Manual, determine the allowable axial compressive strength of a simply supported 8 ft beam, laterally restrained in the weak axis. Alloy 6061-T6 will be used as the material. [1].

This ADM verification is carried out using an I-beam in accordance with Example 9 from the ADM 2020 [1], Which is selected to carry an axial load of 10 kips. Figure **1**.

From Part V, Table 8, the section properties of an 8 $\times$ 6.18 I-beam and other model parameters are given in the following table.

Material		Modulus of Elasticity	E	10100.000	ksi
		Yield Strength	F_{ty}	35.000	ksi
		Ultimate Strength	F_{tu}	38.000	ksi
Geometry	Structure	Length	L	8.000	ft
	Cross-section I 8×6.18	Width	b_w	7.300	in
			b_f	5.000	in
		Depth	d	8.000	in
		Thickness	t_f	0.350	in
			t_w	0.230	in
		Radius of Gyration	r_x	3.370	in
		Gross Area	A_g	5.260	in^2
		Moment of Inertia	I_x	59.700	in^4
			I_y	7.300	in^4
		Torsional Constant	J	0.188	in^4
		Effective Length Factor	k_z	0.500	-
		Unbraced Length	L_z	96.000	in
Load		Dead	P	10.000	kips

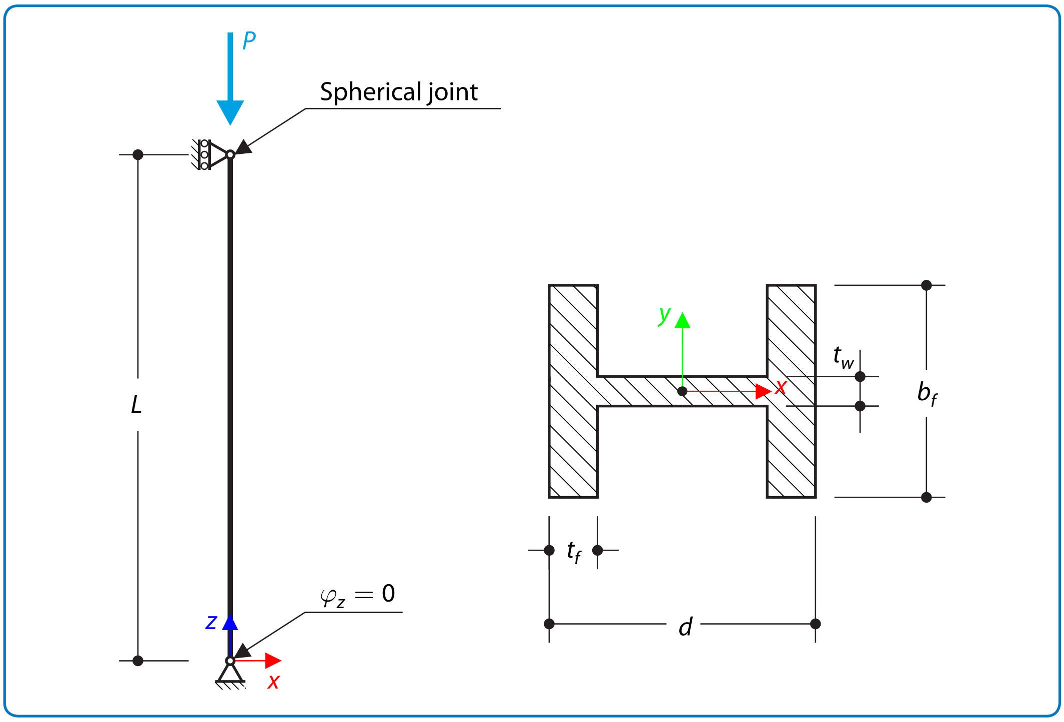

Figure 1: I-Beam in Axial Compression

ADM Solution

Chapter E addresses columns. Section E.1 requires that the allowable compressive strength is the least of the limit states of member buckling, local buckling, and the interaction between member buckling and local buckling, and establishes that $\Omega_c = 1.65$ for building structures. Allowable stresses for 6061-T6 given in Part VI Table 2-19 are used below.

Member buckling

For flexural buckling, Section E.2.1 gives the slenderness λ_{flex} as

$$\lambda_{\text{flex}} = \frac{L_z}{r_x} \approx 28.487 < \lambda_2 = 66.000, \tag{1007 – 1}$$

Section E.2.2a) addresses torsional buckling for doubly symmetric members. Assuming the ends are fixed against torsion,

$$F_e = \left(\frac{\pi^2 E C_w}{(k_z L_z)^2} + GJ\right) \frac{1}{I_x + I_y} \approx 79.758 \text{ ksi}, \tag{1007 – 2}$$

and the the largest slenderness ratio λ_{tors} for torsional buckling is

$$\lambda_{\text{tors}} = \pi \sqrt{\frac{E}{F_e}} \approx 35.497 < 66.000 = \lambda_2, \tag{1007 – 3}$$

so member buckling stress for torsional buckling $F_{\text{c,tors}}$ equals

$$F_{\text{c,tors}}/\Omega_c = 0.00047\lambda_{\text{tors}}^2 - 0.232\lambda_{\text{tors}} + 25.200 \approx 17.585 \text{ ksi}. \tag{1007 – 4}$$

The allowable axial compressive strength for the member buckling is

$$P_{\text{nc,tors}}/\Omega_c = \frac{F_{\text{c,tors}}}{\Omega_c} A_g \approx 92.497 \text{ kips.} \tag{1007 – 5}$$

Local buckling

Local buckling of the flange (a flat element with one edge supported) is addressed in Section B.5.4.1. The slenderness is

$$\lambda_f = \frac{b_f - t_w}{2t_f} \approx 5.957, \tag{1007 – 6}$$

which is between $\lambda_1 = 6.7$ and $\lambda_2 = 10.5$, hence, see Section VI Table 2.19,

$$F_{c,f}/\Omega_c = 27.3 - 0.91\lambda_f = 21.879 \text{ ksi.} \tag{1007 – 7}$$

The area of the flanges is equal to

$$A_f = 2(b_f - t_w)t_f = 3.339 \text{ in}^2 \tag{1007 – 8}$$

Local buckling of the web (a flat element with both edges supported) is addressed in Section B.5.4.2. The slenderness equals

$$\lambda_w = \frac{d - 2t_f}{t_w} \approx 29.130, \tag{1007 – 9}$$

which is between $\lambda_1 = 20.8$ and $\lambda_2 = 33$, therefore, see Section VI Table 2.19,

$$F_{c,w}/\Omega_c = 27.3 - 0.291\lambda_w \approx 18.823 \text{ ksi.} \tag{1007 – 10}$$

The area of the web is equal to

$$A_w = (d - 2t_f)t_w = 1.679 \text{ in}^2. \tag{1007 – 11}$$

The weighted average allowable local buckling strength is

$$P_{\text{nc,loc}}/\Omega_c = \frac{F_{c,f}}{\Omega_c} A_f + \frac{F_{c,w}}{\Omega_c} A_w + \frac{F_{ty}}{\Omega_c}(A_g - A_w - A_f) \approx 107.618 \text{ kips.} \tag{1007 – 12}$$

Interaction between member buckling and local buckling

Elastic buckling stresses are given in Section B.5.6.

The elastic buckling stress of the flange (a flat element with one edge supported) for the slenderness λ_f determined in **(1007 – 6)** above equals

$$F_{e,f} = \frac{\pi^2 E}{(5\lambda_f)^2} \approx 112.364 \text{ ksi} \tag{1007 – 13}$$

The elastic buckling stress of the web (a flat element with both edges supported) for the slenderness λ_w determined in **(1007 – 9)** above is

$$F_{e,w} = \frac{\pi^2 E}{(1.6\lambda_w)^2} \approx 45.888 \text{ ksi} > 29.015 \text{ ksi} \tag{1007 – 14}$$

The member buckling stress is 29.015 ksi; therefore, the strength is not reduced by interaction between member and local buckling.

The allowable axial compressive strength is the lesser of **(1007 – 5)** and **(1007 – 12)**, which is 92.497 kips.

RFEM 5 Settings

- Modeled in RFEM 5.29.01
- Isotropic linear elastic model is used
- Shear stiffness of members is activated

Results

Structure File	Cross-Section Shape
1007.01	AW 8×6.18
1007.02	4×4×0.063 Tube
1007.03	CHS 6.000 OD×0.188 Wall

Results Summary - Allowable Axial Compressive Strength

Shape	RFEM Solution [kips]	ADM Solution [kips]	Ratio [-]
AW 8×6.18	92.409	92.600	1.002
4×4×0.063 Tube	5.644	5.600	1.018
CHS 6.000 ODx0.188 Wall	72.758	72.700	1.008

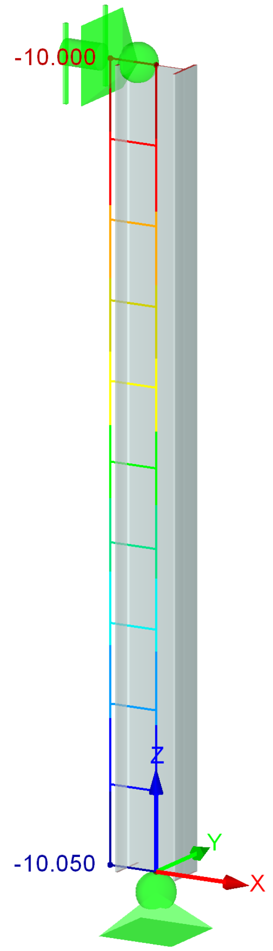

Figure 2: RFEM 5 Results - Normal force *N* along the negative *x*-axis for the I 8×6.18 beam

References

[1] THE ALUMINIUM ASSOCIATION, *Aluminium Design Manual*. 2015.