



Program: RFEM 5, RF-ALUMINIUM ADM

Category: Design Check

Verification Example: 1008 – Beam in Flexure According to ADM

1008 – Beam in Flexure According to ADM

Description

Verify that a beam of different cross-sections made of Alloy 6061-T6 is adequate for the required load, as shown in Figure 1, in accord with the Aluminium Design Manual [1].

The ADM solution is demonstrated on an ADM 6 inch standard pipe—with parameters shown in the table below—the result table, however, contains many more different cross-section comparisons.

Material		Modulus of Elasticity	E	10,100.000	ksi
		Yield Strength	F_{ty}	35.000	ksi
		Ultimate Strength	F_{tu}	38.000	ksi
Geometry	Structure	Length	L	10.000	ft
	Cross-section NPS 6"	Diameter	d	6.625	in
		Thickness	t	0.280	in
		Elastic Section Modulus	S	8.500	in
		Plastic Section Modulus	Z	11.300	in
		Radius of Gyration	r_y	1.260	in
		Torsional Constant	J	56.200	in ⁴
		Moment of Inertia	I_y	28.100	in ⁴
Load		Dead	P	5.500	kips

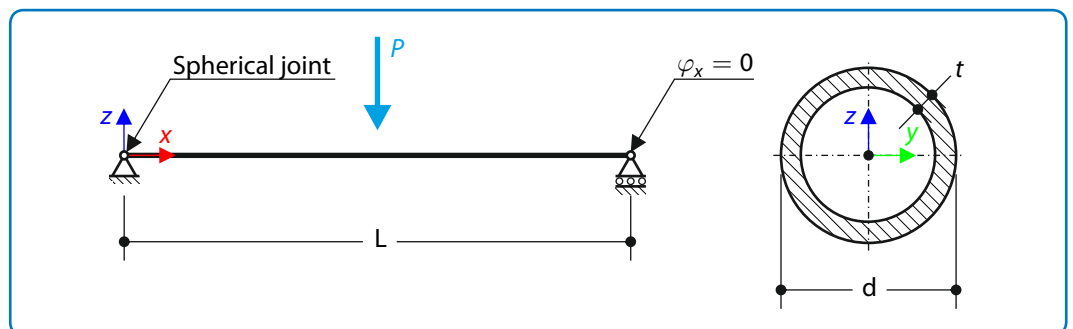


Figure 1: Pipe in flexure

ADM Solution

Section F.1 establishes safety factors of $\Omega_b = 1.95$ on tensile rupture and 1.65 on all other limit states for flexure of building-type structures. The allowable stresses for 6061-T6 given in Part VI Table 2-19 are used below.

Yielding

Section F.2 addresses the limit states of yielding and rupture.

For the limit state of yielding, the allowable moment is the lesser of

$$M_{np}/\Omega_b = \min\{1.5SF_{ty}/\Omega_b, ZF_{ty}/\Omega_b\} \approx 239.697 \text{ kip}\cdot\text{in.} \quad (1008 - 1)$$

Rupture

For the limit state of rupture, the allowable moment is

$$M_{nu}/\Omega_b = ZF_{tu}/k_t/\Omega_b \approx 220.205 \text{ kip}\cdot\text{in.}, \quad (1008 - 2)$$

where $k_t = 1$.

Local buckling

The allowable moment for local buckling determined using Section F.3.3 is based on Section B.5.5.4.

$$\sqrt{R_b}/t = \sqrt{\frac{d-t}{2t}} \approx 3.36 < 7.44 = \lambda_1, \quad (1008 - 3)$$

hence

$$F_b/\Omega_b = 39.300 - 2.7R_b/t, \quad (1008 - 4)$$

and the allowable moment for local buckling equals

$$M_{nlb}/\Omega_b = SF_b/\Omega_b \approx 256.799 \text{ kip}\cdot\text{in.} \quad (1008 - 5)$$

Lateral-torsional buckling

For closed shapes, the slenderness for lateral-torsional buckling using Section F.4.2.3 is

$$\lambda = 2.3 \sqrt{\frac{LS}{C_b \sqrt{I_y J}}} \approx 11.652 < 66 = C_c \quad (1008 - 6)$$

where $C_b = 1$, therefore, the allowable moment for lateral-torsional buckling equals

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$$M_{nmb}/\Omega_b = \frac{M_{np}}{\Omega_b} \left(\left(1 - \frac{\lambda}{C_c} \right) + \frac{\pi^2 E \lambda S}{C_c^3} \right) \approx 218.191 \text{ kip}\cdot\text{in} \quad (1008 - 7)$$

The allowable moment is the least of the allowable moments for yielding (**1008 – 1**), rupture (**1008 – 2**), local buckling (**1008 – 5**), and lateral-torsional buckling (**1008 – 7**), which is 218.191 kip·in.

From Part VI Beam Formulas Case 1, for a simply supported beam with a concentrated load P at the center, the maximum moment equals

$$M_{\max} = PL/4 = 165.000 < 218.191 \text{ kip}\cdot\text{in}, \quad (1008 - 8)$$

therefore, the 6 in schedule 40 pipe is satisfactory.

RFEM 5 Settings

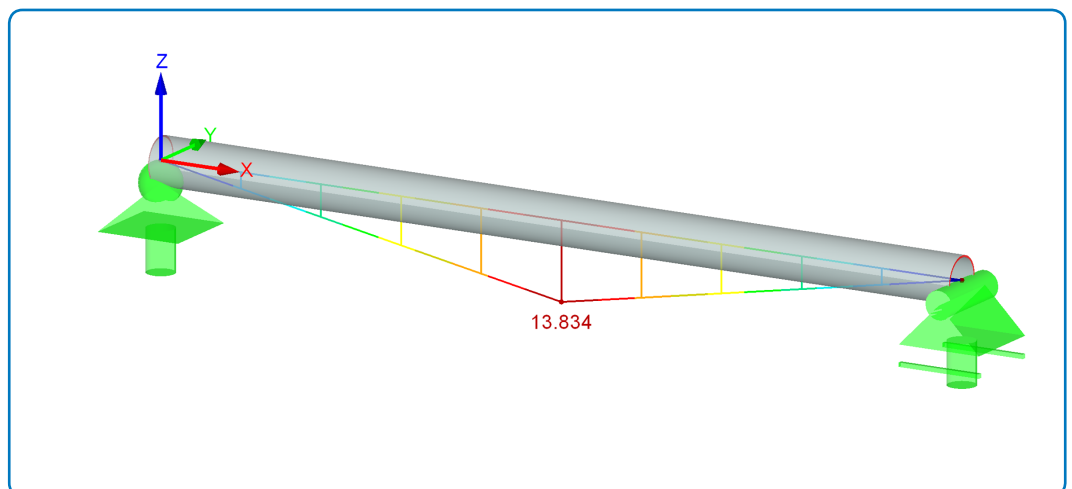
- Modeled in RFEM 5.29.01
- Isotropic linear elastic model is used
- Shear stiffness of members is activated

Results

Structure File	Cross-Section Shape
1008.01	NPS 6×SCH 40
1008.02	Bar 0.500/1.5
1008.03	RT 4×2×0.188
1008.04	I 10×8.65
1008.05	Unsymmetric Beam
1008.06	2.5×2×0.125 Channel, No Stiffeners
1008.06	2.5×2×0.125 Channel, Stiffeners
1008.07	I 8×6.18
1008.08	I 12×14.3, Symmetric
1008.09	I 12×14.3, Unsymmetric
1008.10	RT 3×3×0.095

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Shape	RFEM Solution [kip·in]	ADM Solution [kip·in]	Ratio [-]
NPS 6×SCH 40	218.294	218.294	1.000
Bar 0.500/1.5	3.036	3.19	0.952
RT 4×2×0.188	20.461	20.500	0.998
I 10×8.65	560.004	560.000	1.000
Unsymmetric Beam	37.869	37.900	0.999
2.5×2×0.125 Channel, No Stiffeners	3.843	3.810	1.009
2.5×2×0.125 Channel, Stiffeners	5.822	5.800	1.004
I 8×6.18	316.063	316.000	1.000
Symmetric I 12×14.3	1151.480	1152.000	0.999
Unsymmetric I 12×14.3	401.568	402.000	0.999
RT 3×3×0.095	17.227	17.100	1.007

**Figure 2:** RFEM 5 Results - Bending Moment M_y about Y-axis (Dead Load)**References**

[1] THE ALUMINIUM ASSOCIATION, *Aluminium Design Manual*. 2020.