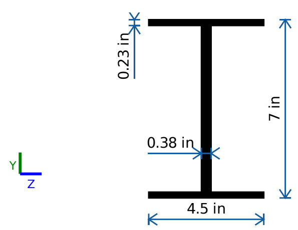
ADM 2020 Aluminum Member Design

Input Summary

Input	Description	Value
$Label$	**Member Label**	Member 1
$Shape$	**Shape**	I-Section
$Section$	**Section**	Custom
$Welded$	**Welded**	Welded
$Alloy$	**Alloy**	1060
$Temper$	**Temper**	H12
$Product$	**Product**	B209, sheet & plate
B	**Width (B)** *The width of the section.*	4.5 in
D	**Depth (D)** *The depth of the section.*	7 in
t_f	**Thickness t_f** *Flange thickness, top/btm wall thickness (Rectangular Hollow Sections).*	0.23 in
t_w	**Thickness t_w** *Web thickness, or side wall thickness (Rectangular Hollow Sections) or Hollow Circular Section thickness.*	0.38 in
$NetAreaFactor$	**Net Area Factor** *Reduction factor for the net area of the section (including holes). 100% means the net area is equal to the section's gross area.*	100 %
Lb	**L_b** *Length between bending restraints.*	48 in
Lz	**$L_{z.comp}$** *Distance between restraints for compression buckling about the Major Z axis.*	48 in
Ly	**$L_{y.comp}$** *The span of the member, as unbraced length in the Y (minor) direction.*	48 in
kz	**k_z** *Distance between restraints for compression buckling about the Minor Y axis.*	1
ky	**k_y** *Effective length coefficient for buckling about the minor Y axis.*	1
Cb	**Moment Gradient Factor (C_b)** *User defined Cb factor, to be calculated to ADM 2020 Cl F.4.1.1*	1
$Method$	**Design Method** *ASD - Allowable Stress Design* *LRFD - Load Resistance Factor Design*	ASD
Mdz	**Major Bending ($M_{d.z}$)** *Moment about major Z-axis. Positive for compression at the top of section.*	2.5 kip-ft
Mdy	**Minor Bending ($M_{d.y}$)** *Moment about minor Y-axis. Positive for compression at right of section.*	0.5 kip-ft
Vdy	**Major Shear ($V_{d.y}$)** *Shear along major Y-axis.*	5 kip
Vdz	**Minor Shear ($V_{d.z}$)** *Shear along minor Z-axis.*	5 kip
Pdc	**Axial Compression ($P_{d.c}$)** *Design axial compression.*	1 kip
Pdt	**Axial Tension ($P_{d.t}$)** *Design axial tension.*	0 kip
$FlexureMethod$	**Bending**	Weighted Average

Section Profile



Section Properties

Gross Section Area	$A_g =$	4.56 in^2
Net Section Area	$A_n =$	4.56 in^2
Centroid Z	$C_z =$	2.25 in
Centroid Y	$C_y =$	3.5 in
Moment of Inertia (Z)	$I_z =$	32.59 in^4
Moment of Inertia (Y)	$I_y =$	3.52 in^4
Elastic Section Modulus (Compression Side, Z)	$S_{z.c} =$	9.31 in^3
Elastic Section Modulus (Tension Side, Z)	$S_{z.t} =$	9.31 in^3
Elastic Section Modulus (Compression Side, Y)	$S_{y.c} =$	1.57in^3
Elastic Section Modulus (Tension Side, Y)	$S_{y.t} =$	1.57 in^3
Plastic Section Modulus (about Z axis)	$Z_z =$	11.07 in^3
Plastic Section Modulus (about Y axis)	$Z_y =$	2.56 in^3
Radius of Gyration about Z	$r_z =$	2.67 in
Radius of Gyration about Y	$r_y =$	0.88 in
Torsion Constant	$J =$	0.16 in^4

Material Properties

ADM 2020 Table A.4.1 & Table A.4.3

Material properties imported based on Welded 1060 - H12, B209, sheet & plate with material thickness of 0.38 inches.

Tensile Ultimate Strength#	$F_{tu} =$	8 ksi
Tensile Yield Strength#	$F_{ty} =$	2.5 ksi
Compressive Yield Strength	$F_{cy} =$	2.5 ksi
Shear Ultimate Strength	$F_{su} =$	4.8 ksi
Shear Yield Strength	$F_{sy} =$	1.5 ksi
Modulus of Elasticity	$E =$	10100 ksi
Coefficient for Tension Members	$k_t =$	1

#Note: As the section is specified as being welded, the variables F_{tu} and F_{ty} used throughout the report are based on the value of F_{tuw} and F_{tyw} respectively from Table A.4.3

Buckling Coefficients

ADM 2020 Table B.4.1

Member Buckling

$B_c =$ 2.625
$D_c =$ 0.005
$C_c =$ 337.644

Uniform Compression in Flat Elements

$B_p =$ 2.946
$D_p =$ 0.006
$C_p =$ 318.713

Uniform Compression in Curved Elements

$B_t =$ 3.019
$D_t =$ 0.055
$C_t =$ 48.306

Flexural Compression in Flat Elements

$B_{br} =$ 3.882
$D_{br} =$ 0.009
$C_{br} =$ 277.65

Flexural Compression in Curved Elements

$B_{tb} =$ 4.528
$D_{tb} =$ 0.128
$C_{tb} =$ 20.45

Shear in Flat Elements

$B_s =$ 1.776

$D_s =$ 0.003
$C_s =$ 410.455

Strength Checks

Axial Tension

ADM 2020 Cl D.1

Use the following factors for all bending checks assessed using the ASD method:

Safety Factor (ASD) - Rupture	$\Omega_{t.r} =$	1.95
Safety Factor (ASD) - Yielding	$\Omega_{t.y} =$	1.65

ADM2020 Cl D.2

Check axial tension capacity

Check Yielding

$$P_{nt.y} = \frac{F_{ty}A_g}{\Omega_{t.y}} = 6.909 \text{ kip}$$

Check rupture

$$P_{nt.r} = \frac{F_{tu}A_g}{k_t\Omega_{t.r}} = 18.708 \text{ kip}$$

$$P_t = \min(P_{nt.y}, P_{nt.r}) = 6.909 \text{ kip}$$

$$UR = \frac{P_{d.t}}{P_t} = \frac{0}{6.909}$$

UTILITY: 0.00

Axial Compression

ADM2020 Cl E.1

Use the following factor for all compression checks assessed using the ASD method:

Safety Factor	$\Omega_c =$	1.65

Compression - Member Buckling

ADM2020 Cl E.2

Check member buckling capacity about major Z-axis

Slenderness Limit 1	$\lambda_1 =$	24.117
Slenderness Limit 2	$\lambda_2 =$	337.644

Calculate slenderness value

$$\lambda_z = \left(\frac{kL_z}{r_z}\right)$$

$$\lambda_z = \left(\frac{1 \times 48}{2.67}\right)$$

$$\lambda_z = 17.978$$

$$\lambda_z \leq \lambda_1$$

$$\therefore F_c = F_{cy} = 2.5 \text{ ksi}$$

$$P_c = \frac{F_c A_g}{\Omega} = 6.909 \text{ kip}$$

$$UR = \frac{P_{d.c}}{P_c} = \frac{1}{6.909}$$

UTILITY: 0.14

ADM2020 Cl E.2

Check member buckling capacity about minor Y-axis

Slenderness Limit 1	$\lambda_1 =$ 24.117
Slenderness Limit 2	$\lambda_2 =$ 337.644

Calculate slenderness value

$$\lambda_y = \left(\frac{kL_y}{r_y}\right)$$

$$\lambda_y = \left(\frac{1 \times 48}{0.88}\right)$$

$$\lambda_y = 54.545$$

$$\lambda_1 < \lambda_y < \lambda_2$$

$$\therefore F_c = (B_c - D_c\lambda_y)\left(0.85 + 0.15\frac{C_c - \lambda_y}{C_c - \lambda_1}\right) = 2.308 \text{ ksi}$$

$$P_c = \frac{F_c A_g}{\Omega} = 6.379 \text{ kip}$$

$$UR = \frac{P_{d.c}}{P_c} = \frac{1}{6.379}$$

UTILITY: 0.16

Compression - Local Buckling

Assess capacity of each element using the weighted average method to ADM 2020 Cl E.3.1

ADM2020 Cl B.5.4.1 Check capacity of flange subjected to axial compression

Slenderness Limit 1	$\lambda_1 =$ 14.478
Slenderness Limit 2	$\lambda_2 =$ 47.807

Calculate slenderness value

$$\lambda = b/t$$

$$\lambda = 2.06/0.23 = 8.957$$

$$\lambda \leq \lambda_1$$

$$\therefore F_c = F_{cy} = 2.5$$

ADM2020 Cl B.5.4.2 Check capacity of webs subjected to axial compression

Slenderness Limit 1	$\lambda_1 =$ 45.244
Slenderness Limit 2	$\lambda_2 =$ 149.397

Calculate slenderness value

$$\lambda = b/t$$

$$\lambda = 6.54/0.38 = 17.211$$

$$\lambda < \lambda_1$$

$$\therefore F_c = F_{cy} = 2.5 \text{ ksi}$$

ADM2020 Cl E.3.1 Check local buckling using the weighted average method

$$P_{nc} = \sum_{i=1}^{n} F_{ci} A_i + F_{cy}\left(A_g - \sum_{i=1}^{n} A_i\right)$$

Individual Element Data

Element	F_{ci} (ksi)	A_i (in^2)	F_{ci} x A_i (kip)
Flange Outstand	2.5	0.474	1.185
Flange Outstand	2.5	0.474	1.185
Flange Outstand	2.5	0.474	1.185
Flange Outstand	2.5	0.474	1.185
Web	2.5	2.485	6.213
SUM OF ELEMENTS:	12.5	4.38	10.951

$$P_{nc} = 10.951 + 2.5(4.56 - 4.38)$$

$$\therefore P_{nc} = 11.4 \text{ kip}$$

$$P_c = \frac{P_{nc}}{\Omega} = 6.909 \text{ kip}$$

$$UR = \frac{P_{d.c}}{P_c} = \frac{1}{6.909}$$

UTILITY: 0.14

Compression - Member and Local Buckling Interaction

ADM 2020 Cl E4

Check for interaction between member buckling and local buckling

ADM 2020 Cl B.5.6

Evaluate elastic buckling stress F_e of each element and check whether F_e is < F_c:

Fc is based on the minimum member buckling strength calculated previously in Clause E2

$$\therefore F_c = 2.308 \text{ ksi}$$

Element Name	Element Type/Support	F_e (ksi)	> Fc (ksi)?
Flange	Flat - One Edge	49.705	YES
Web	Flat - Both Edges	131.46	YES

As all values of F_e exceeded the value of F_c, no additional check for interaction between member buckling and local buckling is required

Governing Compression Capacity:

Axial compression capacity is governed by member buckling about minor Y-axis

$$P_c = 6.379 \text{ kip}$$

UTILITY: 0.16

Bending - Major Axis

Convert user defined bending moments from kip-ft to kip-in

Major Axis Bending	$M_{d.z} =$	30 kip-in
Minor Axis Bending	$M_{d.y} =$	6 kip-in

ADM 2020 Cl F.1

Use the following factors for all bending checks assessed using the ASD method:

Safety Factor (ASD) - Rupture	$\Omega_{b.r} =$	1.95
Safety Factor (ASD) - Other Bending Limit States	$\Omega_b =$	1.65

Major Axis Bending - Yielding and Rupture

ADM2020 Cl F.2

Check strength of member for yielding and rupture about major axis

Check yielding:

Assuming the product is wrought as per Clause F.2(a):

$$M_{npz} = \min(Z_z F_{cy},\ 1.5 S_{z.t} F_{ty},\ 1.5 S_{z.c} F_{cy})$$

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$$\therefore M_{npz} = \min(27.675, 34.913, 34.913) = 27.675 \text{ kip-in}$$

$$M_{nz.yield} = \frac{M_{npz}}{\Omega_b} = 16.773 \text{ kip-in}$$

Check rupture:

$$M_{nz.rupt} = \frac{ZF_{tu}}{k_t \Omega_{b.r}} = 45.415 \text{ kip-in}$$

$$M_{cz} = \min(M_{nz.yield}, M_{nz.rupt}) = 16.773 \text{ kip-in}$$

$$UR = \frac{M_{d.z}}{M_{cz}} = \frac{30}{16.773}$$

UTILITY: 1.79

Major Axis Bending - Local Buckling

Assess flexure capacity using the weighted average method to ADM 2020 Cl F.3.1

$$M_{nlb.z} = \frac{F_c I_f}{c_{cf}} + \frac{F_b I_w}{c_{cw}}$$

Check the individual components applicable to the flexure weighted average method:

ADM2020 Cl B.5.4.1

Check flange in uniform compression:

Slenderness Limit 1	$\lambda_1 =$	14.478
Slenderness Limit 2	$\lambda_2 =$	47.807

Calculate slenderness value

$$\lambda = b/t$$

$$\lambda = 2.06/0.23 = 8.957$$

$$\lambda \leq \lambda_1$$

$$\therefore F_c = F_{cy} = 2.5$$

ADM2020 Cl B.5.5.1

Check web subject to bending about major axis:

Assess 'm' coefficient required for Clause B.5.5.1

Centroid to element extreme compressive fiber	$c_c =$	-3.27 in
Centroid to other extreme fiber of the element	$c_o =$	3.27 in

$$c_o/c_c = -1$$

$$\therefore m = \frac{1.3}{(1 - c_o/c_c)} = 0.65$$

Slenderness Limit 1	$\lambda_1 =$	21.784
Slenderness Limit 2	$\lambda_2 =$	320.365

Calculate slenderness value

$$\lambda = b/t$$

$$\lambda = 6.54/0.38 = 17.211$$

$$\lambda \leq \lambda_1$$

$$\therefore F_b = 1.5F_{cy} = 3.75 \text{ ksi}$$

Compression Element Data:

Element	F_c (ksi)	I_f (in^4)	c_{cf} (in)	F_c I_f / c_{cf}
Flange	2.5	23.732	3.385	17.527

Flexure Element Data:

Element	F_b (ksi)	I_w (in^4)	c_{cw} (in)	F_b I_w / c_{cw}
Web	3.75	8.858	3.27	10.158

$$\therefore M_{nlb.z} = 17.527 + 10.158 = 27.686 \text{ kip-in}$$

$$M_{c.z} = \frac{M_{nlb.z}}{\Omega_b} = 16.779 \text{ kip-in}$$

$$UR = \frac{M_{d.z}}{M_{c.z}} = \frac{30}{16.779}$$

UTILITY: 1.79

Lateral-Torsional Buckling

ADM2020 Cl F.4

Check lateral-torsional buckling capacity of member

Slenderness Limit 1 $\lambda_1 =$ 337.644

Calculate slenderness value

ADM 2020 Cl F.4.2.1

$$\lambda = \frac{L_b}{r_{ye}\sqrt{C_b}}$$

ADM 2020 Cl F.4.2.1

$$r_{ye} = 1.2r_y = 1.056$$

$$\therefore \lambda = \frac{48}{1.056\sqrt{1}} = 45.455$$

Calculate capacity:

$$\lambda < \lambda_1$$

From Design Check F.2 for above: $M_{np} =$ 27.675 kip-in

$$\therefore M_{nmb} = M_{np}\left(1 - \frac{\lambda}{C_c}\right) + \frac{\pi^2 E\lambda S_{xc}}{C_c^3} = 25.045 \text{ kip-in}$$

$$M_c = \frac{M_{nmb}}{\Omega_b} = 15.179 \text{ kip-in}$$

$$UR = \frac{M_d}{M_c} = \frac{30}{15.179}$$

UTILITY: 1.98

Governing Major Axis Bending Capacity:

Major axis bending capacity is governed by lateral-torsional buckling

$$M_{c.z} = 15.179 \text{ kip-in}$$

UTILITY: 1.98

Bending - Minor Axis

Minor Axis Bending - Yielding and Rupture

Check strength of member for yielding and rupture about minor axis

ADM2020 Cl F.2

Check yielding:

Assuming the product is wrought as per Clause F.2(a):

$$M_{npy} = \min(Z_y F_{cy},\ 1.5 S_{y.t} F_{ty},\ 1.5 S_{y.c} F_{cy})$$

$$\therefore M_{npy} = \min(6.4, 5.888, 5.888) = 5.888 \text{ kip-in}$$

$$M_{ny.yield} = \frac{M_{npy}}{\Omega_b} = 3.568 \text{ kip-in}$$

Check rupture:

$$M_{ny.rupt} = \frac{Z F_{tu}}{k_t \Omega_{b.r}} = 10.503 \text{ kip-in}$$

$$M_{cy} = \min(M_{ny.yield}, M_{ny.rupt}) = 3.568 \text{ kip-in}$$

$$UR = \frac{M_{d.y}}{M_{cy}} = \frac{6}{3.568}$$

UTILITY: 1.68

Minor Axis Bending - Local Buckling

Assess flexure capacity using the weighted average method to ADM 2020 Cl F.3.1

$$M_{nlb.y} = \frac{F_c I_f}{c_{cf}} + \frac{F_b I_w}{c_{cw}}$$

Check the individual components applicable to the flexure weighted average method:

ADM2020 Cl B.5.5.2

Check flange subject to bending about minor axis:

Slenderness Limit 1	$\lambda_1 =$	4.046
Slenderness Limit 2	$\lambda_2 =$	79.328

Calculate slenderness value

$$\lambda = b/t$$

$$\lambda = 2.06/0.23 = 8.957$$

$$\lambda_1 < \lambda < \lambda_2$$

$$\therefore F_b = B_{br} - 3.5 D_{br} \lambda = 3.59$$

Flexure Element Data:

Element	F_b (ksi)	I_w (in^4)	c_{cw} (in)	$F_b\ I_w\ /\ c_{cw}$
Flange	3.59	3.52	2.25	5.616

$$\therefore M_{nlb.y} = 0 + 5.616 = 5.616 \text{ kip-in}$$

$$M_{c.y} = \frac{M_{nlb.y}}{\Omega_b} = 3.404 \text{ kip-in}$$

$$UR = \frac{M_{d.y}}{M_{c.y}} = \frac{6}{3.404}$$

UTILITY: 1.76

Governing Minor Axis Bending Capacity:

Minor axis bending capacity is governed by local-buckling using the weighted-average method

$$M_{c.y} = 3.404 \text{ kip-in}$$

UTILITY: 1.76

Shear

ADM 2020 Cl G.1

Use the following factors for all shear checks assessed using the ASD method:

Safety Factor (ASD) - Other Shear Limit States	$\Omega_v =$	1.65
Safety Factor (ASD) - Rupture	$\Omega_{v.r} =$	1.95

Shear - Major Axis

ADM 2020 Cl G.2

Check shear capacity for shear in web (major axis shear)

Assume shear along major axis is resisted by both webs together

Check shear yielding:

ADM 2020 Cl G.1

$$V_n = F_s A_v$$

Slenderness Limit 1	$\lambda_1 =$	76.615
Slenderness Limit 2	$\lambda_2 =$	328.364

Calculate slenderness value

$$\lambda = b/t$$

$$\lambda = 6.54/0.38 = 17.211$$

$$\lambda \leq \lambda_1$$

$$\therefore F_s = F_{sy} = 1.5 \text{ ksi}$$

$$A_v = 2.485 \ in^2$$

$$\therefore V_{n.yield} = 3.728 \text{ kip}$$

$$V_{c.yield} = \frac{V_{n.yield}}{\Omega_v} = 2.259 \text{ kip}$$

Check shear rupture:

Note: Calculations assume full area is welded therefore non-welded area is ignored from Eq G.2-2

ADM 2020 Cl G.2

$$V_n = F_{su} A_v$$

$$\therefore V_{n.rupture} = 11.929 \text{ kip}$$

$$V_{c.rupture} = \frac{V_{n.rupture}}{\Omega_{v.r}} = 6.117 \text{ kip}$$

Evaluate governing shear capacity:

$$V_c = \min(V_{c.yield}, V_{c.rupture}) = 2.259 \text{ kip}$$

$$UR = \frac{V_{d.y}}{V_c} = \frac{5}{2.259}$$

UTILITY: 2.21

Shear - Minor Axis

ADM 2020 Cl G.2

Check shear capacity for shear in flange (minor axis shear)

Assume shear along minor axis is resisted by both flanges together

Check shear yielding:

ADM 2020 Cl G.1	$$V_n = F_s A_v$$	
	Slenderness Limit 1 $\lambda_1 =$ 31.923	
	Slenderness Limit 2 $\lambda_2 =$ 136.818	
	Calculate slenderness value	
	$$\lambda = b/t$$	
	$$\lambda = 2.06/0.23 = 8.957$$	
	$$\lambda \leq \lambda_1$$	
	$$\therefore F_s = F_{sy} = 1.5 \text{ ksi}$$	
	$$A_v = 2.07\ in^2$$	
	$$\therefore V_{n.yield} = 3.105 \text{ kip}$$	
	$$V_{c.yield} = \frac{V_{n.yield}}{\Omega_v} = 1.882 \text{ kip}$$	
	Check shear rupture:	
	Note: Calculations assume full area is welded therefore non-welded area is ignored from Eq G.3-2	
ADM 2020 Cl G.3	$$V_n = F_{su} A_v$$	
	$$\therefore V_{n.rupture} = 9.936 \text{ kip}$$	
	$$V_{c.rupture} = \frac{V_{n.rupture}}{\Omega_{v}.r} = 5.095 \text{ kip}$$	
	Evaluate governing shear capacity:	
	$$V_c = \min(V_{c.yield}, V_{c.rupture}) = 1.882 \text{ kip}$$	
	$$UR = \frac{V_{d.z}}{V_c} = \frac{5}{1.882}$$	**UTILITY: 2.66**

Combined Actions

ADM 2020 Cl H.1	Check combined axial and bending	
	Check combined compression and bending	
	$$UR = \frac{P_{d.c}}{P_c} + \frac{M_{d.z}}{M_{cz}} + \frac{M_{d.y}}{M_{cy}} \leq 1$$	
	$$UR = \frac{1}{6.379} + \frac{30}{15.179} + \frac{6}{3.404}$$	
	$$\therefore UR = 3.896$$	**UTILITY: 3.90**
	Check combined tension and bending	
	$$UR = \frac{P_{d.t}}{P_t} + \frac{M_{d.z}}{M_{cz}} + \frac{M_{d.y}}{M_{cy}} \leq 1$$	
	$$UR = \frac{0}{6.909} + \frac{30}{15.179} + \frac{6}{3.404}$$	

$$\therefore UR = 3.739$$

UTILITY: 3.74

ADM 2020 Cl H.3

Check combined bending compression and shear, major axis

Check combined compression, bending and shear

$$UR = \frac{P_{d.c}}{P_c} + \left(\frac{M_d}{M_c}\right)^2 + \left(\frac{V_d}{V_c}\right)^2 \leq 1$$

$$UR = \frac{1}{6.379} + \left(\frac{30}{15.179}\right)^2 + \left(\frac{5}{2.259}\right)^2$$

$$\therefore UR = 8.961$$

UTILITY: 8.96

ADM 2020 Cl H.3

Check combined bending compression and shear, minor axis

Check combined compression, bending and shear

$$UR = \frac{P_{d.c}}{P_c} + \left(\frac{M_d}{M_c}\right)^2 + \left(\frac{V_d}{V_c}\right)^2 \leq 1$$

$$UR = \frac{1}{6.379} + \left(\frac{6}{3.404}\right)^2 + \left(\frac{5}{1.882}\right)^2$$

$$\therefore UR = 10.324$$

UTILITY: 10.32

Results Summary

Result Name	Results
MEMBERS	
Tension Utilization	0.00
Compression Utilization	0.16
Major Axis Bending Utilization	1.98
Minor Axis Bending Utilization	1.76
Shear along Major Z Axis Utilization	2.21
Shear along Minor Y Axis Utilization	2.66
COMBINED	
Combined Compression + Bending	3.90
Combined Tension + Bending	3.74
Combined Bending and Shear (Major Axis)	8.96
Combined Bending and Shear (Minor Axis)	10.32

About this Calculator

Calculator Name: ADM 2020 Aluminum Member Design
Description: Calculates the bending, shear, axial and combined utilization of aluminum sections as per ADM 2020.

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URL: https://platform.skyciv.com/quick-design?uid=2605-us-aluminium-design&member_label=Member%201&shape=i_section§ion=custom&welded=Welded&alloy=1060&temper=H12&product=B209,%20sheet%20%26%20plate&B=4.5&D=7&t_f=0.23&t_w=0.38&an_factor=100&Lb=48&Lz=48&Ly=48&kz=1&ky=1&cb_factor=1&method=ASD&Mrz=2.5&Mry=0.5&Vry=5&Vrz=5&Prc=1&Prt=0&flexure_setting=weighted_average

Contact: support@skyciv.com