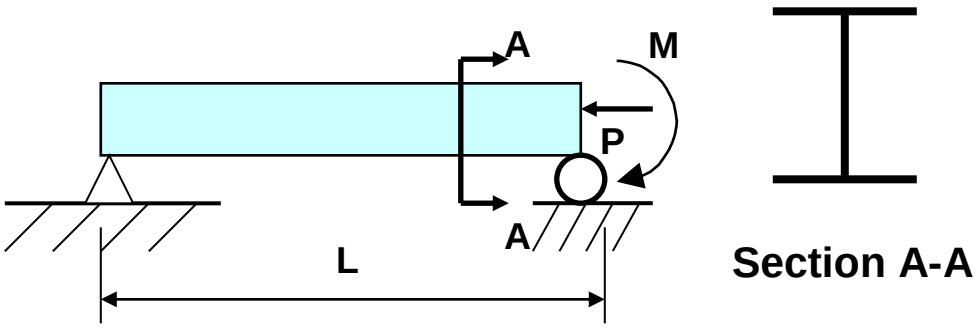
NTC 2008 Example 001

WIDE FLANGE SECTION UNDER COMBINED COMPRESSION & BENDING

EXAMPLE DESCRIPTION

In this example a continuous beam-column is subjected to factored axial load P = 1400 kN and major-axis bending moment M = 200 kN-m. The beam is continuously braced to avoid any buckling effects. This example was tested using the Italian NTC-2008 steel frame design code. The design capacities are compared with independent hand calculated results.

GEOMETRY, PROPERTIES AND LOADING



L = 0.4 m

Material Properties	Loading	Design Properties
E = 210x10^3 MPa	P = 1400 kN	f_y = 235 MPa
v = 0.3	M = 200 kN-m	Section: *457x191x98 UB*
G = 80769 MPa		

TECHNICAL FEATURES TESTED

- Section compactness check (beam-column)
- Section compression capacity
- Section shear capacity
- Section bending capacity with compression & shear reductions
- Interaction capacity, D/C

RESULTS COMPARISON

Independent results are taken from hand calculations based on the CSI steel design documentation contained in the file "SFD-NTC-2008.pdf," which is available through the program "Help" menu.

Output Parameter	SAP2000	Independent	Percent Difference
Compactness	Class 2	Class 2	0.00%
Section Compression Resistance, $N_{c,Rd}$ (kN)	2797.6	2797.6	0.00%
Section Shear Resistance, $V_{c,Rd,y}$ (kN)	719.2	719.2	0.00%
Section Plastic Bending Resistance, $M_{c,y,Rd}$ (kN-m)	499.1	499.1	0.00%
Section Bending Resistance Axially Reduced, $M_{N,y,Rd}$ (kN-m)	310.8	310.8	0.00%
Section Bending Resistance Shear Reduced, $M_{V,y,Rd}$ (kN-m)	481.3	481.3	0.00%
Interaction Capacity, D/C	0.741	0.741	0.00%

COMPUTER FILE: NTC 2008 EX001

CONCLUSION

The results show an exact comparison with the independent results.

HAND CALCULATION

Properties:

Material: S275 Steel

E = 210000 MPa

f_y = 235 MPa

Section: 457x191x98 UB

A = 12,500 mm^2

b = 192.8 mm, t_f = 19.6 mm, h = 467.2 mm, t_w = 11.4 mm, r = 10.2 mm

$$h_w = h - 2t_f = 467.2 - 2 \bullet 19.6 = 428\,\text{mm}$$

$$d = h - 2\left(t_f + r\right) = 467.2 - 2 \bullet \left(19.6 + 10.2\right) = 407.6\,\text{mm}$$

$$c = \frac{b - t_w - 2r}{2} = \frac{192.8 - 11.4 - 2 \bullet 10.2}{2} = 80.5\,\text{mm}$$

$W_{pl,y}$ = 2,230,000 mm^3

Other:

$$\gamma_{M0} = 1.05$$

Loadings:

$P = 1400\,\text{kN}$ axial load

$M_y = 200$ kN-m bending load at one end

Results in the following internal forces:

$N_{Ed} = 1400$ kN

$V_{Ed} = 500$ kN

$M_{y,Ed} = 200$ kN-m

Section Compactness:

$$\varepsilon = \sqrt{\frac{235}{f_y}} = \sqrt{\frac{235}{235}} = 1$$

$$-1 \le \alpha = \frac{1}{2}\left(1 - \frac{N_{Ed}}{2ht_w f_y}\right) \le 1$$

$$\alpha = \frac{1}{2}\left(1 - \frac{1,400,000}{2 \bullet 467.2 \bullet 11.4 \bullet 235}\right) = 2.7818 > 1, \text{ so}$$

$$\alpha = 1.0$$

Localized Buckling for Flange:

For the tip in compression under combined bending & compression

$$\lambda_{cl.1} = \frac{9\varepsilon}{\alpha} = \frac{9 \bullet 1}{1} = 9$$

$$\lambda_e = \frac{c}{t_f} = \frac{80.5}{19.6} = 4.11$$

$$\lambda_e = 4.11 < \lambda_{cl.1} = 9$$

So Flange is Class 1 in combined bending and compression

Localized Buckling for Web:

$$\alpha > 0.5, \; so$$

$$\lambda_{cl.1} = \frac{396\varepsilon}{13\alpha - 1} = \frac{396 \bullet 1}{13 \bullet 1 - 1} = 33.00 \text{ for combined bending \& compression}$$

$$\lambda_e = \frac{d}{t_w} = \frac{407.6}{11.4} = 35.75$$

$$\lambda_e = 35.75 > \lambda_{cl.1} = 33.00$$

$$\lambda_{cl.2} = \frac{456\varepsilon}{13\alpha - 1} = \frac{456 \bullet 1}{13 \bullet 1 - 1} = 38.00$$

$$\lambda_e = 35.75 < \lambda_{cl.2} = 38.00$$

So Web is Class 2 in combined bending & compression.

Since Web is Class 2, Section is Class 2 in combined bending & compression.

Section Compression Capacity

$$N_{c,Rd} = N_{pl,Rd} = \frac{Af_y}{\gamma_{M0}} = \frac{12,500 \bullet 235}{1.05}$$

$$\boxed{N_{c,Rd} = 2797.6\,\text{kN}}$$

Section Shear Capacity

$$A_{V,y} = A - 2bt_f + t_f\left(t_w + 2r\right) = 12,500 - 2 \bullet 192.8 \bullet 19.6 + 19.6\left(11.4 + 2 \bullet 10.2\right)$$

$$A_{V,y} = 5,565.5\,\text{mm}^2$$

$$V_{c,Rd,y} = \frac{f_y}{\gamma_{M0}\sqrt{3}} A_{vy} = \frac{235}{1.05\sqrt{3}} \bullet 5,565.5$$

$$\boxed{V_{c,Rd,y} = 719.2\,\text{kN}}$$

$$\eta = 1.0$$

$$\frac{h}{t_w} = \frac{467.1}{11.4} = 37.5 < \frac{72}{\eta}\sqrt{\frac{235}{f_y}} = \frac{72}{1.0}\sqrt{\frac{235}{235}} = 72$$

So no shear buckling needs to be checked.

Section Bending Capacity

$$M_{c,y,Rd} = M_{pl,y,Rd} = \frac{W_{pl,y} f_y}{\gamma_{M0}} = \frac{2,230,000 \bullet 235}{1.05}$$

$$\boxed{M_{c,y,Rd} = 499.1\,\text{kN-m}}$$

with Shear Reduction

$V_{Ed} = 500\,\text{kN} > 0.5 \bullet V_{c,Rd} = 359.6\,\text{kN}$ Shear Reduction is needed

$A_v = ht_w = 467.2 \bullet 11.4 = 4{,}879.2\,\text{mm}^2$

$$\rho = \left(\frac{2V_{Ed}}{V_{c,Rd}} - 1 \right)^2 = \left(\frac{2 \bullet 500}{719.2} - 1 \right)^2 = 0.1525$$

$$M_{y,V,Rd} = \frac{\left[W_{pl,y} - \frac{\rho A_v^{\,2}}{4t_w} \right] f_{yk}}{\gamma_{M0}} = \frac{\left[2{,}230{,}000 - \frac{0.1525 \bullet 4879.2^2}{4 \bullet 11.4} \right] \bullet 235}{1.05} \le M_{y,c,Rd}$$

$\boxed{M_{V,r,Rd} = 481.3\,\text{kN-m}}$

with Compression Reduction

$$n = \frac{N_{Ed}}{N_{pl,Rd}} = \frac{1400}{2797.6} = 0.50$$

$$a = \frac{A - 2bt_f}{A} = \frac{12{,}500 - 2 \bullet 192.8 \bullet 19.6}{12{,}500} = 0.40 \le 0.5$$

$$M_{N,y,Rd} = M_{pl,y,Rd} \frac{1-n}{1-0.5a} = 499.1 \bullet \frac{1-0.5}{1-0.5 \bullet 0.4}$$

$\boxed{M_{N,y,Rd} = 310.8\,\text{kN-m}}$

Interaction Capacity: Compression & Bending

Section Bending & Compression Capacity

Formula NTC 4.2.39

$$\frac{D}{C} = \left[\frac{M_{y,Ed}}{M_{N,y,Rd}} \right]^2 + \left[\frac{M_{z,Ed}}{M_{N,z,Rd}} \right]^{5n} = \left[\frac{200}{310.8} \right]^2 + 0 = 0.414 \le \frac{M_{y,Ed}}{M_{N,y,Rd}} = 0.644$$

$$\frac{D}{C} = 0.644$$

Member Bending & Compression Capacity: Method B

k factors used are taken from the software, and determined from Method 2 in Annex B of Eurocode 3.

$k_{yy} = 0.540$

$k_{yz} = 0.420$

$k_{zy} = 0.600$

$k_{zz} = 0.700$

Formula NTC 4.2.37

$$\frac{D}{C} = \frac{N_{Ed}}{\frac{\chi_y A f_{yk}}{\gamma_{M1}}} + k_{yy}\frac{M_{y,Ed}}{\chi_{LT}\frac{W_{pl,y} f_{yk}}{\gamma_{M1}}} + k_{yz}\frac{M_{z,Ed}}{\frac{W_{pl,z} f_{yk}}{\gamma_{M1}}}$$

$$\frac{D}{C} = \frac{1,400}{\frac{1\times 12,500\times 235}{1.05}} + 0.54\times\frac{200}{1\times\frac{2,230,000\times 235}{1.05}} + 0$$

$$\frac{D}{C} = 0.5 + 0.22 + 0$$

$$\frac{D}{C} = 0.717$$

Formula NTC 4.2.38

$$\frac{D}{C} = \frac{N_{Ed}}{\frac{\chi_z A f_{yk}}{\gamma_{M1}}} + k_{zy}\frac{M_{y,Ed}}{\chi_{LT}\frac{W_{pl,y} f_{yk}}{\gamma_{M1}}} + k_{zz}\frac{M_{z,Ed}}{\frac{W_{pl,z} f_{yk}}{\gamma_{M1}}}$$

$$\frac{D}{C} = \frac{1,400}{\frac{1\times 12,500\times 235}{1.05}} + 0.600\times\frac{200}{1\times\frac{2,230,000\times 235}{1.05}} + 0$$

$$\frac{D}{C} = 0.5 + 0.24 + 0$$

$$\frac{D}{C} = 0.741 \text{ (Governs)}$$