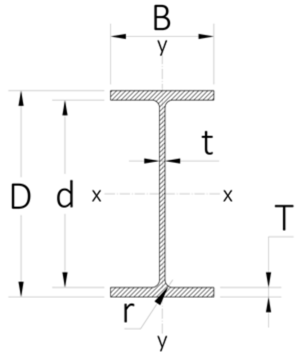
Universal beam with fixed supports and two equi-spaced point loads

Dimensions and properties of structural steel EN 1993-1-1 Universal Beam:



Sizes based on British Steel Section 203 x 102 x 23 UB BS EN 10365:2017

Depth of UB section: $D := 203.2\ mm$

Width of UB section: $B := 101.8\ mm$

Flange thickness: $T := 9.3\ mm$

Web thickness: $t := 5.4\ mm$

Root radius: $r := 7.6\ mm$

Depth between flanges: $d := 184.6\ mm$

Mass of section per metre: $mass := 23.1\ kg\ m^{-1}$

Density of steel: $\rho := 7850\ kg\ m^{-3}$

Poisson's ratio in elastic range: $\nu := 0.30$

Young's modulus of elasticity: $E := 210\ GPa$

Ultimate tensile strength of hot rolled steel: $UTS := 400\ MPa$

Yield strength of hot rolled steel: $\sigma_y := 250\ MPa$

Calculations for beam loading with two supports and point load

Length of beam: $L := 2.0\ m$

Distance to first support along beam: $L_A := 0.0\ m$

Distance to second support along beam: $L_B := 2.0\ m$

Point loads and distance along beam: $F := \begin{bmatrix} 10.7\ kN & 1.0\ kN \\ 0.5\ m & 1.5\ m \end{bmatrix}$

Factor of Safety for bending stress: $FOS := 5$

Distance from support "A" for deflection investigation: $x := 0.5\ m$

Total weight of the beam: $W := mass \cdot L\ g_e = 0.4531\ kN$

Cross sectional area of UB section: $A := \left((2 \cdot r)^2 - \left(\frac{\pi \cdot (2 \cdot r)^2}{4}\right)\right) + 2 \cdot (B \cdot T) + (d \cdot t) = 2939.9\ mm^2$

Second moment of area on x-x axis: $I_{xx} := \left(\frac{t \cdot d^3}{12}\right) + \left(\frac{B}{12}\right) \cdot \left(D^3 - d^3\right) = 2064.18\ cm^4$

Maximum allowable bending stress: $\sigma_a := \frac{\sigma_y}{FOS} = 50\ MPa$

Stress loading on supports

Point load F1 on beam: $F1 = 10.7\ \text{kN}$

Point load F2 on beam: $F2 = 1\ \text{kN}$

Maximum point loads on beam: $F_{max} := F1 + F2 = 11.7\ \text{kN}$

Distances of point loads from support "A" and "B": $a_A = 0.5\ \text{m}$ $a_B = 0.5\ \text{m}$

Left support reaction force: $R1 := \left(-\frac{L_B - a_A}{L_B - L_A}\right) \cdot F_{max} = -8.775\ \text{kN}$

Right support reaction force: $R2 := -R1 - F_{max} = -2.925\ \text{kN}$

Total reaction forces on beam: $R1 + R2 = -11.7\ \text{kN}$

Distance to point load from neutral axis: $y := \frac{D}{2} = 101.6\ \text{mm}$

Normal stress on the beam: $\sigma := \frac{F_{max}}{A} = 3.9797\ \text{MPa}$

Bending moment at "F1" point load: $M_1 := F1 \cdot a_A = 5.35\ \text{kN m}$

Bending moment at "F2" point load: $M_2 := F2 \cdot a_B = 0.5\ \text{kN m}$

Maximum bending moment of beam at F1 point load: $M_{max} := F_{max} \cdot a_A = 5.85\ \text{kN m}$

Bending stress at "F1" point load: $\sigma_1 := \frac{y \cdot F1 \cdot a_A}{I_{xx}} = 26.3329\ \text{MPa}$

Bending stress at "F2" point load: $\sigma_2 := \frac{y \cdot F2 \cdot a_B}{I_{xx}} = 2.461\ \text{MPa}$

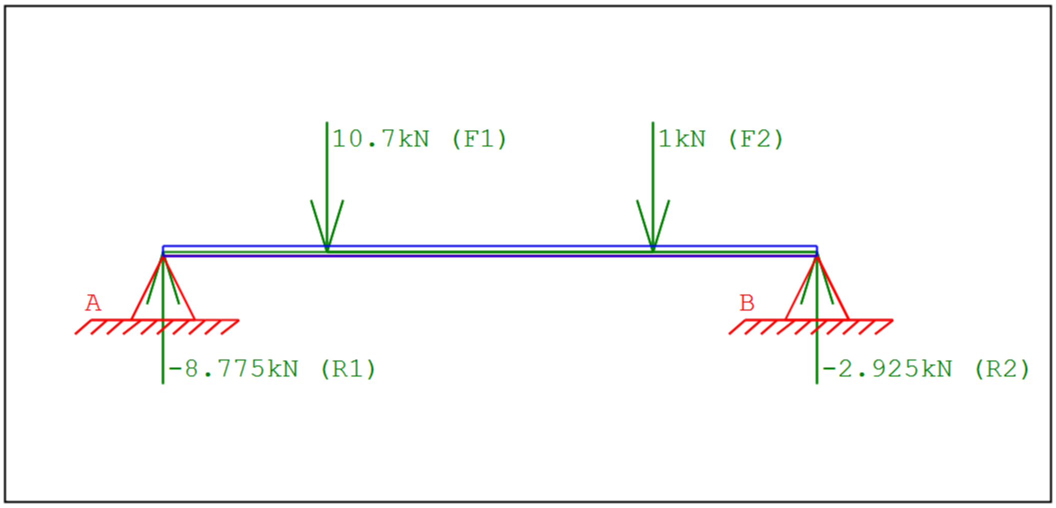
Maximum bending stress on the beam: $\sigma_b := \frac{y \cdot F_{max} \cdot a_A}{I_{xx}} = 28.794\ \text{MPa}$

Strain on the beam: $\varepsilon := \frac{\sigma_b}{E} = 0.000137$

Maximum deflection of beam: $\delta_{max} = 0.67477\ \text{mm}$

Maximum extension of beam: $\Delta L := \varepsilon \cdot L = 0.2742\ \text{mm}$

Diagram showing longitudinal section of beam



UB supported at both ends
2 equi-spaced loads
applied to beam

result = "Beam unlikely to be permanently deformed"

Additional properties of steel beam not included in calculations above

Second moment of area on y-y axis: $I_{yy} := \frac{t^3 \cdot d}{12} + 2 \cdot \left(\frac{B^3 \cdot T}{12}\right) = 163.76\ cm^4$

Radius of gyration on x-x axis: $i_{xx} := \left(\frac{I_{xx}}{A}\right)^{0.5} = 8.3793\ cm$

Radius of gyration on y-y axis: $i_{yy} := \left(\frac{I_{yy}}{A}\right)^{0.5} = 2.3602\ cm$

Section modulus on x-x axis: $Z_{xx} := \frac{2 \cdot I_{xx}}{(d + 2 \cdot T)} = 203.1676\ cm^3$

Section modulus on y-y axis: $Z_{yy} := \frac{2 \cdot I_{yy}}{B} = 32.1736\ cm^3$

Shear modulus: $G := \frac{E}{(2 \cdot (1 + \nu))} = 80769.2308\ MPa$

Breaking stress at the extreme fibre in tension: $\sigma_{max} := \frac{M_{max}}{Z_{xx}} = 28.794\ MPa$

Proof stress,length of plastic deformation of beam before it is permanently deformed: $\sigma_p := L \cdot 0.2\ \% = 4\ mm$