Composite vertical post near window load bearing in long term-duration loading

Wood type:	C24
Width of wooden element:	$b := 45\ mm$
Height of wooden element:	$h := 95\ mm$
Thickness of plywood element:	$b_w := 21\ mm$
Width of plywood element:	$H := 400\ mm$
Clear width between two wood elements:	$h_w := 210\ mm$
Plywood between two posts area:	$A_w := b_w \cdot H = 84\ cm^2$
For I-beam section [EC5 9.1.1 (8)]:	$b_{ef} := \frac{b_w}{2} = 10.5\ mm$
Buckling length about x axis (minus minimal lintel height):	$l_x := 2.886\ m - 0.4\ m = 2.486\ m$
Buckling length about y axis:	$l_y := 1.007\ m$
Factor for support condition at the ends of the element:	$\mu_x := 1 \quad \mu_y := 1$
Factor for solid timber straightness:	$\beta_c := 0.2$
Charac. wood bending strength:	$f_{m.k} := 24\ MPa$
Charac. wood compression strength parallel to the grain:	$f_{c.0.k} := 21\ MPa$
Charac. wood tension strength parallel to the grain:	$f_{t.0.k} := 14\ MPa$
Wood modulus of elasticity parallel to the grain:	$E_{0.05} := 7400\ MPa$
Wood modulus of mean elasticity parallel to the grain:	$E_{0.mean} := 11000\ MPa$
Charac. plywood compression strength:	$f_{p.c.90.k} := 25\ MPa$
Charac. plywood tensile strength :	$f_{p.t.90.k} := 36\ MPa$
Charac. plywood panel shear strength :	$f_{p.v.k} := 9.5\ MPa$
Charac. plywood rolling shear strength :	$f_{p.r.k} := 2.59\ MPa$
Plywood modulus of mean elasticity:	$E_{p.c.90.mean} := 7642\ MPa$
Plywood mean modulus of rigidity:	$G_{w.mean} := 620\ MPa$

Factor for duration loading and service: $k_{mod} := 0.7$

Factor for load shearing: $k_{sys} := 1.0$

Factor for solid timber - bending and axial tension: $k_h := min\left(\left(\frac{150\ mm}{h}\right)^{0.2}, 1.3\right) = 1.096$

Deformation factor for for solid timber class 1: $k_{def.f} := 0.6$

Deformation factor for for plywood class 1: $k_{def.w} := 0.8$

Partial factor for wood properties: $\gamma_{M.f} := 1.30$

Partial factor for plywood properties: $\gamma_{M.w} := 1.25$

Buckling resistance condition with beam laterally supported along its compression flange: $k_c := 1$

Geometric properties - transformed sections

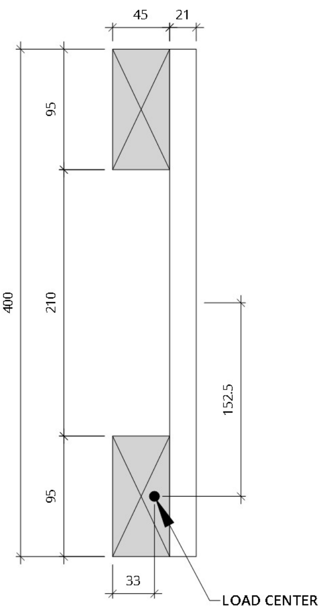
Transformed web thickness (into wood):

$$b_{w.tfd} := \left(b_w \cdot \frac{E_{p.c.90.mean}}{E_{0.mean}}\right) = 14.589\ mm$$

Second moment of area of the flanges (into wood):

$$I_{ef.f.x} := \frac{b \cdot H^3}{12} - \frac{b \cdot (H - 2 \cdot h)^3}{12} = \left(2.053 \cdot 10^8\right)\ mm^4$$

$$I_{ef.f.y} := \frac{b^3 \cdot H}{12} - \frac{b^3 \cdot (H - 2 \cdot h)}{12} = \left(1.443 \cdot 10^6\right)\ mm^4$$



Pic1. Analyed cross-section

Second moment of area of the web:

$$I_{ef.w.x} := \frac{b_{w.tfd} \cdot H^3}{12} = \left(7.781 \cdot 10^7\right)\ mm^4 \qquad I_{ef.w.y} := \frac{b_{w.tfd}^{\ 3} \cdot h}{12} = \left(2.458 \cdot 10^4\right)\ mm^4$$

Instanteous second moment of the tranformed section:

$$I_{ef.x} := I_{ef.f.x} + I_{ef.w.x} = \left(2.831 \cdot 10^8\right)\ mm^4 \qquad I_{ef.y} := I_{ef.f.y} + I_{ef.w.y} = \left(1.467 \cdot 10^6\right)\ mm^4$$

Factor for quasi-permanent value of variable action:

$$\psi_2 := 0.3$$

Transformed web thickness (into wood):

$$b_{c.w.tfd} := \left(b_w \cdot \frac{E_{p.c.90.mean}}{E_{0.mean}}\right) \cdot \frac{1 + \psi_2 \cdot k_{def.f}}{1 + \psi_2 \cdot k_{def.w}} = 13.883\ mm$$

$$I_{c.ef.w.x} := \frac{b_{c.w.tfd} \cdot H^3}{12} = \left(7.404 \cdot 10^7\right)\ mm^4 \qquad I_{c.ef.w.y} := \frac{b_{c.w.tfd}{}^3 \cdot H}{12} = \left(8.92 \cdot 10^4\right)\ mm^4$$

$$I_{c.ef.x} := I_{ef.f.x} + I_{c.ef.w.x} = \left(2.793 \cdot 10^8\right)\ mm^4 \qquad I_{c.ef.y} := I_{ef.f.y} + I_{c.ef.w.y} = \left(1.532 \cdot 10^6\right)\ mm^4$$

Cross-sectional area:

$$A := b \cdot h \cdot 2 + A_w = 169.5\ cm^2$$

Second moment of area*:*

$$I_x := I_{c.ef.x} \qquad I_x = \left(2.793 \cdot 10^8\right)\ mm^4 \qquad I_y := I_{c.ef.y} \qquad I_y = \left(1.532 \cdot 10^6\right)\ mm^4$$

$$W_x := \frac{b_{c.w.tfd} \cdot H^2 + 2 \cdot b \cdot H^2 - 2 \cdot b \cdot (H - 2 \cdot h)^2}{6} = \left(2.109 \cdot 10^6\right)\ mm^3$$

$$W_y := \frac{b_{c.w.tfd}{}^2 \cdot H + (2 \cdot b)^2 \cdot H - (2 \cdot b)^2 \cdot (H - 2 \cdot h)}{6} = \left(2.693 \cdot 10^5\right)\ mm^3$$

Radius of gyration:

$$i_x := \sqrt{\frac{I_x}{A}} = 128.37\ mm \qquad i_y := \sqrt{\frac{I_y}{A}} = 9.507\ mm \qquad i := min\left(i_x, i_y\right) = 9.507\ mm$$

Design element length:

$$l_{ef.x} := \mu_x \cdot l_x = 2.486\ m \qquad l_{ef.y} := \mu_y \cdot l_y = 1.007\ m$$

Slenderness ratio:

$$\lambda_x := \frac{l_{ef.x}}{i_x} = 19.366 \qquad \lambda_y := \frac{l_{ef.y}}{i_y} = 105.921 \qquad \lambda := \max\left(\lambda_x, \lambda_y\right) = 105.921$$

Relative slenderness:

$$\lambda_{rel.x} := \frac{\lambda_x}{\pi} \cdot \sqrt{\frac{f_{c.0.k}}{E_{0.05}}} = 0.328 \qquad \lambda_{rel.y} := \frac{\lambda_y}{\pi} \cdot \sqrt{\frac{f_{c.0.k}}{E_{0.05}}} = 1.796$$

Instability factor:

$$k_x := 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel.x} - 0.3\right) + {\lambda_{rel.x}}^2\right) = 0.557 \qquad k_y := 0.5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel.y} - 0.3\right) + {\lambda_{rel.y}}^2\right) = 2.263$$

$$k_{c.x} := \frac{1}{k_x + \sqrt{{k_x}^2 - {\lambda_{rel.x}}^2}} = 0.994 \qquad k_{c.y} := \frac{1}{k_y + \sqrt{{k_y}^2 - {\lambda_{rel.y}}^2}} = 0.275$$

Axial strength in compression:

$$f_{c.0.d} := \frac{k_{mod} \cdot k_{sys} \cdot f_{c.0.k}}{\gamma_{M.f}} = 11.308 \ MPa$$

Axial strength in tension:

$$f_{t.0.d} := \frac{k_{mod} \cdot k_h \cdot k_{sys} \cdot f_{t.0.k}}{\gamma_{M.f}} = 8.26 \ MPa$$

Compressive stress/Design buckling strength equation :

$$N_{c.k.x} := f_{c.0.k} \cdot A \cdot k_{c.x} = 353.701 \ kN \qquad N_{c.k.y} := f_{c.0.k} \cdot A \cdot k_{c.y} = 97.828 \ kN$$

$$N_{c.d.x} := f_{c.0.d} \cdot A \cdot k_{c.x} = 190.454 \ kN \qquad N_{c.d.y} := f_{c.0.d} \cdot A \cdot k_{c.y} = 52.676 \ kN$$

$$\sigma_{c.0.d.x} := \frac{N_{c.d.x}}{A} = 11.236 \ MPa \qquad \sigma_{c.0.d.y} := \frac{N_{c.d.y}}{A} = 3.108 \ MPa$$

Design wood bending strength:

$$f_{m.d} := \frac{k_{mod} \cdot k_h \cdot k_{sys} \cdot f_{m.k}}{\gamma_{M.f}} = 14.159 \ MPa$$

Moment about the axis x-x:

$$e_y := \frac{H}{2} - \frac{h}{2} = 152.5 \ mm \qquad e_x := \frac{b_w}{2} + \frac{b}{2} = 33 \ mm$$

$$M_{x.d} := N_{c.d.x} \cdot e_y = 29.044 \ kN \cdot m \qquad M_{y.d} := N_{c.d.y} \cdot e_x = 1.738 \ kN \cdot m$$

Bending strength of the web in compression:

$$f_{c.w.d} := \frac{k_{mod} \cdot k_{sys} \cdot f_{p.c.90.k}}{\gamma_{M.w}} = 14 \ MPa$$

Bending stress in top and the bottom flange:

$$\sigma_{f.c.max.d.x} := \frac{M_{x.d}}{I_{c.ef.x}} \cdot \frac{H}{2} = 20.797\ \text{MPa}$$

$$\sigma_{f.c.max.d.y} := \frac{M_{y.d}}{W_y} = 6.454\ \text{MPa}$$

Bending strength of the web in tension:

$$f_{c.w.d} := \frac{k_{mod} \cdot k_{sys} \cdot f_{p.t.90.k}}{\gamma_{M.w}} = 20.16\ \text{MPa}$$

Bending stress in the web:

$$\sigma_{w.c.max.d.x} := \frac{M_{x.d}}{I_{ef.x}} \cdot \frac{H}{2} \cdot \left(\frac{E_{p.c.90.mean}}{E_{0.mean}}\right) = 14.256\ \text{MPa}$$

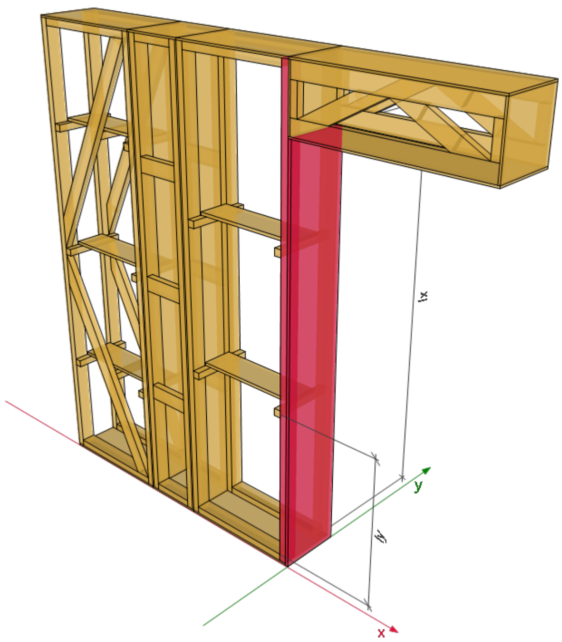
$$\sigma_{w.c.max.d.y} := \frac{M_{y.d}}{W_y} \cdot \left(\frac{E_{p.c.90.mean}}{E_{0.mean}}\right) = 4.484\ \text{MPa}$$

Axial stress in the top and bottom flange:

$$\sigma_{f.c.max.d.c} := \frac{M_{x.d}}{I_{c.ef.x}} \cdot e_y = 15.858\ \text{MPa}$$

Design buckling strength:

$$k_c \cdot f_{c.0.d} = 11.308\ \frac{\text{N}}{\text{mm}^2}$$



Checking combined compression and
bending stress condition about the x-x axis:

$$a := \frac{\sigma_{c.0.d.x}}{k_{c.x} \cdot f_{c.0.d}} + \frac{\sigma_{f.c.max.d.x}}{f_{m.d}} = 2.469$$

$$N_{c.d.x.final} := \frac{N_{c.d.x}}{a} = 77.145\ \text{kN}$$

$$b := \frac{\sigma_{c.0.d.y}}{k_{c.y} \cdot f_{c.0.d}} + \frac{\sigma_{f.c.max.d.y}}{f_{m.d}} = 1.456$$

$$N_{c.d.y.final} := \frac{N_{c.d.y}}{b} = 36.184\ \text{kN}$$

$$N_{c.d.max} := N_{c.d.y.final} = 36.184\ \text{kN}$$