

TALAT Lecture 2301

Design of Members

Shear Force

Example 6.7 : Shear force resistance of orthotropic plate. Open or closed stiffeners

6 pages

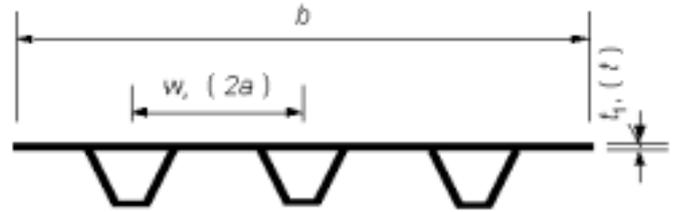
Advanced Level

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Example 6.7. Shear force resistance of orthotropic plate. Open or closed stiffeners



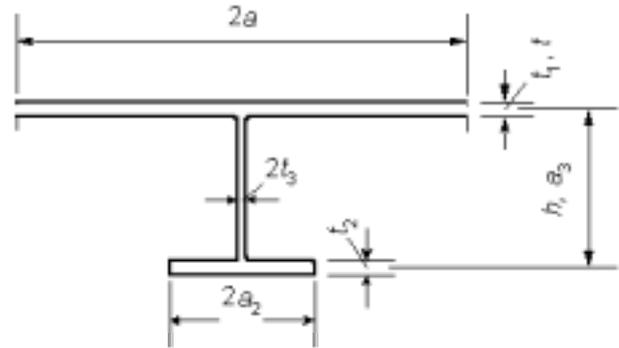
Dimensions

(highlighted)

Plate thickness	$t := 16.5 \cdot \text{mm}$	$t_1 := t$	$f_o := 240 \cdot \text{MPa}$	$N \equiv \text{newton}$
Plate width	$b := 1500 \cdot \text{mm}$		$f_u := 260 \cdot \text{MPa}$	$kN \equiv 1000 \cdot \text{newton}$
Plate length	$L := 2200 \cdot \text{mm}$		$E := 70000 \cdot \text{MPa}$	$\text{MPa} \equiv 10^6 \cdot \text{Pa}$
Stiffener pitch	$w := 300 \cdot \text{mm}$	$a := \frac{w}{2}$	$\gamma_{MF} 1.1$	
If heat-treated alloy, then	$ht = 1$ else $ht = 0$		$ht := 1$	
If cold formed (trapezoidal), then	$cf = 1$ else $cf = 0$		$cf := 0$	

a) Open stiffeners

Half stiffener pitch	$a = 150 \cdot \text{mm}$
Half bottom flange	$a_2 := 50 \cdot \text{mm}$
Thickness of bottom flange	$t_2 := 10 \cdot \text{mm}$
Stiffener depth	$h := 160 \cdot \text{mm}$
Half web thickness	$t_3 := 4.4 \cdot \text{mm}$
Half width of trapezoidal stiffener at the top	$a_1 := 0 \cdot \text{mm}$
Width of web	$a_3 := h$ $a_3 = 160 \cdot \text{mm}$



Local buckling

Length of web panel $L = 2.2 \cdot 10^3 \cdot \text{mm}$ $a = 150 \cdot \text{mm}$ $\frac{L}{2 \cdot a} = 7.333$

(5.97) $k_\tau := \text{if} \left[\frac{L}{2 \cdot a} > 1.00, 5.34 + 4.00 \cdot \left(\frac{2 \cdot a}{L} \right)^2, 4.00 + 5.34 \cdot \left(\frac{2 \cdot a}{L} \right)^2 \right]$ $k_\tau = 5.414$

(5.96) $\lambda_{\bar{w}} = \frac{0.81}{\sqrt{k_\tau}} \cdot \frac{2 \cdot a}{t} \cdot \sqrt{\frac{f_o}{E}}$ $\lambda_{\bar{w}} = 0.371$

Table 5.12 $\rho_{\bar{v}} = \frac{0.48}{\lambda_{\bar{w}}}$ $\rho_{\bar{v}} = 1.295$

Table 5.12 $\eta := 0.4 + 0.2 \cdot \frac{f_u}{f_o}$ $\eta = 0.617$

Table 5.12 $\rho_{\bar{v}} := \text{if}(\rho_{\bar{v}} > \eta, \eta, \rho_{\bar{v}})$ $\rho_{\bar{v}} = 0.617$

(5.95) $V_{w,Rd} := \rho_{\bar{v}} \cdot b \cdot t \cdot \frac{f_o}{\gamma_{MI}}$ $V_{w,Rd} = 3.33 \cdot 10^3 \cdot \text{kN}$

5.11.6 Overall buckling, shear force

Cross sectional area $A := 2 \cdot t_1 \cdot a_1 + 2 \cdot t_2 \cdot a_2 + 2 \cdot t_3 \cdot a_3 - 2 \cdot t_1 \cdot a_1$ $A = 7.358 \cdot 10^3 \cdot \text{mm}^2$

Gravity centre $e := \frac{2 \cdot t_2 \cdot a_2 \cdot h + 2 \cdot t_3 \cdot a_3 \cdot \frac{h}{2}}{A}$ $e = 37.054 \cdot \text{mm}$

Second moment of area

$$I_L := 2 \cdot t_2 \cdot a_2 \cdot h^2 + 2 \cdot t_3 \cdot a_3 \cdot \frac{h^2}{3} - A \cdot e^2$$
 $I_L = 2.751 \cdot 10^7 \cdot \text{mm}^4$

$$s := \text{if}[cf=1, [2 \cdot a_3 - 2 \cdot (a_1 - a_2)], 2 \cdot a_2]$$
 $s = 300 \cdot \text{mm}$

Rigidities of orthotropic plate

Table 5.10 $B_x := \frac{E \cdot I_L}{2 \cdot a}$ $\nu := 0.3$ $B_x = 6.42 \cdot 10^9 \cdot \left(\frac{\text{N} \cdot \text{mm}^2}{\text{mm}}\right)$

Table 5.10 $B_y := \frac{E \cdot t^3}{12 \cdot (1 - \nu^2)}$ $G := \frac{E}{2 \cdot (1 + \nu)}$ $B_y = 2.88 \cdot 10^7 \cdot \left(\frac{\text{N} \cdot \text{mm}^2}{\text{mm}}\right)$

Table 5.10 $H := \frac{G \cdot t^3}{6}$ $H = 2.016 \cdot 10^7 \cdot \left(\frac{\text{N} \cdot \text{mm}^2}{\text{mm}}\right)$

Elastic buckling load

(5.83) (5.84) $\phi := \frac{L}{b} \cdot \left(\frac{B_y}{B_x}\right)^{\frac{1}{4}}$ $\eta := \frac{H}{\sqrt{B_x \cdot B_y}}$ $\phi = 0.38$

$\eta = 0.047$

(5.82) $k_\tau := 3.25 - 0.567 \cdot \phi + 1.92 \cdot \phi^2 + (1.95 + 0.1 \cdot \phi + 2.75 \cdot \phi^2) \cdot \eta$ $k_\tau = 3.423$

(5.81) $V_{o.cr} := \frac{k_\tau \cdot \pi^2}{b} \cdot (B_x \cdot B_y)^{\frac{1}{4}}$ $V_{o.cr} = 2.506 \cdot 10^3 \cdot \text{kN}$

Buckling resistance

(5.120) $\lambda_{ow} := \sqrt{\frac{b \cdot t \cdot f_o}{V_{o.cr}}}$ $\lambda_{ow} = 1.54$

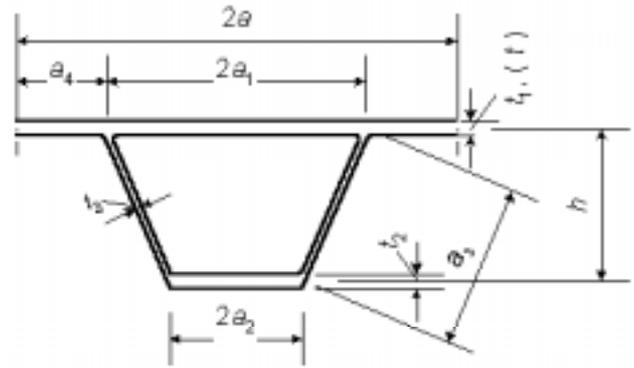
(5.119) $\chi_{\bar{\sigma}} := \frac{0.6}{0.8 + \lambda_{ow}^2}$ $\chi_o := \text{if}(\chi_o > 0.6, 0.6, \chi_o)$ $\chi_{\bar{\sigma}} = 0.189$

(5.118) $V_{o.Rd} := \chi_{\bar{\sigma}} \cdot b \cdot t \cdot I \cdot \frac{f_o}{\gamma_{MI}}$ $V_{o.Rd} = 1.022 \cdot 10^3 \cdot \text{kN}$

$$V_{Rd} := \text{if}(V_{w.Rd} < V_{o.Rd}, V_{w.Rd}, V_{o.Rd})$$
 $V_{Rd} = 1.022 \cdot 10^3 \cdot \text{kN}$

b) Closed stiffeners

Half stiffener pitch	$a = 150 \text{ mm}$
Plate thickness	$t_1 = 16.5 \text{ mm}$
Half bottom flange	$a_2 = 50 \text{ mm}$
Thickness of bottom flange	$t_2 = 10 \text{ mm}$
Stiffener depth	$h = 160 \text{ mm}$
Web thickness	$t_3 = 9 \text{ mm}$
Half width of trapezoidal stiffener at the top	$a_1 = 80 \text{ mm}$



$$\text{width of web} \quad a_3 := \sqrt{(a_1 - a_2)^2 + h^2} \quad a_3 = 162.8 \text{ mm}$$

$$a_4 := a - a_1 \quad a_4 = 70 \text{ mm}$$

Local buckling

$$\text{Length of web panel} \quad L = 2.2 \cdot 10^3 \text{ mm} \quad a_m := 2 \cdot a - 2 \cdot a_1 \quad a_m = 140 \text{ mm} \quad \frac{L}{a_m} = 15.714$$

$$(5.97) \quad k_\tau := \text{if} \left[\frac{L}{a_m} > 1.00, 5.34 + 4.00 \cdot \left(\frac{a_m}{L} \right)^2, 4.00 + 5.34 \cdot \left(\frac{a_m}{L} \right)^2 \right] \quad k_\tau = 5.356$$

$$(5.96) \quad \lambda_{\bar{w}} := \frac{0.81}{\sqrt{k_\tau}} \cdot \frac{a_m}{t} \cdot \sqrt{\frac{f_o}{E}} \quad \lambda_{\bar{w}} = 0.174$$

$$\text{Table 5.12} \quad \rho_{\bar{v}} := \frac{0.48}{\lambda_{\bar{w}}} \quad \rho_{\bar{v}} = 2.76$$

$$\text{Table 5.12} \quad \eta := 0.4 + 0.2 \cdot \frac{f_u}{f_o} \quad \eta = 0.617$$

$$\text{Table 5.12} \quad \rho_{\bar{v}} := \text{if}(\rho_{\bar{v}} > \eta, \eta, \rho_{\bar{v}}) \quad \rho_{\bar{v}} = 0.617$$

$$(5.95) \quad V_{w.Rd} := \rho_{\bar{v}} \cdot b \cdot t \cdot I \cdot \frac{f_o}{\gamma \cdot M1} \quad V_{w.Rd} = 3.33 \cdot 10^3 \text{ kN}$$

5.11.6 Overall buckling, shear force

Cross sectional area $A := 2 \cdot t_1 \cdot a_1 + 2 \cdot t_2 \cdot a_2 + 2 \cdot t_3 \cdot a_3$ $A = 8.88 \cdot 10^3 \cdot \text{mm}^2$

Gravity centre $e := \frac{2 \cdot t_2 \cdot a_2 \cdot h + 2 \cdot t_3 \cdot a_3 \cdot \frac{h}{2}}{A}$ $e = 44.415 \cdot \text{mm}$

Second moment of area $I_L := 2 \cdot t_2 \cdot a_2 \cdot h^2 + 2 \cdot t_3 \cdot a_3 \cdot \frac{h^2}{3} - A \cdot e^2$ $I_L = 3.309 \cdot 10^7 \cdot \text{mm}^4$

Torsion constant $I_T := \frac{4 \cdot [h \cdot (a_1 + a_2)]^2}{\frac{2 \cdot a_1}{t_1} + \frac{2 \cdot a_2}{t_2} + 2 \cdot \frac{a_3}{t_3}}$ $I_T = 3.097 \cdot 10^7 \cdot \text{mm}^4$

(5.79c) $C_1 := 4 \cdot (1 - \nu^2) \cdot (a_2 + a_3) \cdot a_1^2 \cdot a_2^2 \cdot h^2 \cdot \frac{t_2}{3 \cdot a \cdot t_1^3}$ $C_1 = 3.076 \cdot 10^9 \cdot \text{mm}^4$

(5.79d) $B := \frac{E \cdot t^3}{12 \cdot (1 - \nu^2)}$ $B = 2.88 \cdot 10^7 \cdot \text{N} \cdot \text{mm}$

(5.79e) $C_2 := \frac{4 \cdot (a_1 + a_2)^2 \cdot a_1 \cdot a_4 \cdot \left(1 + \frac{a_1}{a_2} + \frac{a_2}{a_1} + \frac{a^2}{a_1 \cdot a_3}\right) \cdot \left(\frac{t_2}{t_1}\right)^3}{a_2^3 \cdot (3 \cdot a_3 + 4 \cdot a_2)}$ $C_2 = 4.851$

Rigidities of orthotropic plate

Table 5.10 $B_x := \frac{E \cdot I_L}{2 \cdot a}$ $\nu := 0.3$ $G := \frac{E}{2 \cdot (1 + \nu)}$ $B_x = 7.72 \cdot 10^9 \cdot \left(\frac{\text{N} \cdot \text{mm}^2}{\text{mm}}\right)$

(5.79a) $B_y := \frac{2 \cdot B \cdot a}{2 \cdot a_1 \cdot a_3 \cdot t_1^3 \cdot (4 \cdot a_2 \cdot t_3^3 - a_3 \cdot t_2^3) + \frac{2 \cdot a_4}{a_3 \cdot t_1^3 \cdot (4 \cdot a_2 \cdot t_3^3 - a_3 \cdot t_2^3) + a_1 \cdot t_3^3 \cdot (12 \cdot a_2 \cdot t_3^3 - 4 \cdot a_3 \cdot t_2^3)}}$

(5.79b) $H := 2 \cdot B + \frac{G \cdot I_T}{6 \cdot a}$ $B_y = 3.929 \cdot 10^7 \cdot \left(\frac{\text{N} \cdot \text{mm}^2}{\text{mm}}\right)$

$H = 7.305 \cdot 10^8 \cdot \left(\frac{\text{N} \cdot \text{mm}^2}{\text{mm}}\right)$

Elastic buckling load

(5.83) (5.84) $\phi := \frac{L}{b} \cdot \left(\frac{B_y}{B_x}\right)^{\frac{1}{4}}$ $\eta := \frac{H}{\sqrt{B_x \cdot B_y}}$ $\phi = 0.392$
 $\eta = 1.326$

(5.82) $k_\tau := 3.25 - 0.567 \cdot \phi + 1.92 \cdot \phi^2 + (1.95 + 0.1 \cdot \phi + 2.75 \cdot \phi^2) \cdot \eta$ $k_\tau = 6.52$

(5.81) $V_{o.cr} := \frac{k_\tau \cdot \pi^2}{b} \cdot (B_x \cdot B_y)^{\frac{1}{4}}$ $V_{o.cr} = 6.311 \cdot 10^3 \cdot \text{kN}$

Buckling resistance

$$(5.120) \quad \lambda_{ow} := \sqrt{\frac{b \cdot t \cdot I \cdot f_o}{V_{o.cr}}} \quad \lambda_{ow} = 0.97$$

$$(5.119) \quad \chi_{\bar{\sigma}} := \frac{0.6}{0.8 + \lambda_{ow}^2} \quad \chi_o := \text{if}(\chi_o > 0.6, 0.6, \chi_o) \quad \chi_{\bar{\sigma}} = 0.345$$

$$(5.118) \quad V_{o.Rd} := \chi_{\bar{\sigma}} \cdot b \cdot t \cdot I \cdot \frac{f_o}{\gamma_{M1}} \quad V_{o.Rd} = 1.861 \cdot 10^3 \text{ kN}$$