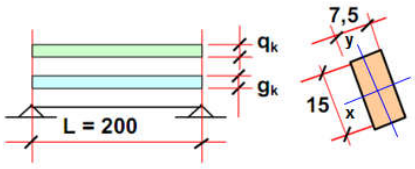
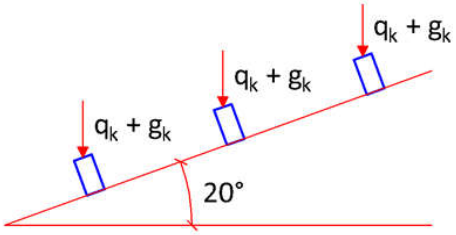
AM2-16.5

Verificar as condições de segurança da terça de madeira indicada nas figuras.



Dados:
- ELU combinação normal;
- Dicotiledônea C-30 , 2ª. categoria;
- Classe 1 de umidade;
- ELUti carregamento de longa duração;

gk = 0,904 kN/m (permanente)
qk = 0,565 kN/m (sobrecarga)



** Exercício extraído das notas de aula do Prof. Miguel Hilgenberg Neto (UFPR)*

(1) Propriedades da Madeira:

$$k_{mod} = 0{,}56$$
$$f_{c0d} = k_{mod} \times f_{c0k}/\gamma_w = 0{,}56 \times 30{,}00\,MPa \;/\; 1{,}4 = 12{,}00\,MPa = 1{,}200\,kN/cm^2$$
$$f_{v0d} = k_{mod} \times f_{v0k}/\gamma_w = 0{,}56 \times 5{,}000\,MPa \;/\; 1{,}8 = 1{,}560\,MPa = 0{,}156\,kN/cm^2$$
$$E_{c0m} = 14500\,MPa = 1450\,kN/cm^2$$
$$E_{c0ef} = 0{,}56 \times 1450\,kN/cm^2 = 812\,kN/cm^2$$

(2) Combinações de Ações:

- ELU:

$$q_{sxd} = (1{,}4\times g_k + 1{,}4\times q_k)\times\cos 20° = (1{,}4\times 0{,}00904\,kN/cm + 1{,}4\times 0{,}00565\,kN/cm)\times\cos 20° = 0{,}01933\,kN/cm$$
$$q_{syd} = (1{,}4\times g_k + 1{,}4\times q_k)\times sen\,20° = (1{,}4\times 0{,}00904\,kN/cm + 1{,}4\times 0{,}00565\,kN/cm)\times sen\,20° = 0{,}007034\,kN/cm$$

- ELUti (ELS):

$$q_{x,util} = (g_k + \psi_0\times q_k)\times\cos 20° = (0{,}00904\,kN/cm + 0{,}2\times 0{,}00565\,kN/cm)\times\cos 20° = 0{,}009557\,kN/cm$$
$$q_{y,util} = (g_k + \psi_0\times q_k)\times sen\,20° = (0{,}00904\,kN/cm + 0{,}2\times 0{,}00565\,kN/cm)\times sen\,20° = 0{,}003478\,kN/cm$$

(3) Propriedades Geométricas da Seção Transversal:

$$I_x = 7{,}5\,cm\times(15\,cm)^3 \;/\; 12 = 2109{,}4\,cm^4$$
$$I_y = 15\,cm\times(7{,}5\,cm)^3 \;/\; 12 = 527{,}3\,cm^4$$
$$W_x = 7{,}5\,cm\times(15\,cm)^2 \;/\; 6 = 281{,}3\,cm^3$$
$$W_x = 15\,cm\times(7{,}5\,cm)^2 \;/\; 6 = 140{,}6\,cm^3$$

(4) Verificação de Flexão Oblíqua:

$$M_{sxd} = q_{sxd}\times L^2 \;/\; 8 = 0{,}01933\,kN/cm\times(200\,cm)^2 \;/\; 8 = 96{,}65\,kN.cm$$
$$M_{syd} = q_{syd}\times L^2 \;/\; 8 = 0{,}007034\,kN/cm\times(200\,cm)^2 \;/\; 8 = 35{,}17\,kN.cm$$
$$\sigma_{Msxd} = M_{sxd} \;/\; W_x = 96{,}65\,kN.cm \;/\; 281{,}3\,cm^3 = 0{,}3435\,kN/cm^2$$
$$\sigma_{Msyd} = M_{syd} \;/\; W_y = 35{,}17\,kN.cm \;/\; 140{,}6\,cm^3 = 0{,}2501\,kN/cm^2$$
$$\frac{\sigma_{Msxd}}{f_{cod}} + k_M.\frac{\sigma_{Msyd}}{f_{cod}} \le 1 \rightarrow \frac{0{,}3435\,kN/cm^2}{1{,}2\,kN/cm^2} + 0{,}5.\frac{0{,}2501\,kN/cm^2}{1{,}2\,kN/cm^2} = 0{,}3905 \le 1 \;\; logo\;\; OK!\;\; Verifica!!!$$
$$k_M.\frac{\sigma_{Msxd}}{f_{cod}} + \frac{\sigma_{Msyd}}{f_{cod}} \le 1 \rightarrow 0{,}5.\frac{0{,}3435\,kN/cm^2}{1{,}2\,kN/cm^2} + \frac{0{,}2501\,kN/cm^2}{1{,}2\,kN/cm^2} = 0{,}3515 \le 1 \;\; logo\;\; OK!\;\; Verifica!!!$$

(5) Verificação de Cisalhamento:

$$V_{sxd} = q_{sxd} \times L \;/\; 2 = 0{,}01933\,kN\times 200\,cm \;/\; 2 = 1{,}933\,kN$$
$$V_{syd} = q_{syd} \times L \;/\; 2 = 0{,}007034\,kN\times 200\,cm \;/\; 2 = 0{,}7034\,kN$$
$$\tau_{sxd} = \frac{3}{2}\frac{V_{sxd}}{bh} = \frac{3}{2}\frac{1{,}933\,kN}{7{,}5\times 15\,cm^2} = 0{,}02577\,kN/cm^2 \le f_{v0d} = 0{,}156\,kN/cm^2$$
$$\tau_{syd} = \frac{3}{2}\frac{V_{syd}}{bh} = \frac{3}{2}\frac{0{,}7034\,kN}{7{,}5\times 15\,cm^2} = 0{,}009379\,kN/cm^2 \le f_{v0d} = 0{,}156\,kN/cm^2$$

(6) Verificação de Deformações Excessivas (Flechas):

- Eixo x:

$$\delta_{calc,x} = \frac{5}{384}\frac{q_{x,util}\,L^4}{E_{c0,ef}\,I_x} = \frac{5}{384}\frac{0{,}009557\,kN/cm^2\times(200\,cm)^4}{812\,kN/cm^2\times 2109{,}4\,cm^4} = 0{,}1162\,cm$$

$$\delta_{calc,x} = 0{,}1162\,cm \le \delta_{limite} = L/200 = 200\,cm/200 = 1\,cm \quad OK!\ Verifica!!!$$

- Eixo y:

$$\delta_{calc,y} = \frac{5}{384}\frac{q_{y,util}\,L^4}{E_{c0,ef}\,I_y} = \frac{5}{384}\frac{0{,}003478\,kN/cm^2\times(200\,cm)^4}{812\,kN/cm^2\times 527{,}3\,cm^4} = 0{,}1692\,cm$$

$$\delta_{calc,y} = 0{,}1692\,cm \le \delta_{limite} = L/200 = 200\,cm/200 = 1\,cm \quad OK!\ Verifica!!!$$

(7) Verificação Alternativa de Deformações Excessivas segundo Pfeil & Pfeil (2003) :

- Eixo x:

$$\delta_{x,elástico} = \frac{5}{384}\frac{q_{x,util}\,L^4}{E_{c0m}\,I_x} = \frac{5}{384}\frac{0{,}009557\,kN/cm^2\times(200\,cm)^4}{1450\,kN/cm^2\times 2109{,}4\,cm^4} = 0{,}06510\,cm$$

$$\delta_{x,total} = \delta_{x,elástico}\times(1+\phi) = 0{,}06510\,cm.(1+0{,}8) = 0{,}1172\,cm$$

$$\delta_{x,total} = 0{,}1172\,cm \le \delta_{limite} = L/200 = 200\,cm/200 = 1\,cm \quad OK!\ Verifica!!!$$

- Eixo y:

$$\delta_{y,elástico} = \frac{5}{384}\frac{q_{y,util}\,L^4}{E_{c0m}\,I_y} = \frac{5}{384}\frac{0{,}003478\,kN/cm^2\times(200\,cm)^4}{1450\,kN/cm^2\times 527{,}3\,cm^4} = 0{,}09477\,cm$$

$$\delta_{y,total} = \delta_{y,elástico}\times(1+\phi) = 0{,}09477\,cm.(1+0{,}8) = 0{,}1706\,cm$$

$$\delta_{y,total} = 0{,}1706\,cm \le \delta_{limite} = L/200 = 200\,cm/200 = 1\,cm \quad OK!\ Verifica!!!$$