PAFPAF

Customer: Client de test – Project reference: Bâtiment de test
Executed by Vincent Juhel, on Wednesday, 16 May 2018.
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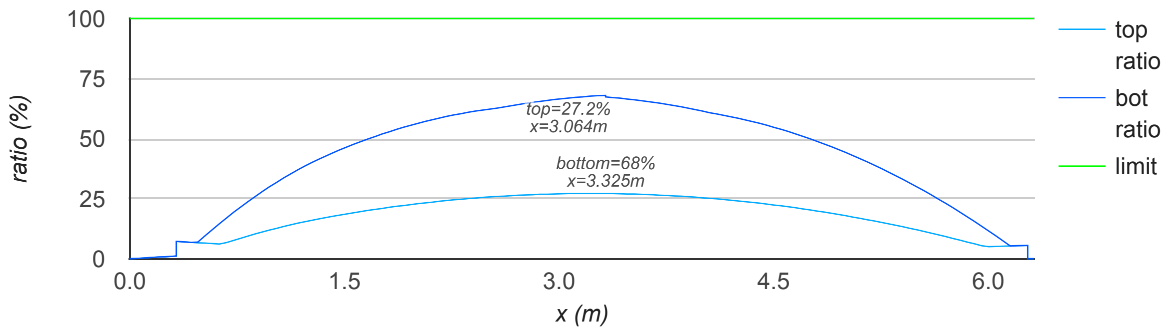
Report: Purlin between frames 1 and 2 of course 2 on couverture droite

ReferenceZed profiles - Z200*2.0 S350GD Z275

Properties | Loadings | Forces | Deformations | Stresses | ULS 68% | + | SLS 73% | +

ULS StructuralG + 1.5*$W_{240(cpe+,cpi+)}$



Location

At absciss x= 3.325 m, the calculations are performed on :

- span zone on z-z axis
- span zone on y-y axis

The span of the section is 6000 mm between supports on z-z axis .

Load direction

The load combination causes uplift.

Restraint given by the sheeting :

Surface reference name : Nersup C42S perforé sur plage [4.42.1010] 88/100e
Surface structural class :

- Wanted class from user: 2
- Optimal class from catalogue: 2
- Corrected class according to surface use: 2

Details :

- Geometrical proportions of the beam: Yes(check catalogue)
- Geometrical proportions of the surface: Yes(check catalogue)

- Lateral restraint: Yes
  with :
  - According to EN 1993-1-3 §10.1.1(10) :
    the portion of the shear stiffness provided by the sheeting for the examined member connected to the sheeting :
    $S = 1000 \cdot \sqrt{t_{core}^3} \cdot \left(50 + 10 \cdot \sqrt[3]{b_{roof}}\right) \cdot \frac{s}{h_w}$
    $S = 1000 \cdot \sqrt{0.842^3} \cdot \left(50 + 10 \cdot \sqrt[3]{7987}\right) \cdot \frac{1778.0}{42.0}$
    S = 8171232.3 N = 8171.2 kN
    with :
    - The design thickness of the surface :
      t_{core} = 0.842 mm
    - The roof width :
      b_{roof} = 7987 mm
    - The max spacing of the beams :
      s = 1778 mm
    - The profile depth of sheeting :
      h_w = 42 mm
  - According to EN 1993-1-3 §10.1.1(6) :
    the permissible limit of the shear stiffness of the sheet :
    $S_{min} = \left(E \cdot I_w \cdot \frac{\pi^2}{L^2} + G \cdot I_t + E \cdot I_z \cdot \frac{\pi^2}{L^2} \cdot 0.25 \cdot h^2\right) \cdot \frac{70}{h^2}$
    $S_{min} = (210000.0 \cdot 3984699828 \cdot \frac{\pi^2}{6000.0^2} + 80769.0 \cdot 889 + 210000.0 \cdot 558976 \cdot \frac{\pi^2}{6000.0^2} \cdot 0.25 \cdot 200.0^2) \cdot \frac{70}{200.0^2}$
    S_{min} = 1090258.1 N = 1090.3 kN - Requirement S ≥ Smin is verified
    with :
    - The warping constant of the beam :
      $I_w = 3984699828\ mm^6$
    - The span of the beam :
      L = 6000 mm
    - The torsion constant of the beam :
      $I_t = 889\ mm^4$
    - The second moment of area of the cross-section about the minor axis of the cross-section of the beam :
      $I_z = 558976\ mm^4$
    - The height of the beam :
      h = 200 mm
- Rotational restraint: Yes (0.01300 N/mm²)
  with :
  - Sheet fastened through : trough
  - Laying direction of the sheeting : positive (the narrow flange is on the beam.)
  - According to EN 1993-1-3 §10.1.5.2(5) :
    Rotational stiffness of the connection between the sheeting and the purlin:
    $c_{D,A} = C_{100} \cdot k_{ba} \cdot k_t \cdot k_{bR} \cdot k_A \cdot k_{bT}$
    $c_{D,A} = 2600.0 \cdot 0.354 \cdot 1.192 \cdot 0.733 \cdot 1.0 \cdot 1.0$
    $c_{D,A}$ = 804.047 N.m/m/rad
    with :
    - Rotation coefficient for trapezoidal steel sheeting :
      C_{100} = 2600N.m/m
    - Coefficient depending of the width of the beam flange :
      k_{ba} = 0.354
    - Coefficient depending of the thickness :
      k_t = 1.192
    - Coefficient depending of the corrugation width :
      k_{bR} = 0.733
    - Coefficient depending of the load :
      k_A = 1
    - Coefficient depending of the width of the sheeting flange through which it is fastened to the beam :
      k_{bT} = 1
  - According to EN 1993-1-3 §10.1.5.2(4)
    Rotational stiffness corresponding to the flexural stiffness of the sheeting :
    $c_{D,C} = \frac{k \cdot E \cdot I_{eff}}{s} = \frac{6 \cdot 210000.0 \cdot 219.3}{1778.0}$ = 155450.505 N.m/m/rad
    with :
    - Coefficient depending of the beam position and the load direction :
      k = 6
    - The effective second moment of area per unit width of the sheeting :
      $I_{eff} = 219.3\ mm^4/mm$ ($21.93\ cm^4/m$)
    - The max spacing of the beams :
      s = 1778 mm

- According to EN 1993-1-3 §10.1.5.2(1)
  Total rotational spring stiffness :
  $c_D = \frac{1}{\left(\frac{1}{c_{D,A}} + \frac{1}{c_{D,C}}\right)} = \frac{1}{\left(\frac{1}{804.047} + \frac{1}{155450.505}\right)}$ = 799.909 N.m/m/rad
- According to EN 1993-1-3 §10.1.5.1(1)
  Total lateral spring stiffness :
  $K = \frac{1}{\left(\frac{1}{k_A} + \frac{1}{k_B} + \frac{1}{k_C}\right)} = \frac{1}{\left(\frac{1}{0.02} + \frac{1}{0.034} + \frac{1}{3.886}\right)}$ = 0.013N/mm²
  with :
  - Lateral spring stiffness corresponding to the rotational stiffness of the joint between the sheeting and the beam :
    $K_A = \frac{c_{D,A}}{h^2} = \frac{804.047}{200.0^2}$ = 0.02N/mm²
  - Lateral spring stiffness due to distortion of the cross-section of the beam :
    $K_B = \frac{E \cdot t_{core}^3}{4 \cdot (1-\nu^2) \cdot h^2 \cdot (h_d + b_{mod})}$
    $K_B = \frac{210000.0 \cdot 1.962^3}{4 \cdot (1-0.3^2) \cdot 200.0^2 \cdot (200.0 + 119.0)}$
    K_B = 0.034N/mm²
    with :
    - The developed height of the beam web :
      h_d = 200 mm
    - The dimension :
      b_{mod} = 2a + b = 2*29.75 + 59.5 = 119 mm
  - Lateral spring stiffness due to the flexural stiffness of the sheeting :
    $K_C = \frac{c_{D,C}}{h^2} = \frac{155450.505}{200.0^2}$ = 3.886N/mm²

Main recommandations

- In order to avoid web crippling under support reaction, the purlin is assumed to be suspended on the cleats.
- During assembly phase, the burdens will be stored above the rafters.

Analysis of the global cross section

- Axial force : $N_{,Ed}$ = 0 kN
- Shear force : $V_{z,Ed}$ = -0.089 kN
- Shear resistance (EN 1993-1-3 §6.1.5):
  $V_{b,Rd} = \frac{\frac{h_w}{\sin\Phi} \cdot t \cdot f_{bv}}{\gamma_{M0}} = \frac{\frac{198.0}{\sin 90} \cdot 1.962 \cdot 121.3}{1.0}$ = 47130.4 N = 47.13 kN
  <u>Checking</u> : $V_{z,Ed}$ / $V_{b,Rd}$ = -0.089 / 47.13 = 0.2% ≤ 100%
  with :
  - The web height between the midlines of the flanges : h_w = 198 mm (EN 1993-1-3 fig. 5.1(c))
  - The slope of the web relative to the flanges : Φ = 90° (EN 1993-1-3 fig. 6.5)
  - The shear strength considering buckling, for $0.83 < \overline{\lambda_w} = 1.385 < 1.40$:
    $f_{bv} = 0.48 \cdot \frac{f_{yb}}{\overline{\lambda_w}} = 0.48 \cdot \frac{350.0}{1.385}$ = 121.3 MPa (EN 1993-1-3 tab. 6.1)
    with :
    - The relative web slenderness :
      $\overline{\lambda}_w = 0.346 \cdot \frac{s_w}{t}\sqrt{\frac{f_{yb}}{E}} = 0.346 \cdot \frac{192.3}{1.962}\sqrt{\frac{350.0}{210000.0}}$ = 1.385 (EN 1993-1-3 eq. 6.10a - for webs without longitudinal stiffeners)
    - The slant height of the web, between the median points of the corners : s_w = 192.3 mm

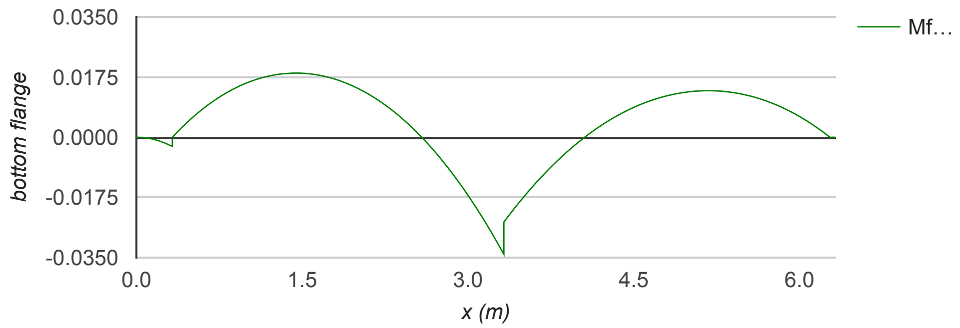
Analysis of the flanges

- Bending moments :
  - Around of y-y major axis : $M_{y,Ed}$ = -4.021 kN.m
  - Around of z-z minor axis : $M_{z,Ed}$ = 0 kN.m
- The equivalent lateral load acting on the flange, due to torsion and lateral bending :
  $q_{h,Ed} = k_h \cdot qEd = 0.03 \cdot 0.864$ = 0.026 kN/m (EN 1993-1-3 eq. 10.4)
  with :
  - The linear load on z-z axis : q_{Ed} = 0.864 kN/m
  - The coefficient in suction : $k_h = k_{h0} - \frac{\frac{b-t_N}{2} - e}{h - t_N} = 0.166 - \frac{\frac{59.5-2.0}{2} - 1.9}{200.0-2.0}$ = 0.03 (EN 1993-1-3 fig. 10.3)
  - The shear center position on y-y axis : e = 1.9 mm
  - The factor for lateral load on flange : $k_{h,0} = \frac{h \cdot t_N \cdot \left(b^2 + 2 \cdot c \cdot b - 2 \cdot c^2 \cdot \frac{b}{h}\right)}{4 \cdot I_y} = \frac{200.0 \cdot 2.0 \cdot \left(65.0^2 + 2 \cdot 22.0 \cdot 65.0 - 2 \cdot 22.0^2 \cdot \frac{65.0}{200.0}\right)}{4 \cdot 4086086}$ = 0.166
    (EN 1993-1-3 fig. 10.3)
- **<u>Top flange</u>**

- In-plane bending (EN 1993-1-3 §6.1.4) :
  $M_{y,Rd} = \frac{W_{y,eff} \cdot f_{yb}}{\gamma_{M0}} = \frac{42326.0 \cdot 350.0}{1.0}$ = 14814139 N.mm = 14.814 kN.m
  Checking : $M_{y,Ed}$ / $M_{y,Rd}$ = -4.021 / 14.814 = 27.1% ≤ 100%
  with :
  - The effective section modulus about y-y axis : $W_{y,eff}$ = 42326 mm^3
- Lateral bending due to load in the slope direction (EN 1993-1-3 §6.1.4) :
  $M_{z,Ed}$ = 0 kN.m; (The bending about z-z axis is taken over by the surface)
  Checking : $M_{z,Ed}$ / $M_{fz,Rd}$ = 0.0% ≤ 100%
- Combined shear force, axial force and bending moment (EN 1993-1-3 eq. 6.27) :
  No reduction due to shear force need not be done provided that $V_{z,Ed} \le 0{,}5\ V_{w,Rd}$.
  Here: 0.2% ≤ 50%
- Buckling resistance of flange (EN 1993-1-3 eq. 10.7) :
  The flange is in tension, so it is not necessary to check its lateral buckling resistance.

Ratio max: 27.2%

- **Bottom flange**
  - In-plane bending (EN 1993-1-3 §6.1.4) :
    $M_{y,Rd} = \frac{W_{y,eff} \cdot f_{yb}}{\gamma_{M0}} = \frac{36274.0 \cdot 350.0}{1.0}$ = 12695868 N.mm = 12.696 kN.m
    Checking : $M_{y,Ed}$ / $M_{y,Rd}$ = -4.021 / 12.696 = 31.7% ≤ 100%
    with :
    - The effective section modulus about y-y axis : $W_{y,eff}$ = 36274 mm^3
  - Lateral bending due to the equivalent lateral load acting on the flange (EN 1993-1-3 §6.1.4) :
    $M_{fz,Rd} = \frac{W_{fz} \cdot f_{yb}}{\gamma_{M0}} = \frac{3990 \cdot 350.0}{1.0}$ = 1396500 N.mm = 1.396 kN.m
    Checking : $M_{fz,Ed}$ / $M_{fz,Rd}$ = -0.034 / 1.396 = 2.4% ≤ 100%
    with :
    - Lateral bending moment for the flange:



    $M_{fz,Ed}$ = -0.034 kN.m (Analytic resolution)
    - The effective section modulus about z-z axis : W_{fz} = 3990 mm^3
  - Biaxial bending (EN 1993-1-3 eq. 6.7) :
    Checking : $M_{y,Ed}$ / $M_{y,Rd}$ + $M_{fz,Ed}$ / $M_{fz,Rd}$ = 31.7% + 2.4% = 34.1% ≤ 100%
  - Combined shear force, axial force and bending moment (EN 1993-1-3 eq. 6.27) :
    No reduction due to shear force need not be done provided that $V_{z,Ed} \le 0{,}5\ V_{w,Rd}$.
    Here: 0.2% ≤ 50%

- Buckling resistance of flange (EN 1993-1-3 eq. 10.7) :
  $\left(\frac{1}{\chi_{LT}} \cdot \left(\frac{M_{y,Ed}}{M_{y,Rd}} + \frac{N_{Ed}}{N_{c,Rd}}\right) + \frac{M_{fz,Ed} + \Delta M_{z,Ed}}{M_{fz,Rd}}\right) \cdot \frac{\gamma_{M1}}{\gamma_{M0}} = \left(\frac{1}{0.483} \cdot (31.7\% + 0.0\%) + 2.4\%\right) \cdot \frac{1.0}{1.0} = 68.0\% \leq 100\%$ 👍
  with :
  - The reduction factor for lateral-torsional buckling : (EN 1993-1-1 §6.3.2.3)
    $\chi_{LT} = \min \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \beta \cdot \overline{\lambda_{LT}}^2}}, \frac{1}{\overline{\lambda_{LT}}^2}, 1 = \min \frac{1}{1.379 + \sqrt{1.379^2 - 0.75 \cdot 1.379^2}}, \frac{1}{1.379^2}, 1 = 0.483$
    with :
    - $\Phi_{LT} = 0.5 \cdot \left[1 + \alpha_{LT} \cdot \left(\overline{\lambda_{LT}} - \overline{\lambda_{LT,0}}\right) + \beta \cdot \overline{\lambda_{LT}}^2\right] = 0.5 \cdot \left[1 + 0.34 \cdot (1.379 - 0.4) + 0.75 \cdot 1.379^2\right] = 1.379$
    - $\alpha_{LT} = 0.34$ (using buckling curve b - EN 1993-1-3 §10.1.4.2(1))
    - $\overline{\lambda_{LT,0}} = 0.4$ (EN 1993-1-3 §10.1.4.2(1))
    - $\beta = 0.75$ (EN 1993-1-3 §10.1.4.2(1))
    - $\overline{\lambda_{LT}} = \overline{\lambda_{fz}} = \frac{\frac{l_{fz}}{i_{fz}}}{\lambda_1} = \frac{\frac{2472.1}{23.3}}{76.95} = 1.379$ (EN 1993-1-3 eq. 10.8)
      with :
      - $\lambda_1 = \pi \cdot \sqrt{\frac{E}{f_{yb}}} = \pi \cdot \sqrt{\frac{210000.0}{350.0}} = 76.95$
      - The radius of gyration of the gross cross-section of the flange plus the contributing part of the web for bending about the z-z axis : $i_{fz} = 23.3$ mm
      - The buckling length for the flange :
        $l_{fz} = \eta_1 \cdot L_a \cdot (1 + \eta_2 \cdot R^{\eta_3})^{\eta_4} = 0.902 \cdot 3000.0 \cdot \left(1 + 8.55 \cdot 0.415^{2.18}\right)^{-0.111} = 2472.1$ mm (EN 1993-1-3 eq. 10.9)
        with :
        - The distance between anti-sag bars : $L_a = 3000$ mm
        - The coefficient of the spring support : $R = \frac{K \cdot L_a^4}{\pi^4 \cdot E \cdot I_{fz}} = \frac{0.013 \cdot 3000.0^4}{\pi^4 \cdot 210000.0 \cdot 120300} = 0.415$
        - As given in EN 1993-1-3 Tables 10.2, for simple span of a non uniformly loaded beam system :
          $\eta_1 = 0.902$; $\eta_2 = 8.55$; $\eta_3 = 2.18$; $\eta_4 = -0.111$
  - Lateral bending of the flange :
    $\frac{M_{fz,Ed} + \Delta M_{z,Ed}}{M_{fz,Rd}} = \frac{-0.034 + 0.0}{1.396} = 2.4\%$

Ratio max: 68%