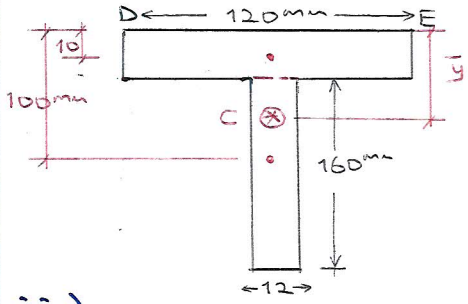
①

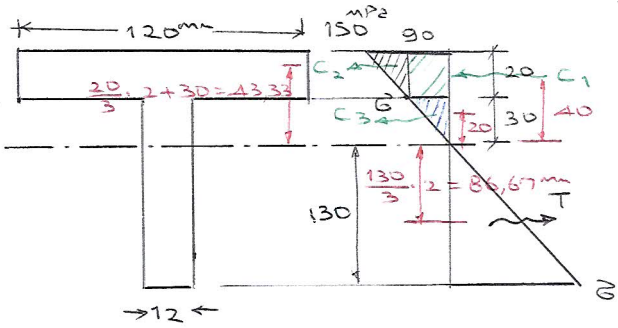
i-) $\bar{y}$ must be 50mm since stress crosses zero at 50mm. But Let's calculate to confirm.



- $\bar{y} = \dfrac{120 \cdot 20 \cdot 10 + 160 \cdot 12 \cdot 100}{120 \cdot 20 + 160 \cdot 12} = 50\,mm$ ok

- Due to symmetry, $\bar{x}$ is at the centre of DE.

ii-)



$\frac{\sigma}{150} = \frac{30}{50} \Rightarrow \sigma = 90\ MPa$

$C_1 = 90\ MPa \cdot 20\ mm \cdot 120\ mm = 216 \cdot 10^3\ N$

$C_2 = \frac{(150-90)}{2} \cdot 20 \cdot 120 = 72 \cdot 10^3\ N$

$C_3 = \frac{90}{2} \cdot 12 \cdot 30 = 16,2 \cdot 10^3\ N$

$C = \sum_{i=1}^{3} C_i = 304,2\ kN$

iii-) $T = C = 304,2 \cdot 10^3\ N = \frac{\sigma_t}{2} \cdot 130 \cdot 12 \Rightarrow \sigma_t = 390\ MPa$

L.F. $= \sigma_{yield} / \sigma_{t,max} = 400/390 = 1,03 < 1,7 \Rightarrow$ Section is **NOT adequate!**

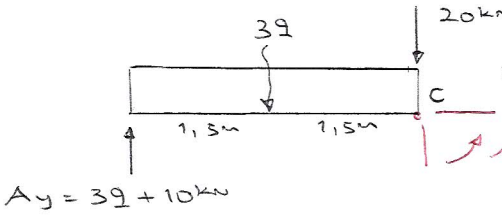
iv-) Take moments of all forces about centroid

$M_C = C_1 \cdot 40 + C_2 \cdot 43,33 + C_3 \cdot 20 + T \cdot 86,67 = 38,45\ kNm$

v-) $F_{DEFG} = C_1 + C_2 = 288\ kN$

vi-) Need support reactions, first.

Due to symmetry, $A_y = B_y = 39 + 10\ kN$



$\sum M_C = 0$

$38,45\ kNm + 39 \cdot 1,5\ m = (39 + 10) \cdot 3,0\ m$

$\Rightarrow q = 1,88\ kN/m$

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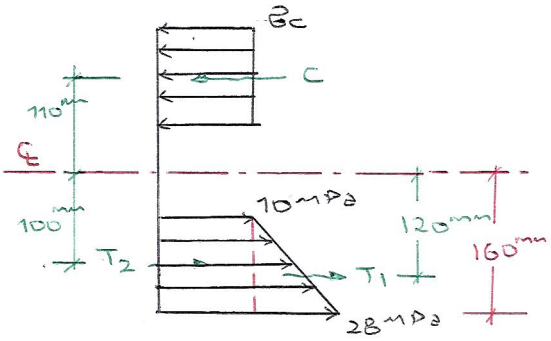
2.

(i) Simplify the question into 2D.



- $T_1 = (28-10)^{MPa} \cdot 120^{mm} \cdot 200^{mm} \cdot 0,5 = 216\ kN$
- $T_2 = 10^{MPa} \cdot 120 \cdot 200 = 240\ kN$
- $C = T = T_1 + T_2 = 456\ kN$
- $C = G_c^{MPa} \cdot 100^{mm} \cdot 200^{mm} = 456 \cdot 10^3\ N$
  $\Rightarrow$ $G_c = 22,8\ MPa$ (compression)

Answer:

(ii) Take the moments about the centerline.

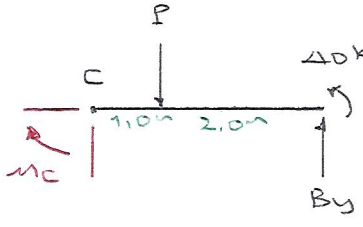
- $M_c = T_1^{kN} \cdot 120^{mm} + T_2^{kN} \cdot 100^{m} + C \cdot 110^{m} = 100,1\ kN\,m\ (\circlearrowleft)$

Answer

(iii) Look at the right hand side of the beam. But first need to find the reaction at support B.

- $\Sigma M_A = 0 \Rightarrow 40\,kN \cdot 2,0^{m} + P \cdot 6,0^{m} = B_y \cdot 8,0^{m} + 40\ kNm$
  $\Rightarrow B_y = 5,0 + 0,75 \cdot P\ kN$

- Now look at a section cut:



$\Sigma M_C = 0 \Rightarrow M_c + P \cdot 1,0^{m} = 40^{kNm} + B_y \cdot 3,0$

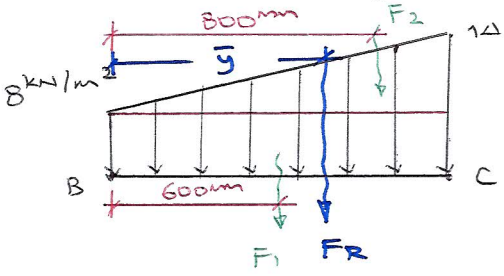
sub. $100,1\ kN\,m$ sub. $5,0 + 0,75P$

$\Rightarrow P = 36,1\ kN\ (\downarrow)$

Answer

3. (i) Due to symmetry, $\bar{x}$ coordinate is $\frac{1500}{2} = 750\ mm$

To determine $\bar{y}$, consider a 2D view.



- $F_1 = 8\ kN/m^2 \cdot 1{,}2^m \cdot 1{,}5^m = 14{,}4\ kN$
- $F_2 = (14-8) \cdot 1{,}2 \cdot 1{,}5 \cdot 0{,}5 = 5{,}4\ kN$
- $\Rightarrow F_R = F_1 + F_2 = 19{,}8\ kN$
- $\Sigma M_B = F_1 \cdot 600 + F_2 \cdot 800 = F_R \cdot \bar{y}$
- $\Rightarrow \bar{y} = 655\ mm$

- Answer: $F_R(750^{mm}; 655^{mm}; 0^{mm}) = 19{,}8\ kN$

Answer Ans.

(ii) Need to take a moment about a point or a line to eliminate all unwanted unknowns. Support rxns are not asked for. Best to take a moment about line AD

- $\Sigma M_{AD} = 0 \Rightarrow \boxed{\underset{\sim}{\mu}_{AD} \cdot (\underset{\sim}{r}_{AB} \times \underset{\sim}{T}_{BE} + \underset{\sim}{r}_{F_R} \times \underset{\sim}{F}_{FR}) = 0}$

$B(1500^{mm}; 0; 0)$; $E(1100; -200; 1300)$

$R(750; 600; 0)$; $F(0; 600; 0)$

$\underset{\sim}{r}_{BE} = -400\underset{\sim}{i} - 200\underset{\sim}{j} + 1300\underset{\sim}{k}$; $r_{BE} = 1374{,}77\ mm$

$\underset{\sim}{\mu}_{BE} = \frac{\underset{\sim}{r}_{BE}}{r_{BE}} = -0{,}291\underset{\sim}{i} - 0{,}146\underset{\sim}{j} + 0{,}946\underset{\sim}{k}$

$\underset{\sim}{T}_{BE} = -0{,}291T\underset{\sim}{i} - 0{,}146T\underset{\sim}{j} + 0{,}946T\underset{\sim}{k}$

$\underset{\sim}{F}_R = -19{,}8\underset{\sim}{k}$; $\underset{\sim}{r}_{AB} = 1500\underset{\sim}{i}$; $\underset{\sim}{r}_{FR} = 750\underset{\sim}{i}$; $\underset{\sim}{\mu}_{AD} = \underset{\sim}{j}$

$\underset{\sim}{\mu}_{AD} \cdot \underset{\sim}{r}_{AB} \times \underset{\sim}{T}_{BE} + \underset{\sim}{\mu}_{AD} \cdot \underset{\sim}{r}_{FR} \times \underset{\sim}{F}_R = 0$

$$\begin{vmatrix} 0 & 1 & 0 \\ 1500 & 0 & 0 \\ -0{,}291T & -0{,}146T & +0{,}946T \end{vmatrix} + \begin{vmatrix} 0 & 1 & 0 \\ 750 & 0 & 0 \\ 0 & 0 & -19{,}8 \end{vmatrix} = 0$$

$-1419T + 14850 = 0 \Rightarrow T = 10{,}465\ kN$

Answer