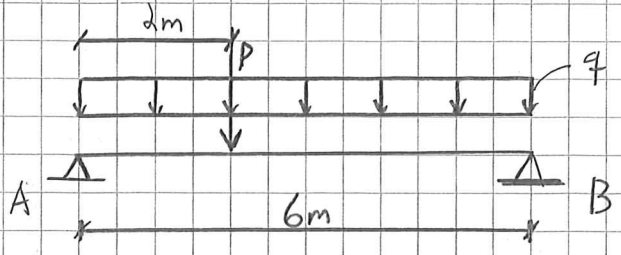
Vedlegg 19

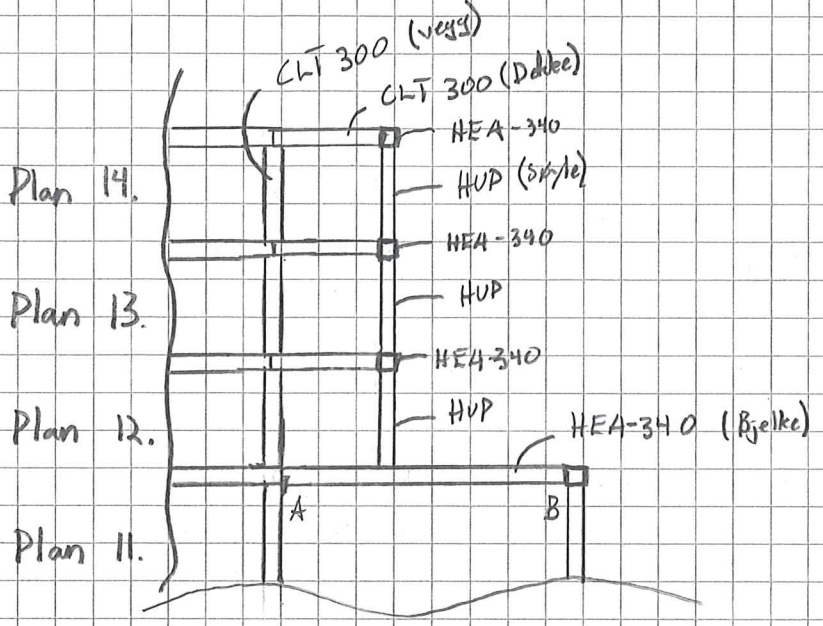
Håndberegningskontroll av bjelke

Beregning Bjelke

HEA - 340

L = 6m





Laster: (Alle håndberegninger vil resultere i mindre utnyttet en det som egentlig er tilfelle)

Dekke (CLT 300):

$500\ kg/m^3 \cdot 0{,}300\ m = 150\ kg/m^2 \Rightarrow 1{,}5\ kN/m^2$

Påstøp:

$2500\ kg/m^3 \cdot 0{,}05\ m = 125\ kg/m^2 \Rightarrow 1{,}25\ kN/m^2$

Himling, membran, lettvegger, fyllmasse etc:

$50\ kg/m^2 \Rightarrow 0{,}5\ kN/m^2$

Terrasselast: $4{,}0\ kN/m^2$

Snølast: $S_K = 3{,}0\ kN/m^2$

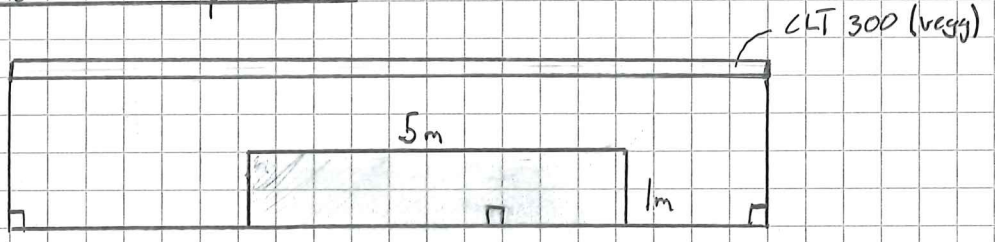
Formfaktor for flatt tak er $\mu_1 = 0{,}8$

$S = S_K \cdot \mu_1$

$= 3{,}0\ kN/m^2 \cdot 0{,}8 = 2{,}4\ kN/m^2$

Finne punktlasten P:

Dekke over plan 12:



Lastareal: $5m \times 1m = 5m^2$

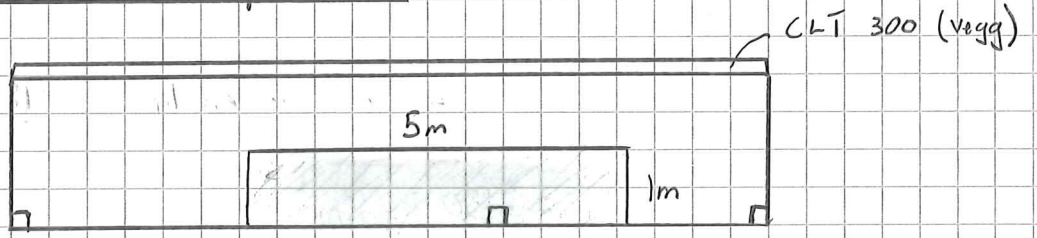
$g_T = 1,5\ kN/m^2 + 1,25\ kN/m^2 + 0,5\ kN/m^2 = 3,25\ kN/m^2$

$n_T = 4,0\ kN/m^2$

$G_{12} = 3,25\ kN/m^2 \cdot 5m^2 = 16,25\ kN$

$N_{12} = 4,0\ kN/m^2 \cdot 5m^2 = 20\ kN$

Dekke over plan 13:



Lastareal: $5m \times 1m = 5m^2$

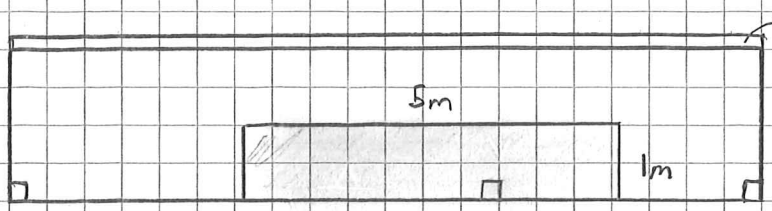
$g_T = 1,5\ kN/m^2 + 1,25\ kN/m^2 + 0,5\ kN/m^2 = 3,25\ kN/m^2$

$n_T = 4,0\ kN/m^2$

$G_{13} = 3,25\ kN/m^2 \cdot 5\ m^2 = 16,25\ kN$

$N_{13} = 4,0\ kN/m^2 \cdot 5\ m^2 = 20\ kN$

Dekke over plan 14:



Lastareal: $5m \times 1m = 5m^2$

$g_T = 1,5\ kN/m^2 + 1,25\ kN/m^2 + 0,5\ kN/m^2 = 3,25\ kN/m^2$

$S = 2,4\ kN/m^2$

$G_{14} = 3,25\ kN/m^2 \cdot 5m^2 = 16,25\ kN$

$S_{14} = 2,4\ kN/m^2 \cdot 5m^2 = 12\ kN$

Totalt 3 etasjer:

$G_{12,13,14} = G_{12} + G_{13} + G_{14}$

$= 16,25\ kN + 16,25\ kN + 16,25\ kN = \underline{48,75\ kN}$

$N_{12,13,14} = N_{12} + N_{13} + S_{14}$

$= 20\ kN + 20\ kN + 12\ kN = \underline{52\ kN}$

Egenvekt stålbjelke:

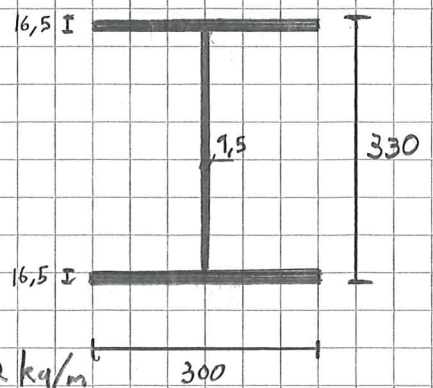
HEA-340

Stål: $7850\ kg/m^3$

$A = 0,0134\ m^2$

$L = 5m$

Mål i mm:



$7850\ kg/m^3 \cdot 0,0134\ m^2 = 105,2\ kg/m$

$\Rightarrow 1,05\ kN/m$

$1,05\ kN/m \cdot 5m = 5,25\ kN/\text{etasje}$

$G_{Bjelke} = 5,25\ kN/\text{etasje} \cdot 3\ \text{etasje} = \underline{15,75\ kN}$

Egenvekt stålsøyle:

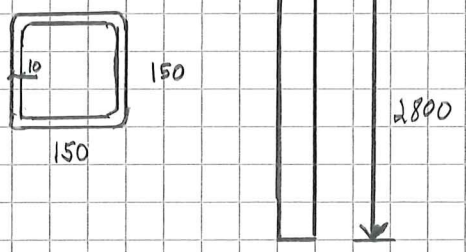
HUP 150 × 150 × 10

Stål: 7850 kg/m³

$A = 0,0055\ m^2$

$L = 2,8\ m$

Mål i mm:



$7850\ kg/m^3 \cdot 0,0055\ m^2 = 43,2\ kg/m$

$\Rightarrow 0,43\ kN/m$

$0,43\ kN/m \cdot 2,8\ m = 1,2\ kN/søyle$

$G_{søyle} = 1,2\ kN/søyle \cdot 3\ søyler = \underline{3,6\ kN}$

Total punktlast P:

$G = G_{12,13,14} + G_{Bjelke} + G_{søyle}$

$= 48,75\ kN + 15,75\ kN + 3,6\ kN = \underline{68,1\ kN}$ (Bruksgrense)

$N = N_{12,13,14} = \underline{52\ kN}$ (Bruksgrense)

B1: $\gamma_G \cdot G + \gamma_Q \cdot N$

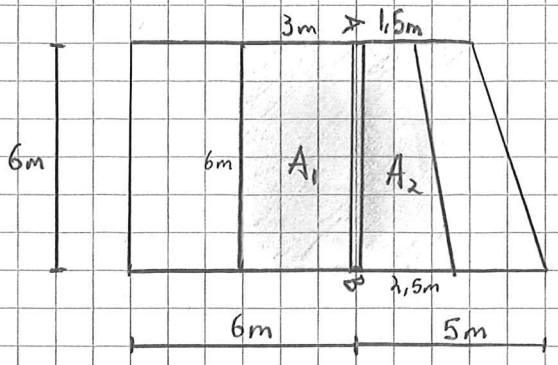
$= 1,35 \cdot 68,1\ kN + 1,05 \cdot 52\ kN = \underline{146,5\ kN}$ (Bruddgrense)

B2: $\gamma_G \cdot G + \gamma_Q \cdot N$

$= 1,2 \cdot 68,1\ kN + 1,5 \cdot 52\ kN = \underline{159,7\ kN}$ (Bruddgrense)

Bruker B2: $\underline{P = 159,7\ kN}$

Finne q (jevnt fordelt last):



(Lengd kjelke 6m)

Lastareal: $\underbrace{6m \times 3m}_{A_1} + \underbrace{\left(6m \times 1,5m + \frac{1m \times 6m}{2}\right)}_{} = 30\ m^2$

CLT 300 (Dekke): $1,5\ kN/m^2$

Påstrøp: $1,25\ kN/m^2$

Himling, membran, lettvegger, fyllmasse etc: $0,5\ kN/m^2$

Terrasselast: $4,0\ kN/m^2$

$$G_1 = (1,5 + 1,25 + 0,5)\ kN/m^2 \cdot 30\ m^2 = 97,5\ kN$$

$$N_1 = 4,0\ kN/m^2 \cdot 30\ m^2 = 120\ kN$$

$$G = \frac{97,5\ kN}{6m} = \underline{16,25\ kN/m} \quad \text{(Bruksgrense)}$$

$$N = \frac{120\ kN}{6m} = \underline{20\ kN/m} \quad \text{(Bruksgrense)}$$

B1: $\gamma_G \cdot G + \gamma_Q \cdot N$

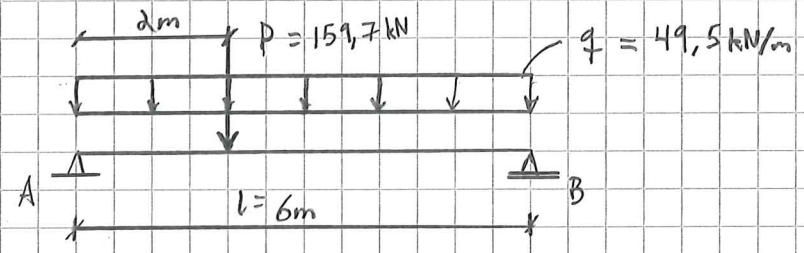
$= 1,35 \cdot 16,25\ kN/m + 1,05 \cdot 20\ kN/m = \underline{42,9\ kN/m}$ (Bruddgrense)

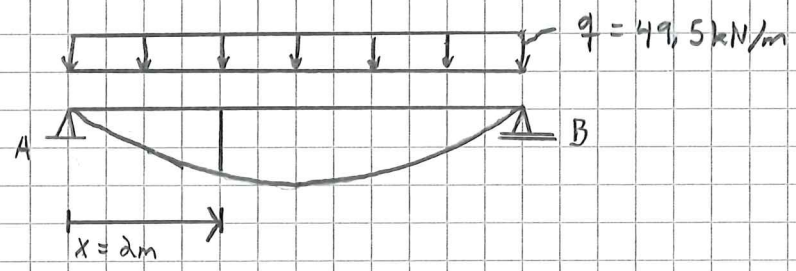
B2: $\gamma_G \cdot G + \gamma_Q \cdot N$

$= 1,2 \cdot 16,25\ kN/m + 1,5 \cdot 20\ kN/m = \underline{49,5\ kN/m}$ (Bruddgrense)

Bruker B2: $\underline{q = 49,5\ kN/m}$

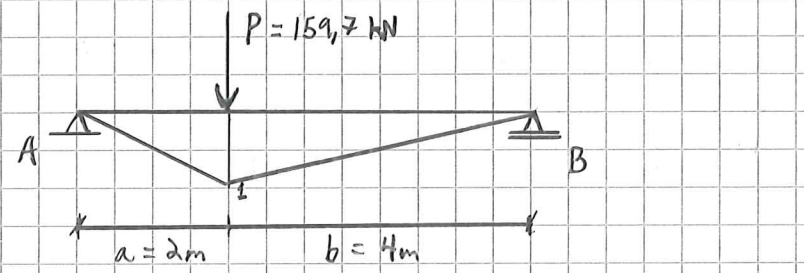
Finne M_{max}:





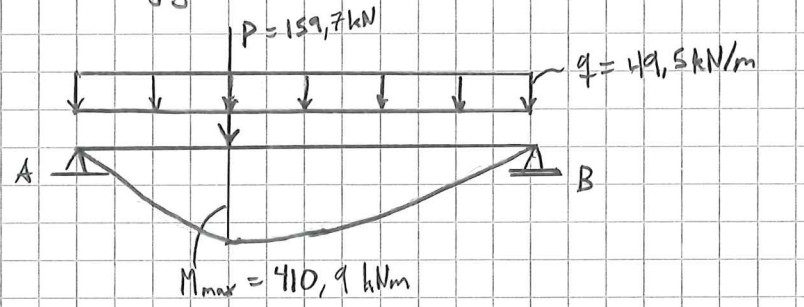
$$M_x = \frac{q \cdot l \cdot x}{2} - \frac{q \cdot x^2}{2}$$

$$= \frac{49,5\ kN/m \cdot 6m \cdot 2m}{2} - \frac{49,5\ kN/m \cdot (2m)^2}{2} = \underline{198\ kNm}$$



$$M_1 = \frac{P \cdot a \cdot b}{l} = \frac{159,7\ kN \cdot 2m \cdot 4m}{6m} = \underline{212,9\ kNm}$$

Samlet figur:



$$M_{max} = M_x + M_1 = 198\ kNm + 212,9\ kNm = \underline{410,9\ kNm}$$

Kontroll bjelkespenningen:

$$\sigma = \frac{M_{max}}{W_y} \quad \frac{410{,}9 \cdot 10^6 \text{ Nmm}}{1850 \cdot 10^3 \text{ mm}^3} = 222{,}1 \text{ N/mm}^2 = 222{,}1 \text{ MPa}$$

$$f_{yd} = \frac{f_y}{\gamma_m} = \frac{355 \text{ MPa}}{1{,}05} = 338{,}1 \text{ MPa}$$

$$\sigma \leq f_{yd}$$

$222{,}1 \text{ MPa} < 338{,}1 \text{ MPa} \Rightarrow$ OK!

$$\frac{222{,}1 \text{ MPa}}{338{,}1 \text{ MPa}} = 0{,}66 \quad \text{utnyttet}$$

Kontroll nedbøyning:

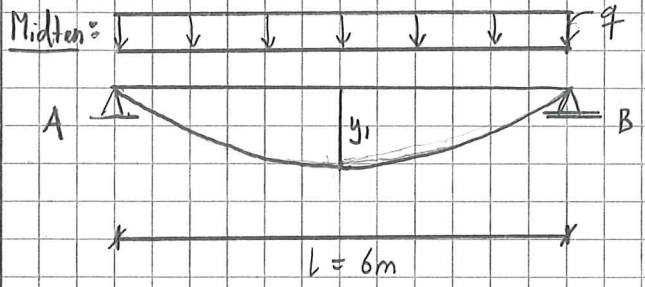
Nedbøyning blir beregnet i bruksgrensetilstand $\gamma_G = 1{,}0$

$\gamma_Q = 1{,}0$

$P = G + N = 68{,}1 \text{ kN} + 52 \text{ kN} = 120{,}1 \text{ kN}$ (Bruksgrense)

$q = G + N = 16{,}25 \text{ kN/m} + 20 \text{ kN/m} = 36{,}25 \text{ kN/m}$ (Bruksgrense)

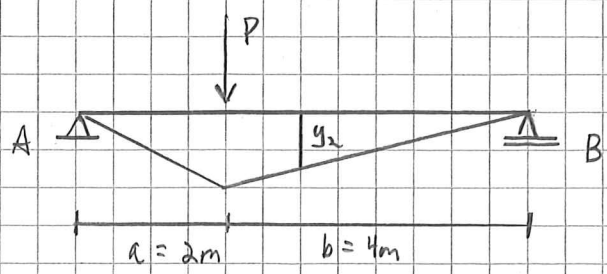
Midten:



(sterk akse)

$$y_1 = \frac{5 \cdot q \cdot l^4}{384 \cdot E \cdot I_y}$$

$$= \frac{5 \cdot 36{,}25 \text{ N/mm} \cdot (6000 \text{ mm})^4}{384 \cdot 2{,}1 \cdot 10^5 \text{ N/mm}^2 \cdot 2{,}769 \cdot 10^8 \text{ mm}^4} = 10{,}52 \text{ mm}$$



$$y_2 = \frac{P \cdot a \left(3 \cdot l^2 - 4 \cdot a^2\right)}{48 \cdot E \cdot I_y}$$

$$= \frac{120{,}1 \cdot 10^3 \text{ N} \cdot 2000 \text{ mm} \cdot \left(3 \cdot (6000 \text{ mm})^2 - 4 \cdot (2000 \text{ mm})^2\right)}{48 \cdot 2{,}1 \cdot 10^5 \text{ N/mm}^2 \cdot 2{,}769 \cdot 10^8 \text{ mm}^4}$$

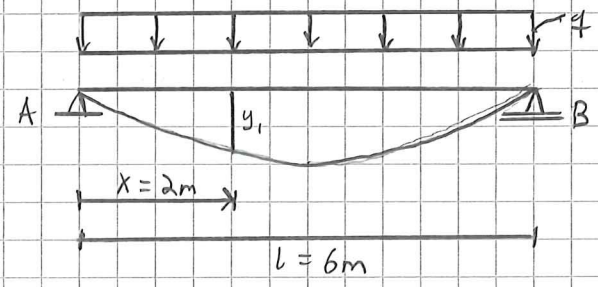
$$= 7{,}92 \text{ mm}$$

$$y_T = y_1 + y_2 = 10,52\,mm + 7,92\,mm = \underline{18,44\,mm}$$

Max nedbøyning: $\frac{6000\,mm}{250} = \underline{24\,mm}$

$$\underline{18,44\,mm < 24\,mm \Rightarrow OK!}$$

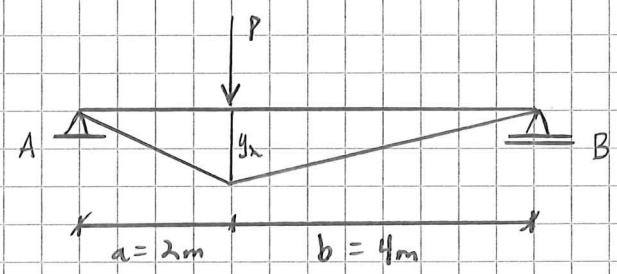
Sjekke nedbøyning ved punktlast:



$$y_1 = \frac{q \cdot l^3 \cdot x}{24 \cdot E \cdot I_y} \cdot \left(1 - 2 \cdot \frac{x^2}{l^2} + \frac{x^3}{l^3}\right)$$

$$= \frac{36,25\,N/mm \cdot (6000\,mm)^3 \cdot (2000\,mm)^2}{24 \cdot 2,1 \cdot 10^5\,N/mm^2 \cdot 2,769 \cdot 10^8\,mm^4} \cdot \left(1 - 2 \cdot \frac{(2000\,mm)^2}{(6000\,mm)^2} + \frac{(2000\,mm)^3}{(6000\,mm)^3}\right)$$

$$= \underline{9,14\,mm}$$



$$y_2 = \frac{P \cdot a^2 \cdot b^2}{3 \cdot E \cdot I_y \cdot L}$$

$$= \frac{120,1 \cdot 10^3\,N \cdot (2000\,mm)^2 \cdot (4000\,mm)^2}{3 \cdot 2,1 \cdot 10^5\,N/mm^2 \cdot 2,769 \cdot 10^8\,mm^4 \cdot 6000\,mm}$$

$$= \underline{7,34\,mm}$$

$$y_T = y_1 + y_2 = 9,14\,mm + 7,34\,mm = \underline{16,48\,mm}$$

$$\underline{16,48\,mm < 24\,mm \Rightarrow OK!}$$