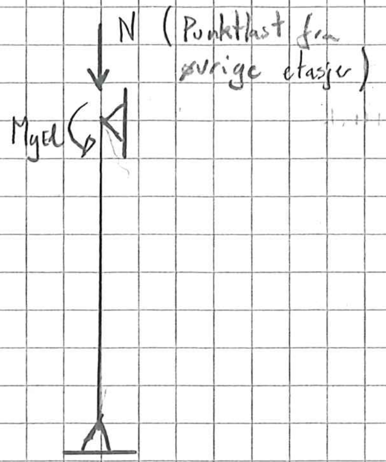
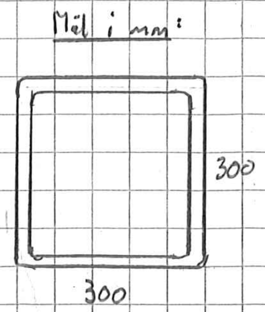
Vedlegg 18

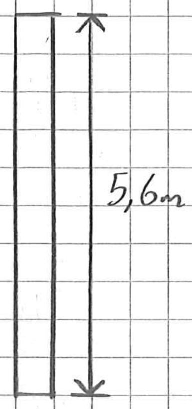
Håndberegningskontroll av søyle

Beregning søyle

HUP 300 × 300 × 10 mm







Når vi skal beregne den nederste søylen må vi legge til etasjereduksjonsfaktoren α_n:

$$\alpha_n = \frac{(2+(n-2)\cdot 0{,}7)}{n} \qquad n = 14 \quad (14 \text{ etasjer})$$

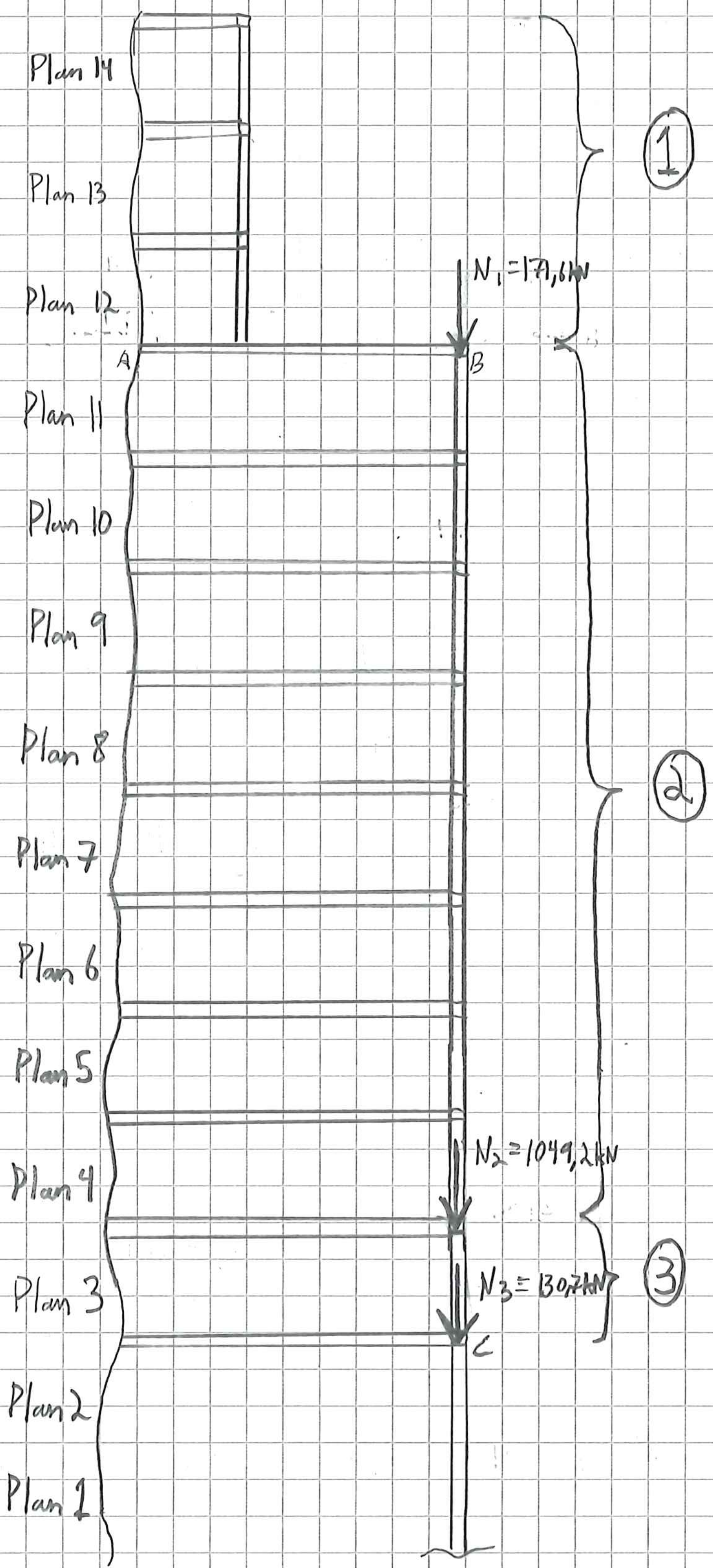
$$= \frac{(2+(14-2)\cdot 0{,}7)}{14}$$

$$= \underline{0{,}74}$$

Etasjereduksjonsfaktoren må gonges inn i nyttelasten for B1 og B2 likningene når vi finner N (punktlast)

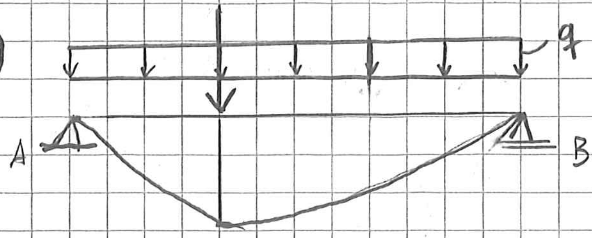
Først finner vi N og M_{yEd}, deretter kontrollerer vi søylen sin kapasitet.

Finne N:



$$N = N_1 + N_2 + N_3$$

1



Fra tidligere beregning for bjelken har vi egenlast og nyttelast, men nå må legge til etasjereduksjonsfaktor.

P: $G_1 = 68{,}1\ kN$ (Bruksgrense)

$N_1 = 52\ kN$ (Bruksgrense)

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

$= 1{,}35 \cdot 68{,}1\ kN + 1{,}05 \cdot 0{,}74 \cdot 52\ kN$

$= 132{,}3\ kN$ (Bruddgrense)

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

$= 1{,}2 \cdot 68{,}1\ kN + 1{,}5 \cdot 0{,}74 \cdot 52\ kN$

$= 139{,}4\ kN$ (Bruddgrense)

B2: $\underline{P = 139{,}4\ kN}$

q:

$G = 16{,}25\ kN/m$ (Bruksgrense)

$N = 20\ kN/m$ (Bruksgrense)

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

$= 1{,}35 \cdot 16{,}25\ kN/m + 1{,}05 \cdot 0{,}74 \cdot 20\ kN/m$

$= \underline{37{,}5\ kN/m}$ (Bruddgrense)

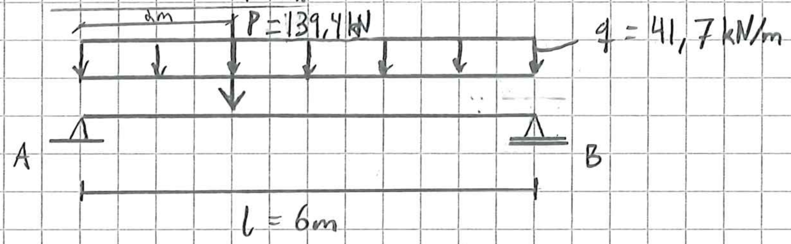
B2: $\gamma_G \cdot G + \gamma_Q \cdot \alpha_n \cdot N$

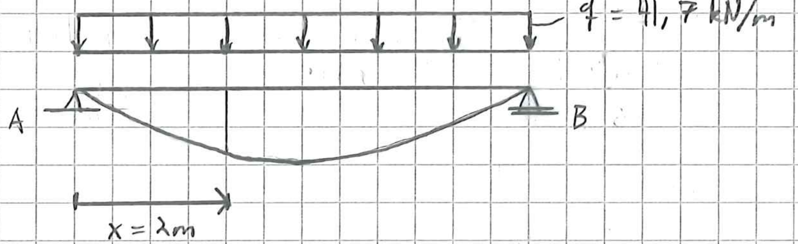
$= 1{,}2 \cdot 16{,}25\ kN/m + 1{,}5 \cdot 0{,}74 \cdot 20\ kN/m$

$= \underline{41{,}7\ kN/m}$ (Bruddgrense)

B2: $\underline{q = 41{,}7\ kN/m}$

Finner M_{max} :

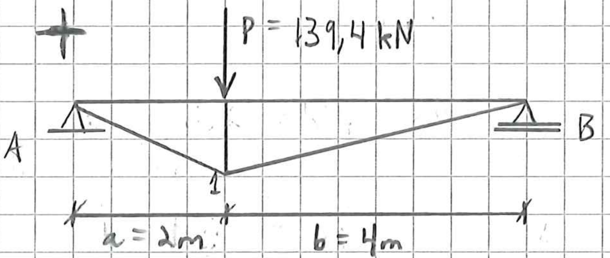




$$M_x = \frac{q \cdot l \cdot x}{2} - \frac{q \cdot x^2}{2}$$

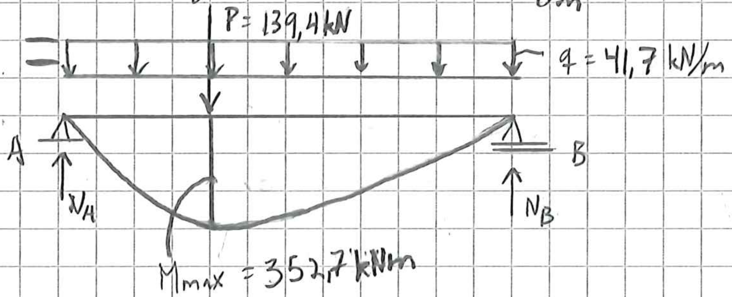
$$= \frac{41,7\ kN/m \cdot 6m \cdot 2m}{2} - \frac{41,7\ kN/m \cdot (2m)^2}{2} = \underline{166,8\ kNm}$$

+



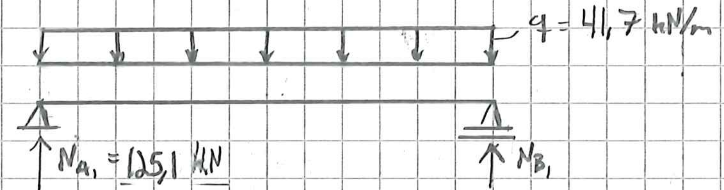
$$M_1 = \frac{P \cdot a \cdot b}{l} = \frac{139,4\ kN \cdot 2m \cdot 4m}{6m} = 185,9\ kNm$$

=

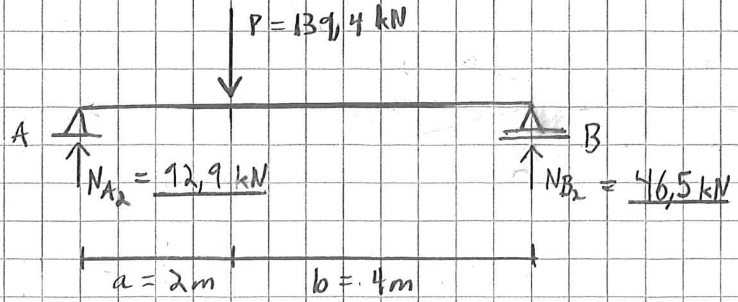


$$M_{max} = M_x + M_1 = 166,8\ kNm + 185,9\ kNm = \underline{352,7\ kNm}$$

Må finne N_B for å finne N_1 som går ned til søylen:

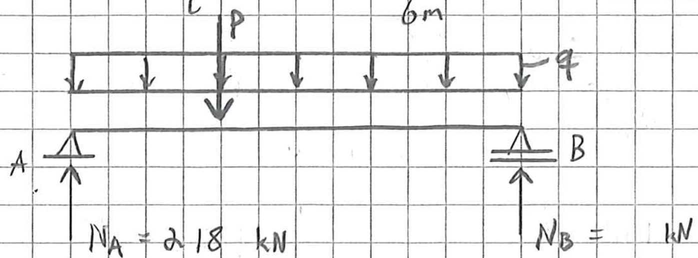


$$N_{B_1} = \frac{q \cdot l}{2} = \frac{41,7\ kN/m \cdot 6m}{2} = \underline{125,1\ kN}$$



$$N_{A_2} = \frac{P \cdot b}{l} = \frac{139,4\,kN \cdot 4m}{6m} = \underline{92,9\,kN}$$

$$N_{B_2} = \frac{P \cdot a}{l} = \frac{139,4\,kN \cdot 2m}{6m} = \underline{46,5\,kN}$$

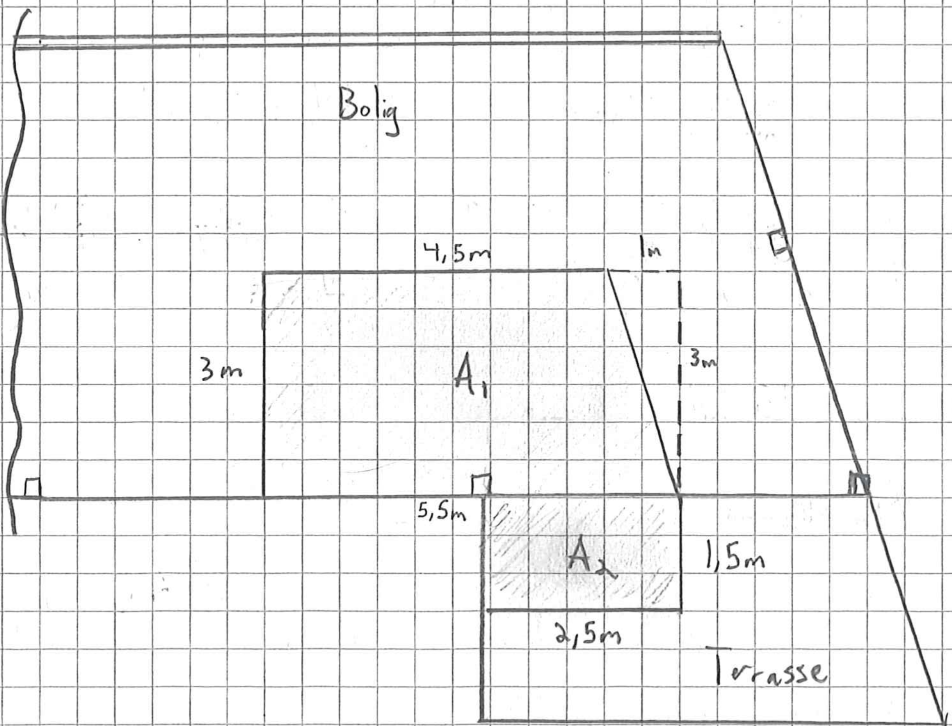


$$N_A = N_{A_1} + N_{A_2} = 125,1\,kN + 92,9\,kN = \underline{218\,kN}$$

$$N_B = N_{B_1} + N_{B_2} = 125,1\,kN + 46,5\,kN = \underline{171,6\,kN}$$

$$N_1 = N_B = \underline{171,6\,kN}$$

② Finne N_2 som er last fra plan 4 - 11 (Alle like)



Lastareal:

$$A_1 = 3m \cdot 4,5m + \frac{3m \cdot 1m}{2} = 15m^2$$

$$A_2 = 2,5m \cdot 1,5m = 3,75m^2$$

CLT 200 (Dekke): $1,0\ kN/m^2$ $\left(500\ kg/m^3 \cdot 0,200m = 100\ kg/m^2 \Rightarrow 1,0\ kN/m^2\right)$

Påstøp: $1,25\ kN/m^2$

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

Boliglast: $2,0\ kN/m^2$

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

$$g_{T_1} = 1,5\ kN/m^2 + 1,25\ kN/m^2 + 0,5\ kN/m^2 = 3,25\ kN/m^2$$

$$g_{T_2} = 1,0\ kN/m^2 + 1,25\ kN/m^2 + 0,5\ kN/m^2 = 2,75\ kN/m^2$$

$$n_{T_1} = 2,0\ kN/m^2 \qquad n_{T_2} = 4,0\ kN/m^2$$

$$G_2 = g_{T_1} \cdot A_1 + g_{T_2} \cdot A_2$$
$$= 3,25\ kN/m^2 \cdot 15m^2 + 2,75\ kN/m^2 \cdot 3,75\ m^2 = \underline{59,1\ kN}$$

$$N_2 = n_{T_1} \cdot A_1 + n_{T_2} \cdot A_2$$
$$= 2,0\ kN/m^2 \cdot 15m^2 + 4,0\ kN/m^2 \cdot 3,75\ m^2 = \underline{45\ kN}$$

$$G_{4-11} = 59,1\ kN \cdot 8 \text{ etasjer} = \underline{472,8\ kN} \text{ (Bruksgrense)}$$

$$N_{4-11} = 45\ kN \cdot 8 \text{ etasjer} = \underline{360\ kN} \text{ (Bruksgrense)}$$

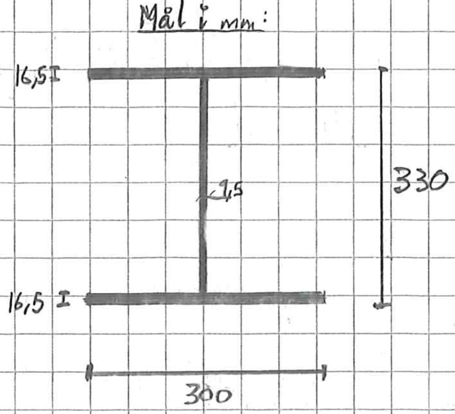
Egenvekt stålbjelke:

HEA - 340 mm

Stål: 7850 kg/m^3

$A = 0,0134 m^2$

$L = 5,5 m$



$7850\ kg/m^3 \cdot 0,0134\ m^2 = 105,2\ kg/m \Rightarrow 1,05\ kN/m \approx 1,1\ kN/m$

$1,1\ kN/m \cdot 5,5 m = 6,1\ kN/_{etasje}$

$G_{Bjelke} = 6,1\ kN/_{etasje} \cdot 9$ etasjer m. bjelker $= \underline{54,9\ kN}$

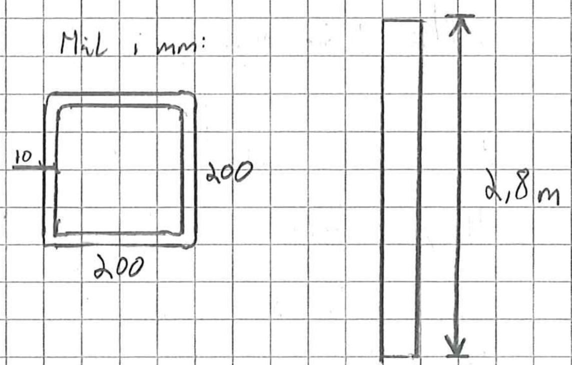
Egenvekt stålsøyle:

HUP 200 × 200 × 10 mm

Stål: 7850 kg/m^3

$A = 0,0075\ m^2$

$L = 2,8m$



$7850\ kg/m^3 \cdot 0,0075 m^2 = 58,9\ kg/m$

$\Rightarrow 0,6\ kN/m$

$0,6\ kN/m \cdot 2,8 m = 1,7\ kN/_{søyle}$

$G_{søyle} = 1,7\ kN/_{søyle} \cdot 8$ søyler $= \underline{13,6\ kN}$

Totalt:

$G = G_{4-11} + G_{Bjelke} + G_{søyle}$

$= 472,8\ kN + 54,9\ kN + 13,6\ kN = \underline{541,3\ kN}$ (Bruksgrense)

$N = N_{4-11} = \underline{360\ kN}$ (Bruksgrense)

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

$= 1{,}35 \cdot 541{,}3\,kN + 1{,}05 \cdot 0{,}74 \cdot 360\,kN$

$= \underline{1010{,}5\,kN}$ (Bruddgrense)

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

$= 1{,}2 \cdot 541{,}3\,kN + 1{,}5 \cdot 0{,}74 \cdot 360\,kN$

$= \underline{1049{,}2\,kN}$ (Bruddgrense)

B2: $N_2 = \underline{1049{,}2\,kN}$

(3) Siste lasten til N er N_3 som kommer fra plan 3.

Fra tidligere beregning på dekke, påstyp, nyttelast etc:

$G_3 = G_2 = \underline{59{,}1\,kN}$ (Bruksgrense)

$N_3 = G_2 = \underline{45\,kN}$ (Bruksgrense)

<u>Egenvekt stålbjelke:</u>

HEA-340 → Lik bjelke som ved (2),

Stål: $7850\,kg/m^3$

$A = 0{,}0134\,m^2$

$L = 5{,}5\,m$

$7850\,kg/m^3 \cdot 0{,}0134\,m^2 = 105{,}2\,kg/m \Rightarrow 1{,}05\,kN/m \approx 1{,}1\,kN/m$

$G_{bjelke} = 1{,}1\,kN/m \cdot 5{,}5\,m = \underline{6{,}1\,kN}$

<u>Egenvekt stålsøyle:</u>

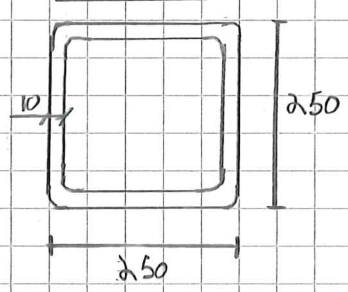
HUP 250 × 250 × 10 mm

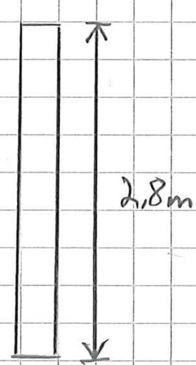
Stål: $7850\,kg/m^3$

$A = 0{,}0095\,m^2$

$L = 2{,}8\,m$

Mål i mm:





$7850 \text{ kg/m}^3 \cdot 0{,}0095 \text{ m}^2 = 74{,}6 \text{ kg/m} \Rightarrow 0{,}75 \text{ kN/m}$

$G_{søyle} = 0{,}75 \text{ kN/m} \cdot 2{,}8 \text{ m} = \underline{2{,}1 \text{ kN}}$

Totalt:

$G = G_3 + G_{Bjelke} + G_{søyle}$

$= 59{,}1 \text{ kN} + 6{,}1 \text{ kN} + 2{,}1 \text{ kN} = \underline{67{,}3 \text{ kN}}$ (Bruksgrense)

$N = N_3 = \underline{45 \text{ kN}}$ (Bruksgrense)

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

$= 1{,}35 \cdot 67{,}3 \text{ kN} + 1{,}05 \cdot 0{,}74 \cdot 45 \text{ kN} = \underline{125{,}8 \text{ kN}}$ (Bruddgrense)

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

$= 1{,}2 \cdot 67{,}3 \text{ kN} + 1{,}5 \cdot 0{,}74 \cdot 45 \text{ kN} = \underline{130{,}7 \text{ kN}}$ (Bruddgrense)

B2: $N_3 = \underline{130{,}7 \text{ kN}}$

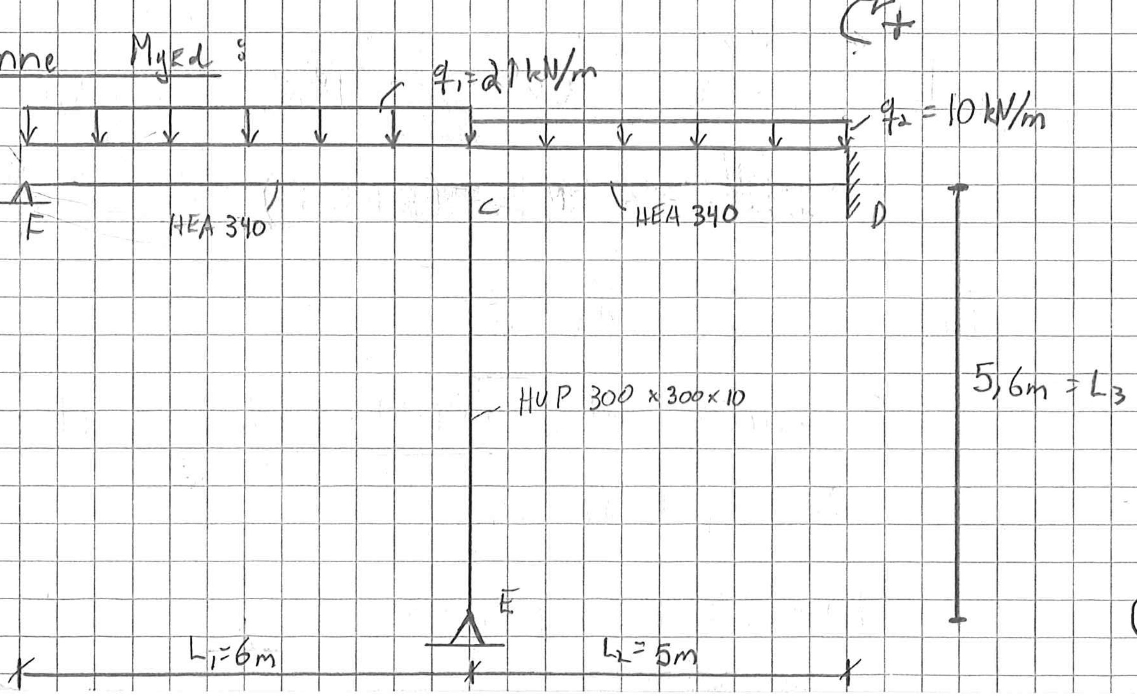
Dette gir da en felles N:

$N = N_1 + N_2 + N_3$

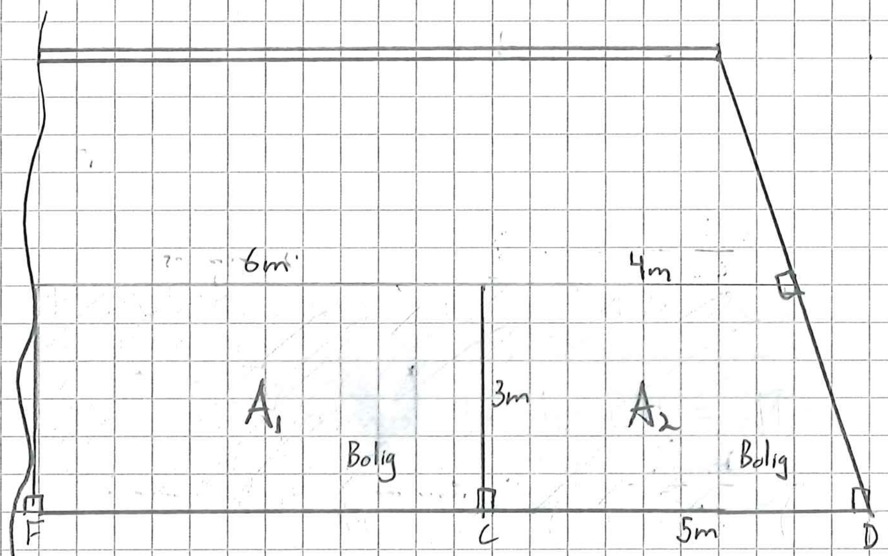
$= 171{,}6 \text{ kN} + 1049{,}2 \text{ kN} + 130{,}7 \text{ kN}$

$= \underline{1351{,}5 \text{ kN}}$

Finne M_{Ed}:



Finne q_1 fra C til F og q_2 fra C til D:



Belastningsareal på bjelker

$A_1 = 6m \times 3m = \underline{18\ m^2}$

$A_2 = 3m \cdot 4m + \left(\frac{3m \cdot 1m}{2}\right) = \underline{13,5\ m^2}$

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

(Dekke, påstøp, membran etc)

$n_T = 2,0\ kN/m^2$ (Bolig)

Bjelke C-F: $L = 6m$

$G_1 = g_T \cdot A_1 = 3,25\ kN/m^2 \cdot 18m^2 = 58,5\ kN$

$= \frac{58,5\ kN}{6m} = \underline{9,8\ kN/m}$ (Bruksgrense)

$N_1 = n_T \cdot A_1 = 2,0\ kN/m^2 \cdot 18\ m^2 = 36\ kN$

$= \frac{36\ kN}{6\ m} = \underline{6\ kN/m}$ (Bruksgrense)

B1: $\gamma_G \cdot G_1 + \gamma_Q \cdot N_1$

$= 1,35 \cdot 9,8\ kN/m + 1,05 \cdot 6\ kN/m = \underline{19,5 kN/m}$ (Bruddgrense)

B2: $\gamma_G \cdot G_1 + \gamma_Q \cdot N_1$

$= 1,2 \cdot 9,8\ kN/m + 1,5 \cdot 6\ kN/m = \underline{20,8 kN/m}$ (Bruddgrense)

B2: $q_1 = 20{,}8 kN/m$ ⇒ Forenkler til $q_1 = 20 kN/m$

Bjelke CD: $L = 5m$

$$G_2 = g_T \cdot A_2 = 3{,}25 \cdot 13{,}5 m^2 = 43{,}9 kN$$

$$= \frac{43{,}9 kN}{5m} = \underline{8{,}8 kN/m} \quad \text{(Bruksgrense)}$$

$$N_2 = n_T \cdot A_2 = 2{,}0 kN/m^2 \cdot 13{,}5 m^2 = 27 kN$$

$$= \frac{27 kN}{5m} = \underline{5{,}4 kN/m} \quad \text{(Bruksgrense)}$$

B1: $\gamma_G \cdot G_2 + \gamma_Q \cdot N_2$

$$= 1{,}35 \cdot 8{,}8 kN/m + 1{,}05 \cdot 5{,}4 kN/m$$
$$= \underline{17{,}6 kN/m} \quad \text{(Bruddgrense)}$$

B2: $\gamma_G \cdot G_2 + \gamma_Q \cdot N_2$

$$= 1{,}2 \cdot 8{,}8 kN/m + 1{,}5 \cdot 5{,}4 kN/m$$
$$= \underline{18{,}7 kN/m} \quad \text{(Bruddgrense)}$$

B2 på $q_2 = 18{,}7 kN/m$ er størst, men siden vi vil ha det største momentet velger vi denne til $q_2 = 10 kN/m$ som er halvparten av $q_1 = 20 kN/m$.

$$M_{CFi} = \frac{q \cdot l^2}{8} = \frac{20 kN/m \cdot (6m)^2}{8} = \underline{90 kNm}$$

$$M_{CDi} = -\frac{q \cdot l^2}{12} = -\frac{10 kN/m \cdot (5m)^2}{12} = \underline{-20{,}8 kNm}$$

HEA-340 : $I_{y_1} = I_{y_2} = 2{,}769 \cdot 10^{-4}$ mm^4

HUP 300 × 300 × 10 : $I_{y_3} = 1{,}6026 \cdot 10^{-4}$ mm^4

$$r_{CF} = \frac{\frac{3 \cdot E \cdot I_{y_1}}{L_1} \cdot \varphi}{\frac{3 \cdot \cancel{E} \cdot I_{y_1}}{L_1} \cdot \cancel{\varphi} + \frac{4 \cdot \cancel{E} \cdot I_{y_2}}{L_2} \cdot \cancel{\varphi} + \frac{3 \cdot \cancel{E} \cdot I_{y_3}}{L_3} \cdot \cancel{\varphi}}$$

$$= \frac{\frac{3 \cdot I_{y_1}}{L_1}}{\frac{3 \cdot I_{y_1}}{L_1} + \frac{4 \cdot I_{y_2}}{L_2} + \frac{3 \cdot I_{y_3}}{L_3}}$$

$$= \frac{\frac{3 \cdot 2{,}769 \cdot 10^{-4}}{6}}{\frac{3 \cdot 2{,}769 \cdot 10^{-4}}{6} + \frac{4 \cdot 2{,}769 \cdot 10^{-4}}{5} + \frac{3 \cdot 1{,}6026 \cdot 10^{-4}}{5{,}6}}$$

$$= \underline{0{,}310}$$

$$r_{CD} = \frac{\frac{4 \cdot E \cdot I_{y_2}}{L_2} \cdot \varphi}{\frac{4 \cdot E \cdot I_{y_2}}{L_2} \cdot \varphi + \frac{3 \cdot E \cdot I_{y_1}}{L_1} \cdot \varphi + \frac{3 \cdot E \cdot I_{y_3}}{L_3} \cdot \varphi}$$

$$= \frac{\frac{4 \cdot I_{y_2}}{L_2}}{\frac{4 \cdot I_{y_2}}{L_2} + \frac{3 \cdot I_{y_1}}{L_1} + \frac{3 \cdot I_{y_3}}{L_3}}$$

$$= \frac{\frac{4 \cdot 2{,}769 \cdot 10^{-4}}{5}}{\frac{4 \cdot 2{,}769 \cdot 10^{-4}}{5} + \frac{3 \cdot 2{,}769 \cdot 10^{-4}}{6} + \frac{3 \cdot 1{,}6026 \cdot 10^{-4}}{5{,}6}}$$

$$= \underline{0{,}497}$$

$$r_{CE} = \frac{\frac{3 \cdot E \cdot I_{y3}}{L_3} \cdot \varphi}{\frac{3 \cdot E \cdot I_{y3}}{L_3} \cdot \varphi + \frac{3 \cdot E \cdot I_{y1}}{L_1} \varphi + \frac{4 \cdot E \cdot I_{y2}}{L_2} \cdot \varphi}$$

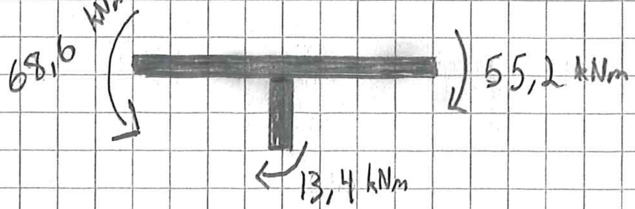
$$= \frac{\frac{3 \cdot I_{y3}}{L_3}}{\frac{3 \cdot I_{y3}}{L_3} + \frac{3 \cdot I_{y1}}{L_1} + \frac{4 \cdot I_{y2}}{L_2}}$$

$$= \frac{\frac{3 \cdot 1{,}6026 \cdot 10^{-4}}{5{,}6}}{\frac{3 \cdot 1{,}6026 \cdot 10^{-4}}{5{,}6} + \frac{3 \cdot 2{,}293 \cdot 10^{-4}}{6} + \frac{4 \cdot 2{,}293 \cdot 10^{-4}}{5}}$$

$$= \underline{0{,}193}$$

Kontroll: $0{,}310 + 0{,}497 + 0{,}193 = \underline{1{,}0}$

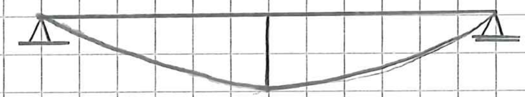
Stav	CF	CD	CE
r	0,310	0,497	0,193
M_{CFi}	90 kNm	0 kNm	0 kNm
$M_{CFi} \cdot r$	-27,9 kNm	-44,7 kNm	-17,4 kNm
M_{CDi}	0 kNm	-20,8 kNm	0 kNm
$M_{CDi} \cdot r$	6,5 kNm	10,3 kNm	4,0 kNm
ΣM	68,6 kNm	-55,2 kNm	-13,4 kNm



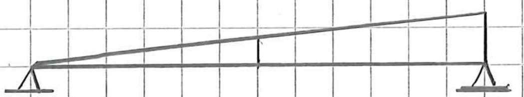
Kontroll: $68{,}6 \text{ kNm} - 55{,}2 \text{ kNm} - 13{,}4 \text{ kNm} = 0 \Rightarrow$ ok!

Momentdiagram:

CF:



$$\frac{q \cdot l^2}{8}$$



$$\frac{M_{CF}}{2}$$

$$M_{mitt} = \frac{q \cdot l^2}{8} - \frac{M_{CF}}{2}$$

$$= \frac{20\ kN/m \cdot (6m)^2}{8} - \frac{68,6\ kNm}{2} = \underline{55,7\ kNm}$$

CD:

$$\frac{q \cdot l^2}{8}$$

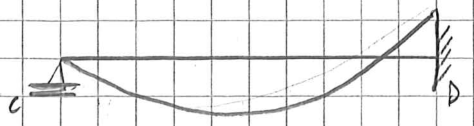
$$\frac{M_{CD}}{2}$$

$$\frac{M_{CD}/2}{2}$$

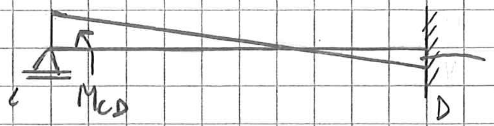
$$M_{mitt} = \frac{q \cdot l^2}{8} - \frac{M_{CD}}{2} + \frac{M_{CD}/2}{2}$$

$$= \frac{10\ kN/m \cdot (5m)^2}{8} - \frac{55,2\ kNm}{2} + \frac{55,2\ kNm/2}{2}$$

$$= \underline{17,45\ kNm}$$ (vil få Nedbøyning)



$$M_{D_0} = \frac{q \cdot l^2}{8}$$

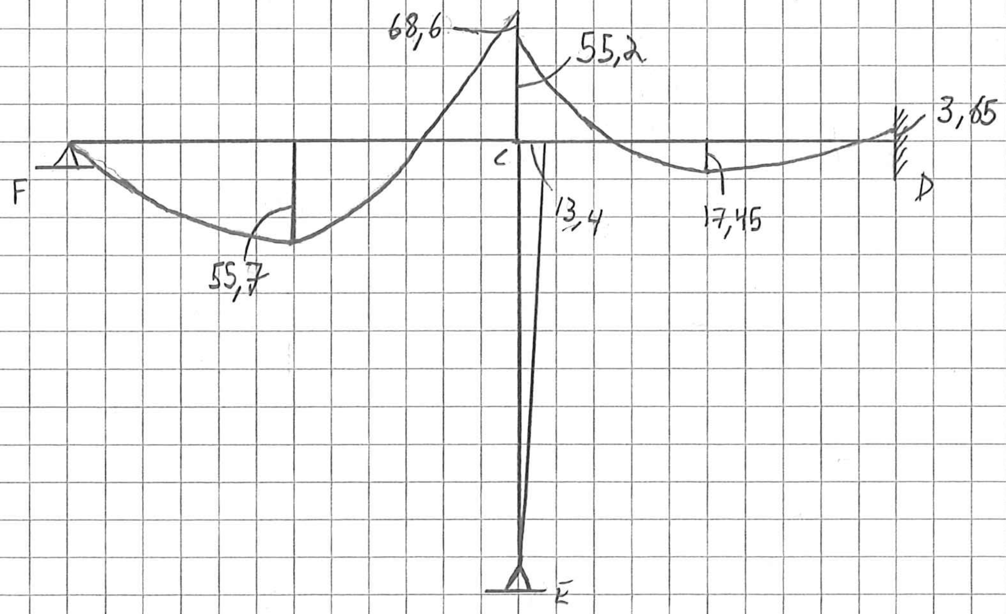


$$\frac{M_{CD}}{2}$$

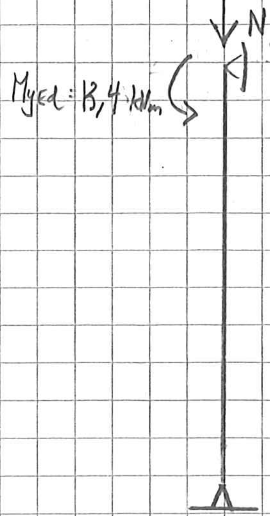
$$M_D = \frac{q \cdot l^2}{8} - \frac{M_{CD}}{2}$$

$$= \frac{10\,kN/m \cdot (5m)^2}{8} - \frac{55{,}2\,kNm}{2}$$

$$= \underline{3{,}65\,kNm} \quad \left(\text{vil få Oppbøyning}\right)$$



Dette gir oss momentet : $M_{yEd} = 13{,}4\ kNm$



Vipping vil ikke oppstå pga kvadratisk tverrsnitt, $\chi_{LT} = 1{,}0$.

Finne χ_y (knekking):

$$\bar{\lambda}_y = \frac{L}{i_y \cdot \pi} \cdot \sqrt{\frac{f_y}{E}} \qquad i_y = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{1{,}6026 \cdot 10^8}{11500}} = 118\,\text{mm}$$

$$= \frac{5600\,\text{mm}}{118\,\text{mm} \cdot \pi} \cdot \sqrt{\frac{355\,\text{N/mm}^2}{2{,}1 \cdot 10^5\,\text{N/mm}^2}} = 0{,}62$$

$$\frac{h}{b} = \frac{300\,\text{mm}}{300\,\text{mm}} = 1{,}0 < 1{,}2$$

$t_f < 100\,\text{mm} \Rightarrow y\text{-}y \Rightarrow$ <u>kurve b</u>

Leser av $\underline{\chi_y = 0{,}84}$

$$\psi = \frac{13{,}4}{0} = 0$$

$$C_{my} = 0{,}6 + 0{,}4 \cdot \psi$$

$$= 0{,}6 + 0{,}4 \cdot 0 = \underline{0{,}6} > 0{,}4 \Rightarrow \underline{\text{OK!}}$$

$$k_{yy} = C_{my}\left(1 + 0{,}6 \cdot \bar{\lambda}_y \cdot \frac{N}{\chi_y \cdot N_{Rd}}\right)$$

$$N_{Rd} = \frac{f_y \cdot A}{\gamma_m} = \frac{355\,\text{N/mm}^2 \cdot 11500\,\text{mm}^2}{1{,}05} = \underline{3888{,}1\,\text{kN}}$$

$$k_{yy} = 0{,}6 \cdot \left(1 + 0{,}6 \cdot 0{,}62 \cdot \frac{1315{,}5\,\text{kN}}{0{,}84 \cdot 3888{,}1\,\text{kN}}\right) = 0{,}69$$

$$\leq C_{my}\left(1 + 0{,}6 \cdot \frac{N}{\chi_y \cdot N_{Rd}}\right)$$

$$\leq 0{,}6 \cdot \left(1 + 0{,}6 \cdot \frac{1315{,}5\,\text{kN}}{0{,}84 \cdot 3888{,}1\,\text{kN}}\right)$$

$< 0{,}74 \Rightarrow \underline{\text{OK!}}$

Kontroll søylen:

$$\frac{N}{\chi_y \cdot \frac{f_y}{\gamma_m} \cdot A} + k_{yy} \frac{M_{yEd}}{\chi_{LT} \cdot W_y \cdot \frac{f_y}{\gamma_m}}$$

$$= \frac{1315{,}5 \cdot 10^3 \ N}{0{,}84 \cdot \frac{355 \ N/mm^2}{1{,}05} \cdot 11500 mm^2} + 0{,}69 \cdot \frac{13{,}4 \cdot 10^6 \ Nmm}{1{,}0 \cdot 1068 \cdot 10^3 mm^3 \cdot \frac{355 \ N/mm^2}{1{,}05}}$$

$$= \underline{\underline{0{,}43 < 1{,}0}} \Rightarrow OK!$$

<u>Søylen har god kapasitet!</u>