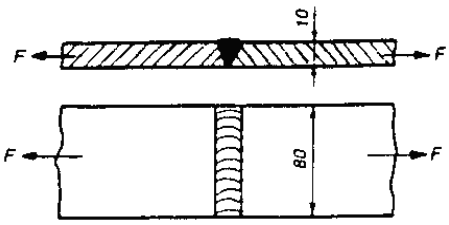
OPPGAVE 1

To plater med mål som vist i figuren under, sveises sammen med V-fuge.
Strekkraften F = 60.000 N, platematerialet er S235JR, materialkoeffisienten settes lik 1,1 og lastkoeffisienten lik 1,5.



a) Bestem spenningen i sveisen.

Spenningen i sveisen = opptredende spenning.

$$\underline{\sigma_o = \frac{F \cdot \gamma_f}{t \cdot b} = \frac{60000 \cdot 1{,}5}{10 \cdot 80} = 112.5 N/mm^2}$$

b) Hvor stor er utnyttelsesgraden av sveisen?

Dimensjonerende spenning:

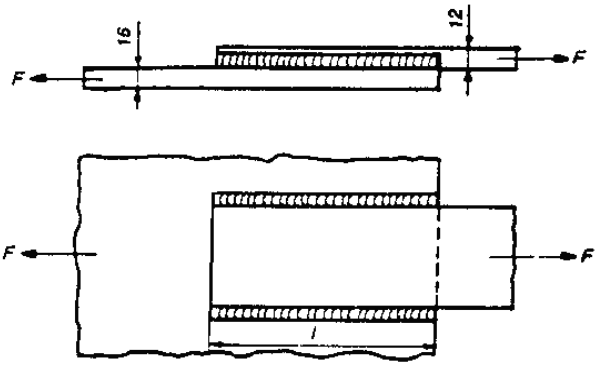
$$\underline{f_d = \frac{f_y}{\gamma_M} = \frac{235}{1{,}1} = 213{,}6 N/mm^2}$$

Utnyttelsesgraden av sveisen:

$$\underline{\underline{\alpha = \frac{\sigma_o}{f_d} = \frac{112{,}5}{213{,}6} \cdot 100\% = 53\%}}$$

OPPGAVE 2

Figuren under viser en overlappskjøt utført med to kilsveiser.
Strekkraften F = 100.000 N og platematerialet er S275.



a) Dimensjoner sveisene på figuren.

$$\underline{a_{maks} = t \cdot \sin 45^0 = 12 \cdot \sin 45^0 = 8{,}5mm}$$

velger $\underline{a = 8mm}$

Spenning (opptredende) i kilsveisene:

$$\sigma_o = \sigma_j = \sqrt{\sigma_\perp^2 + 3\tau_\perp^2 + 3\tau_{II}^2} = \sqrt{3\tau_{II}^2} = \sqrt{3} \cdot \tau_{II}$$

$$\sigma_j \le \sigma_d = \frac{f_u}{\gamma_{Msv} \cdot \beta_W}$$

Setter: $\sigma_j = \sigma_d$

$$\sqrt{3} \cdot \frac{F \cdot \gamma_f}{2 \cdot a \cdot l} = \frac{f_u}{\gamma_{Msv} \cdot \beta_W}$$

$$\Rightarrow \underline{l} = \frac{\sqrt{3} \cdot F \cdot \gamma_f \cdot \gamma_{Msv} \cdot \beta_W}{2 \cdot a \cdot f_u} = \frac{\sqrt{3} \cdot 100000 \cdot 1{,}5 \cdot 1{,}25 \cdot 0{,}85}{2 \cdot 8 \cdot 430} = \underline{40.1mm} \qquad \text{Velger } \underline{\underline{l = 45mm}}$$

OPPGAVE 2, forts.

b) Hvor stor må bredden på flattstålet være?

Setter: $\sigma_o = \sigma_d$

$$\frac{F \cdot \gamma_f}{t \cdot b} = \frac{f_y}{\gamma_M}$$

$$\Rightarrow \underline{\underline{b}} = \frac{F \cdot \gamma_f \cdot \gamma_M}{t \cdot f_y} = \frac{100000 \cdot 1{,}5 \cdot 1{,}1}{12 \cdot 275} \underline{\underline{= 50mm}}$$

OPPGAVE 3

En rørformet torsjonsaksel med diameter Ø 60/50mm er skjøtt med en buttsveis.
Materialet i akselen er S355.

a) Hvor stort vrimoment kan overføres?

Vrispenning:

$$\tau_v = \tau_{ll} = \frac{M_v \cdot \gamma_f}{W_p} \qquad \Rightarrow M_v = \frac{\tau_{ll} \cdot W_p}{\gamma_f}$$

$$\underline{W_p} = \frac{\pi}{16} \cdot \frac{D^4 - d^4}{D} = \frac{\pi}{16} \cdot \frac{60^4 - 50^4}{60} \underline{\approx 22000mm^3}$$

Opptredende spenning = jevnførende spenning:

$$\sigma_o = \sigma_j = \sqrt{\sigma_\perp^2 + 3\tau_\perp^2 + 3\tau_{ll}^2} = \sqrt{3\tau_{ll}^2} = \sqrt{3} \cdot \tau_{ll}$$

$$\sigma_j \le \sigma_d = \frac{f_y}{\gamma_M}$$

Setter: $\sigma_j = \sigma_d$

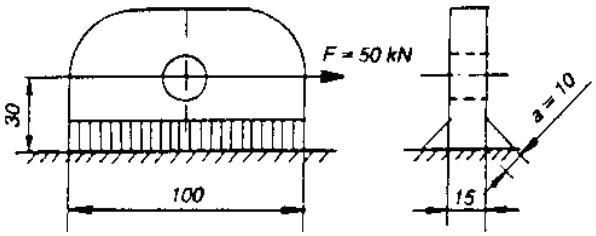
$$\sqrt{3} \cdot \tau_{ll} = \frac{f_y}{\gamma_M} \qquad \Rightarrow \underline{\tau_{ll}} = \frac{f_y}{\sqrt{3} \cdot \gamma_M} = \frac{355}{\sqrt{3} \cdot 1.1} \underline{= 186{,}3N/mm^2}$$

Vrimomentet:

$$\Rightarrow \underline{\underline{M_v}} = \frac{\tau_{ll} \cdot W_p}{\gamma_f} = \frac{186{,}3 \cdot 22000}{1{,}5} \approx 2.733.000Nmm \underline{\underline{= 2.733Nm}}$$

OPPGAVE 4

Et løfteøre av 15mm plate, som vist i figuren under, er sveist fast på langsidene med kilsveis.

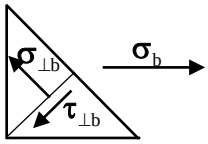


a) Beregn jevnførende spenning i sveisen.

Bøyespenning i sveisen:

$$\underline{\sigma_b} = \frac{M_b}{I_{x_{sveis}}} \cdot y = \frac{F \cdot \gamma_f \cdot l}{2 \cdot \frac{b \cdot h^3}{12}} \cdot \frac{h}{2} = \frac{50 \cdot 10^3 \cdot 1{,}5 \cdot 30}{2\frac{10 \cdot 100^3}{12}} \cdot \frac{100}{2} = \underline{67{,}5 N/mm^2}$$

Spenninger normalt på sveisens lengderetning:



$$\underline{\sigma_{\perp b} = \tau_{\perp b}} = \sigma_b \cdot \sin 45^0 = \frac{\sigma_b}{\sqrt{2}} = \frac{67{,}5}{\sqrt{2}} = \underline{47{,}7 N/mm^2}$$

Spenninger parallelt med sveisens lengderetning:

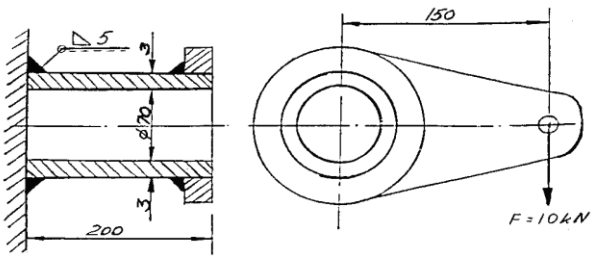
$$\underline{\tau_{ll}} = \frac{F \cdot \gamma_f}{2 \cdot a \cdot l} = \frac{50 \cdot 10^3 \cdot 1{,}5}{2 \cdot 10 \cdot 100} = \underline{37{,}5 N/mm^2}$$

Opptredende spenning = jevnførende spenning:

$$\sigma_o = \underline{\underline{\sigma_j}} = \sqrt{\sigma_{\perp b}^2 + 3\tau_{\perp b}^2 + 3\tau_{ll}^2} = \sqrt{47{,}5^2 + 3 \cdot 47{,}5^2 + 3 \cdot 37{,}5^2} = \underline{\underline{115{,}1 N/mm^2}}$$

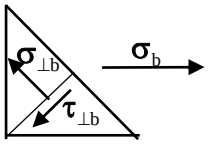
OPPGAVE 5

Figuren under viser et rørstykke som er 200mm langt og påsveist en arm på150mm.
Røret er festet til en vegg med kilsveis, a-mål lik 5mm, og belastes med en rolig virkende kraft F = 10.000N. Materiale er S355.



a) Kontroller sveisen.

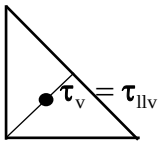
Bøyning:



$$\underline{\sigma_b = \frac{M_b}{I_{x_{sveis}}} \cdot y = \frac{M_b}{W_{x_{sveis}}} = \frac{F \cdot \gamma_f \cdot l_1}{\frac{\pi}{32} \cdot \frac{D^4 - d^4}{D}} = \frac{10 \cdot 10^3 \cdot 1{,}5 \cdot 200}{\frac{\pi}{32} \cdot \frac{86^4 - 76^4}{86}} = 123{,}2 N/mm^2}$$

$$\underline{\sigma_{\perp b} = \tau_{\perp b} = \frac{\sigma_b}{\sqrt{2}} = \frac{123{,}2}{\sqrt{2}} = 87{,}1 N/mm^2}$$

Vridning:



$$\underline{\tau_v = \tau_{llv} = \frac{M_v}{I_{p_{sveis}}} \cdot r = \frac{M_v}{W_{p_{sveis}}} = \frac{F \cdot \gamma_f \cdot l_2}{\frac{\pi}{16} \cdot \frac{D^4 - d^4}{D}} = \frac{10 \cdot 10^3 \cdot 1{,}5 \cdot 150}{\frac{\pi}{16} \cdot \frac{86^4 - 76^4}{86}} = 46{,}2 N/mm^2}$$

Opptredende spenning = jevnførende spenning:

$$\underline{\sigma_j = \sqrt{\sigma_{\perp b}^2 + 3\tau_{\perp b}^2 + 3\tau_{llv}^2} = \sqrt{87{,}1^2 + 3 \cdot 87{,}1^2 + 3 \cdot 46{,}2^2} = 191{,}7 N/mm^2}$$

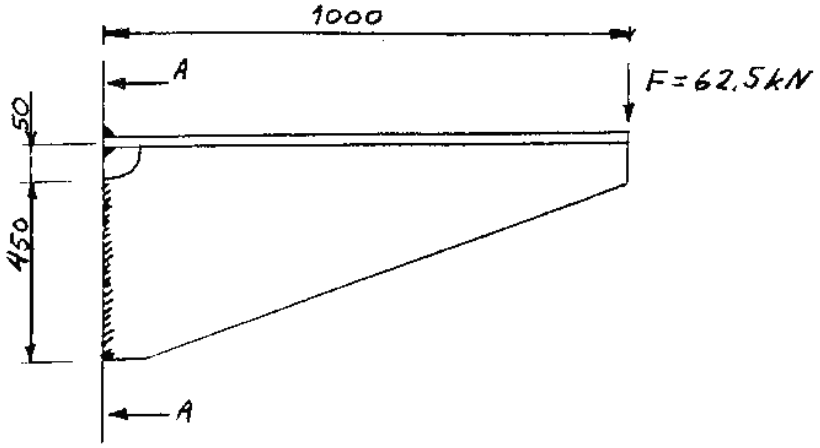
Kontroll:

$$\sigma_j \le \frac{f_u}{\gamma_M \cdot \beta_W}$$

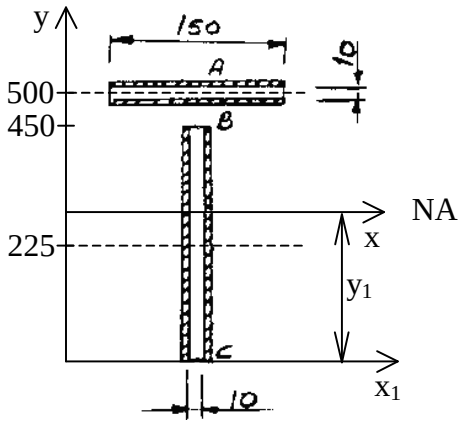
$$191{,}7 \le \frac{510}{1{,}25 \cdot 0{,}9} = 453{,}3 \quad \Rightarrow \text{OK!}$$

OPPGAVE 6

Den sveiste konstruksjonen i figuren under belastes med en kraft på F = 62,5kN.
All sveis har a-mål lik 5mm.



Snitt A-A



a) Gjør passende antagelser om lastoverføring, og beregn jevnførende spenning i sveisen i punktene A, B og C.

Tyngdepunkt, sveis:

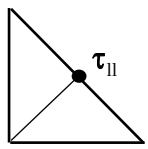
$$\underline{y_1} = \frac{2 \cdot A_1 \cdot 500 + 2 \cdot A_2 \cdot 225}{2 \cdot A_1 + 2 \cdot A_2} = \frac{2(150 \cdot 5) \cdot 500 + 2(450 \cdot 5) \cdot 225}{2(150 \cdot 5) + 2(450 \cdot 5)} \underline{= 294\text{mm}}$$

Treghetsmoment, sveis:

$$I_{x_{sveis}} = 2 \cdot \frac{150 \cdot 5^3}{12} + 2(150 \cdot 5) \cdot (500 - 294)^2 + 2 \cdot \frac{5 \cdot 450^3}{12} + 2(450 \cdot 5) \cdot (294 - 225)^2$$

$$\underline{I_{x_{sveis}} = 1{,}61 \cdot 10^8 \,\text{mm}^4}$$

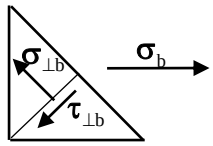
Skjærspenning:



$$\underline{\tau_{ll}} = \frac{F \cdot \gamma_f}{A_{sveis_{vertikal}}} = \frac{62{,}5 \cdot 10^3 \cdot 1{,}5}{2(450 \cdot 5)} \underline{= 20{,}8\text{N/mm}^2}$$

OPPGAVE 6, forts.

Bøyespenning:



$$\underline{\sigma_b} = \frac{M_b}{I_{x_{sveis}}} \cdot y = \frac{F \cdot \gamma_f \cdot l}{I_{x_{sveis}}} \cdot y$$

pkt. A) $\underline{\sigma_{bA}} = \frac{62{,}5 \cdot 10^3 \cdot 1{,}5 \cdot 1000}{1{,}61 \cdot 10^8} \cdot (510 - 294) = \underline{125{,}8 N/mm^2}$

pkt. B) $\underline{\sigma_{bB}} = \frac{62{,}5 \cdot 10^3 \cdot 1{,}5 \cdot 1000}{1{,}61 \cdot 10^8} \cdot (450 - 294) = \underline{90{,}8 N/mm^2}$

pkt. C) $\underline{\sigma_{bC}} = \frac{62{,}5 \cdot 10^3 \cdot 1{,}5 \cdot 1000}{1{,}61 \cdot 10^8} \cdot 294 = \underline{171{,}2 N/mm^2}$

Jevnførende spenning (= opptredende spenning):

pkt. A) $\tau_{ll} = 0$

$$\underline{\sigma_{\perp bA} = \tau_{\perp bA}} = \frac{\sigma_{b_A}}{\sqrt{2}} = \frac{125{,}8}{\sqrt{2}} = \underline{89{,}0 N/mm^2}$$

$$\underline{\underline{\sigma_{jA}}} = \sqrt{\sigma_{\perp bA}^2 + 3\tau_{\perp bA}^2 + 3\tau_{ll}^2} = \sqrt{89{,}0^2 + 3 \cdot 89{,}0^2 + 3 \cdot 0^2} = \underline{\underline{178{,}0 N/mm^2}}$$

pkt. B) $\tau_{ll} = 20{,}8 N/mm^2$

$$\underline{\sigma_{\perp bB} = \tau_{\perp bB}} = \frac{\sigma_{b_B}}{\sqrt{2}} = \frac{90{,}8}{\sqrt{2}} = \underline{64{,}2 N/mm^2}$$

$$\underline{\underline{\sigma_{jB}}} = \sqrt{\sigma_{\perp bB}^2 + 3\tau_{\perp bB}^2 + 3\tau_{ll}^2} = \sqrt{64{,}2^2 + 3 \cdot 64{,}2^2 + 3 \cdot 20{,}8^2} = \underline{\underline{133{,}4 N/mm^2}}$$

pkt. C) $\tau_{ll} = 20{,}8 N/mm^2$

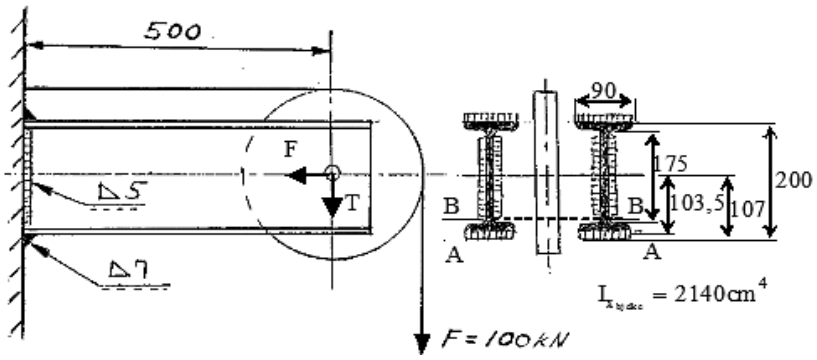
$$\underline{\sigma_{\perp bB} = \tau_{\perp bB}} = \frac{\sigma_{b_B}}{\sqrt{2}} = \frac{171{,}2}{\sqrt{2}} = \underline{121{,}1 N/mm^2}$$

$$\underline{\underline{\sigma_{jC}}} = \sqrt{\sigma_{\perp bB}^2 + 3\tau_{\perp bB}^2 + 3\tau_{ll}^2} = \sqrt{121{,}1^2 + 3 \cdot 121{,}1^2 + 3 \cdot 20{,}8^2} = \underline{\underline{244{,}9 N/mm^2}}$$

OPPGAVE 7

Figuren under viser en snor som er belastet med en kraft F = 100kN.
Snora løper over en trinse og er festet i veggen. Trinsen er lagret på to stk. I-200 bjelker.
I-bjelkene er sveist til veggen som vist i figuren.

Materialet i bjelkene er S275.



a) Kontroller sveisen.

Normalkraft : F=100kN
Skjærkraft : T=N=100kN

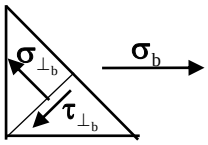
Bøyemoment : $\underline{M_b = T \cdot 500 = 100 \cdot 10^3 \cdot 1{,}5 \cdot 500 = 7{,}5 \cdot 10^7\ \text{Nmm}}$

Treghetsmoment sveis :
Bruker "Steiners formel", $I = I_0 + A \cdot a^2$, og deler opp sveisen i fire flater.
$I_{x\ sveis}$ = Summen av flatenes treghetsmoment om egen tyngdepunktsakse + flatenes areal ganger avstanden opphøyd i annen fra flatens tyngdepunkt til flatenes felles tyngdepunkt.
De fire sveiser / flater er alle rektangulære, så for en flate om eget tyngdepunkt gjelder

$$I_x \frac{b \cdot h^3}{12}$$

$$\Rightarrow \quad \underline{I_{x_{sv}} = 2\left[2\left[\left(\frac{90 \cdot 7^3}{12}\right) + (90 \cdot 7) \cdot 103{,}5^2\right] + 2\left[\left(\frac{5 \cdot 175^3}{12}\right) + (5 \cdot 175) \cdot 0^2\right]\right] = 3{,}6 \cdot 10^7\ \text{mm}^4}$$

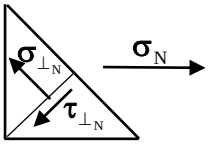
SPENNINGER I FLENS A-A:
Bøyespenning:



$$\underline{\sigma_{bA} = \frac{M_b}{I_{x_{sv}}} \cdot y = \frac{-7{,}5 \cdot 10^7}{3{,}6 \cdot 10^7} \cdot 107 = -222{,}9\ \text{N/mm}^2} \qquad \text{(trykk)}$$

$$\underline{\sigma_{\perp_{bA}} = \tau_{\perp_{bA}} = \frac{\sigma_{b_A}}{\sqrt{2}} = \frac{-222{,}9}{\sqrt{2}} = -157{,}6\ \text{N/mm}^2}$$

Normalspenning:



$$\underline{\sigma_{N_A} = \frac{F \cdot \gamma_f}{A_{sv}} = \frac{100 \cdot 10^3 \cdot 1{,}5}{4(175 \cdot 5 + 90 \cdot 7)} = 24{,}9\ \text{N/mm}^2} \qquad \text{(trykk)}$$

$$\underline{\sigma_{\perp_{NA}} = \tau_{\perp_{NA}} = \frac{\sigma_{N_A}}{\sqrt{2}} = \frac{-24{,}9}{\sqrt{2}} = -17{,}6\ \text{N/mm}^2}$$

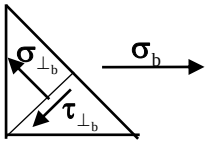
OPPGAVE 7, forts.

Jevnførende spenning:

$$\underline{\sigma_{j_A}} = \sqrt{\left(\sigma_{\perp_{bA}} + \sigma_{\perp_{NA}}\right)^2 + 3\left(\tau_{\perp_{bA}} + \tau_{\perp_{NA}}\right)^2} = \sqrt{\left(-157{,}6 - 17{,}6\right)^2 + 3\cdot\left(-157{,}6 - 17{,}6\right)^2} \underline{= 350{,}4\text{N/mm}^2}$$

SPENNINGER I STEG B-B:

Bøyespenning:



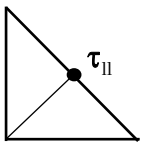
$$\underline{\sigma_{bB}} = \frac{M_b}{I_{x_{sv}}} \cdot y = \frac{-7{,}5\cdot 10^7}{3{,}6\cdot 10^7} \cdot \frac{175}{2} \underline{= -182{,}3\text{N/mm}^2} \text{ (trykk)}$$

$$\underline{\sigma_{\perp_{bB}} = \tau_{\perp_{bB}}} = \frac{\sigma_{b_A}}{\sqrt{2}} = \frac{-182{,}3}{\sqrt{2}} \underline{= -128{,}9\text{N/mm}^2}$$

Normalspenning (som i flens A-A):

$$\underline{\sigma_{\perp_{NB}} = \tau_{\perp_{NB}}} = \frac{\sigma_{N_A}}{\sqrt{2}} = \frac{-24{,}9}{\sqrt{2}} \underline{= -17{,}6\text{N/mm}^2}$$

Skjærspenning:



$$\underline{\tau_{ll_B}} = \frac{T\cdot\gamma_f}{A_{sveis_{vertikal}}} = \frac{100\cdot 10^3\cdot 1{,}5}{4(175\cdot 5)} \underline{= 42{,}9\text{N/mm}^2}$$

Jevnførende spenning:

$$\sigma_{j_B} = \sqrt{\left(\sigma_{\perp_{bB}} + \sigma_{\perp_{NB}}\right)^2 + 3\left(\tau_{\perp_{bB}} + \tau_{\perp_{NB}}\right)^2 \cdot 3\tau_{ll}^2}$$

$$\underline{\sigma_{j_B}} = \sqrt{\left(-128{,}9 - 17{,}6\right)^2 + 3\cdot\left(-128{,}9 - 17{,}6\right)^2 + 3\cdot 42{,}9^2} \underline{= 302{,}3\text{N/mm}^2}$$

► σ_{j_A} størst

Kontroll:

$$\sigma_{j_A} \le \frac{f_u}{\gamma_M \cdot \beta_W}$$

$$350{,}4 \le \frac{430}{1{,}25\cdot 0{,}85} = 404{,}7 \quad \Rightarrow \text{OK!}$$

og

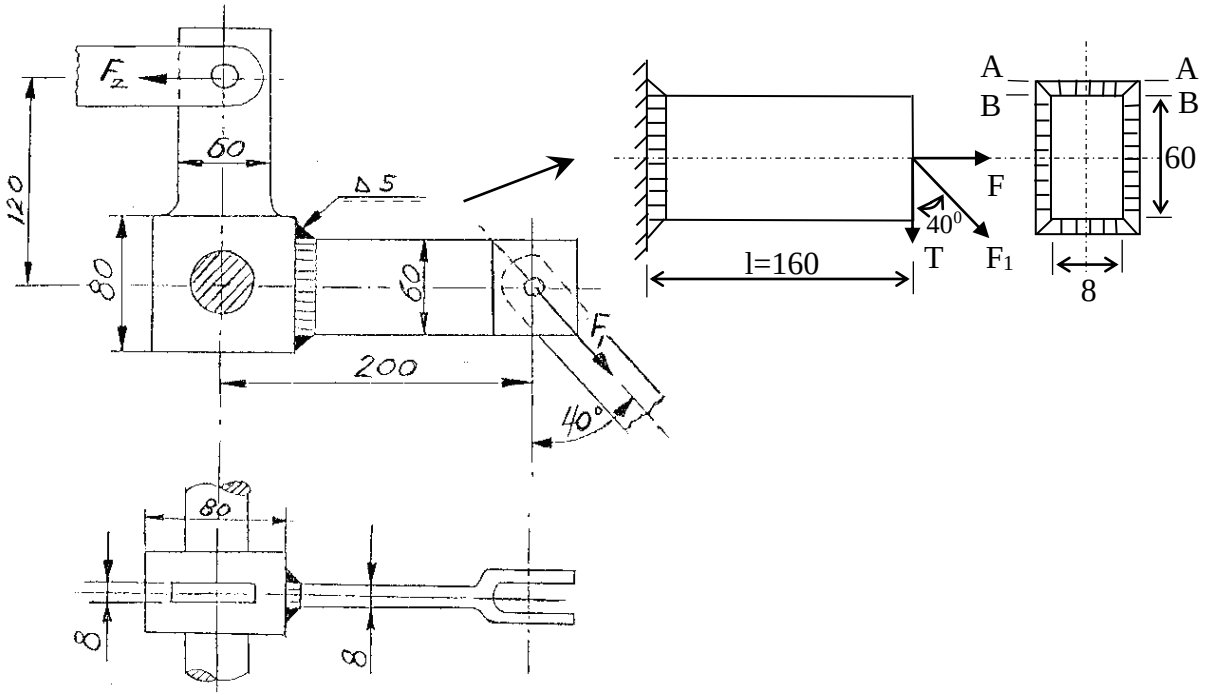
$$\sigma_\perp = \left(\sigma_{\perp_{bA}} + \sigma_{\perp_{NA}}\right) \le \frac{f_u}{\gamma_M}$$

$$\left(157{,}6 + 17{,}6\right) \le \frac{430}{1{,}25}$$

$$175{,}2 \le 344{,}0 \quad \Rightarrow \text{OK!}$$

OPPGAVE 8

Figuren under viser en vinkelarm av materiale S355.
Vinkelarmen er festet til en aksel som utsettes for en påkjenning (stangkraft) F_1 = 2,5kN (som gir stangkraften F_2 = 3,2kN). Sveisen er utført som en kilsveis med a-mål på 5mm.



a) Kontroller sveisen.

Strekkraft: $\underline{F = F_1 \cdot \sin 40^0 = 2{,}5 \cdot \sin 40^0 = 1{,}6kN}$

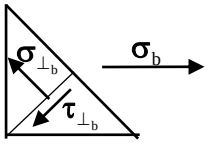
Skjærkraft: $\underline{T = F_1 \cdot \cos 40^0 = 2{,}5 \cdot \cos 40^0 = 1{,}9kN}$

Bøyemoment: $\underline{M_b = T \cdot \gamma_f \cdot l = 1{,}9 \cdot 10^3 \cdot 1{,}5 \cdot 160 = 456{,}0 \cdot 10^3 Nmm}$

Treghetsmoment sveis: $\underline{I_{x_{sv}} = \frac{1}{12}\left[18 \cdot 70^3 - 8 \cdot 60^3\right] = 3{,}7 \cdot 10^5 mm^4}$

SNITT A-A:

Bøyespenning:

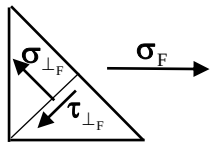


$$\underline{\sigma_{bA} = \frac{M_b}{I_{x_{sv}}} \cdot y = \frac{456{,}0 \cdot 10^3}{3{,}7 \cdot 10^5} \cdot \left(\frac{60}{2} + 5\right) = 43{,}1N/mm^2}$$

$$\underline{\sigma_{\perp bA} = \tau_{\perp bA}} = \frac{\sigma_{b_A}}{\sqrt{2}} = \frac{43{,}1}{\sqrt{2}} = \underline{30{,}5N/mm^2}$$

OPPGAVE 8, forts.

Normalspenning:



$$\underline{\sigma_{F_A} = \frac{F \cdot \gamma_f}{A_{sv}} = \frac{1{,}6 \cdot 10^3 \cdot 1{,}5}{[(8+2\cdot 5)\cdot(60+2\cdot 5) - 8\cdot 60]} = 3{,}1 N/mm^2}$$

$$\underline{\sigma_{\perp FA} = \tau_{\perp FA} = \frac{\sigma_{F_A}}{\sqrt{2}} = \frac{3{,}1}{\sqrt{2}} = 2{,}2 N/mm^2}$$

Jevnførende spenning:

$$\underline{\sigma_{j_A} = \sqrt{(\sigma_{\perp bA} + \sigma_{\perp FA})^2 + 3(\tau_{\perp bA} + \tau_{\perp FA})^2} = \sqrt{(30{,}5 + 2{,}2)^2 + 3\cdot(30{,}5+2{,}2)^2} = 65{,}6 N/mm^2}$$

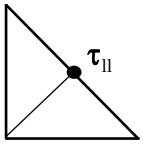
SNITT B-B:

Bøyespenning:

$$\underline{\sigma_{b_B} = \frac{M_b}{I_{x_{sv}}} \cdot y = \frac{456{,}0 \cdot 10^3}{3{,}7 \cdot 10^5} \cdot \frac{60}{2} = 37{,}0 N/mm^2}$$

$$\underline{\sigma_{\perp bB} = \tau_{\perp bB} = \frac{\sigma_{b_B}}{\sqrt{2}} = \frac{37{,}0}{\sqrt{2}} = 26{,}1 N/mm^2}$$

Skjærspenning:



$$\underline{\tau_{ll_B} = \frac{T \cdot \gamma_f}{A_{sveis_{vertikal}}} = \frac{1{,}9 \cdot 10^3 \cdot 1{,}5}{2(60\cdot 5)} = 4{,}8 N/mm^2}$$

Normalspenning (som i snitt A-A):

$$\underline{\sigma_{\perp FB} = \tau_{\perp FB} = \frac{\sigma_{F_B}}{\sqrt{2}} = \frac{3{,}1}{\sqrt{2}} = 2{,}2 N/mm^2}$$

Jevnførende spenning:

$$\underline{\sigma_{j_B} = \sqrt{(\sigma_{\perp bB} + \sigma_{\perp FB})^2 + 3(\tau_{\perp bB} + \tau_{\perp FB})^2 + 3\tau_{ll_B}^2}}$$

$$\underline{\sigma_{j_B} = \sqrt{(26{,}1 + 2{,}2)^2 + 3\cdot(26{,}1+2{,}2)^2 + 3\cdot 4{,}8^2} = 57{,}2 N/mm^2}$$

OPPGAVE 8, forts.

► σ_{jA} størst

Kontroll:

$$\sigma_{jA} \le \frac{f_u}{\gamma_M \cdot \beta_W}$$

$$65{,}6 \le \frac{510}{1{,}25 \cdot 0{,}9} = 453{,}3 \quad \Rightarrow \text{OK!}$$

og

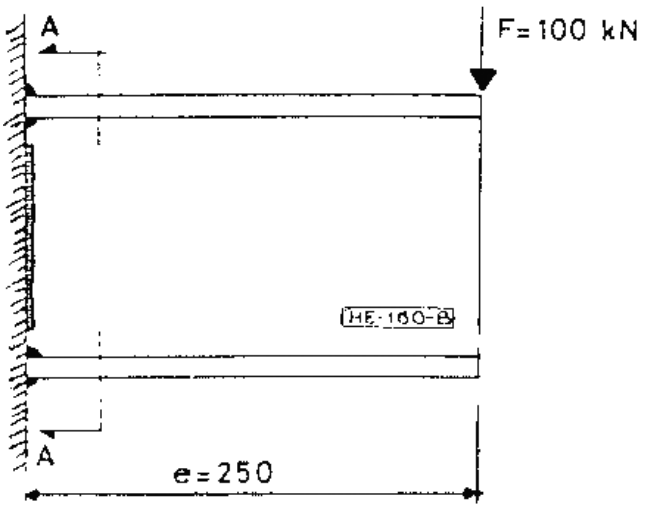
$$\sigma_{\perp} = \left(\sigma_{\perp_{bA}} + \sigma_{\perp_{FA}}\right) \le \frac{f_u}{\gamma_M}$$

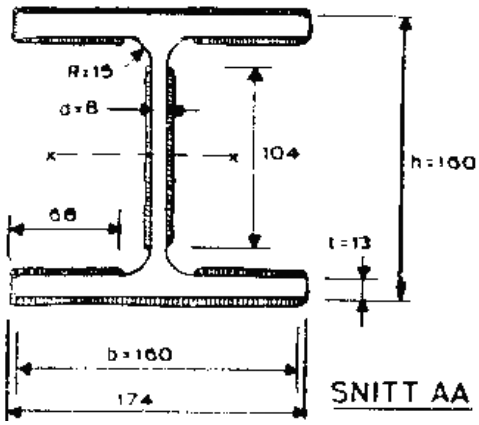
$$\left(30{,}5 + 2{,}2\right) \le \frac{510}{1{,}25}$$

$$32{,}7 \le 408{,}0 \quad \Rightarrow \text{OK!}$$

OPPGAVE 9

Figuren under viser en konsoll bestående av en HE 160B bjelke.
Bjelken er belastet med F = 100kN (bruddgrensetilstanden, F_d = 100kN) i avstand e = 250mm fra innfestingen.
Konsollen sveises med kilsveis (manuell sveising). (Vanligvis sveises det rundt hele profilet.)
Materialfasthet f_y (σ_F) = 235N/mm^2.
Rundt flensene velges kilsveis med a = 7mm.
Langs livplate velges kilsveis med a = 5mm.





a) Kontroller kilsveisen.

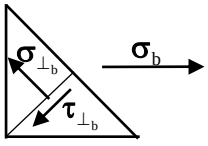
Bøyemoment:

$$\underline{M_b} = F \cdot \gamma_f \cdot e = 100 \cdot 10^3 \cdot 1{,}5 \cdot 250 \underline{= 37{,}5 \cdot 10^6\ \text{Nmm}}$$

Treghetsmoment sveis:

$$\underline{I_{x_{sv}}} = 2\left[\frac{5 \cdot 104^3}{12} + \frac{174 \cdot 7^3}{12} + (174 \cdot 7) \cdot 83{,}5^2 + 2\left[\frac{68 \cdot 7^3}{12} + (68 \cdot 7) \cdot 63{,}5^2\right]\right] \underline{= 25{,}6 \cdot 10^6\ \text{mm}^4}$$

SNITT A-A:
Bøyespenning:



$$\underline{\sigma_{b_A}} = \frac{M_b}{I_{x_{sv}}} \cdot y = \frac{37{,}5 \cdot 10^6}{25{,}6 \cdot 10^6} \cdot \left(\frac{160}{2} + 7\right) \underline{= 127{,}4\text{N/mm}^2}$$

$$\underline{\sigma_{\perp_{bA}} = \tau_{\perp_{bA}}} = \frac{\sigma_{b_A}}{\sqrt{2}} = \frac{127{,}4}{\sqrt{2}} \underline{= 90{,}1\text{N/mm}^2}$$

Jevnførende spenning:

$$\underline{\sigma_{j_A}} = \sqrt{(\sigma_{\perp_{bA}})^2 + 3(\tau_{\perp_{bA}})^2} = \sqrt{(90{,}1)^2 + 3 \cdot (90{,}1)^2} \underline{= 180{,}2\text{N/mm}^2}$$

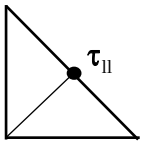
OPPGAVE 9, forts.

SNITT B-B:
Bøyespenning:

$$\underline{\sigma_{b_B}} = \frac{M_b}{I_{x_{sv}}} \cdot y = \frac{37{,}5 \cdot 10^6}{25{,}6 \cdot 10^6} \cdot \left(\frac{104}{2}\right) \underline{= 76{,}2 N/mm^2}$$

$$\underline{\sigma_{\perp_{bB}} = \tau_{\perp_{bB}}} = \frac{\sigma_{b_A}}{\sqrt{2}} = \frac{76{,}2}{\sqrt{2}} \underline{= 53{,}9 N/mm^2}$$

Skjærspenning:



$$\underline{\tau_{ll_B}} = \frac{T \cdot \gamma_f}{A_{sveis_{vertikal}}} = \frac{100 \cdot 10^3 \cdot 1{,}5}{2(104 \cdot 5)} \underline{= 144{,}2 N/mm^2}$$

Jevnførende spenning:

$$\sigma_{jB} = \sqrt{\sigma_{\perp_{bB}}{}^2 + 3\tau_{\perp_{bB}}{}^2 + 3\tau_{ll}^2}$$

$$\underline{\sigma_{jB}} = \sqrt{53{,}9^2 + 3 \cdot 53{,}9^2 + 3 \cdot 144{,}2^2} \underline{= 272{,}1 N/mm^2}$$

► σ_{jB} størst

Kontroll:

$$\sigma_{jB} \le \frac{f_u}{\gamma_M \cdot \beta_W}$$

$$272{,}1 \le \frac{360}{1{,}25 \cdot 0{,}8} = 360{,}0 \quad \Rightarrow \text{OK!}$$

og

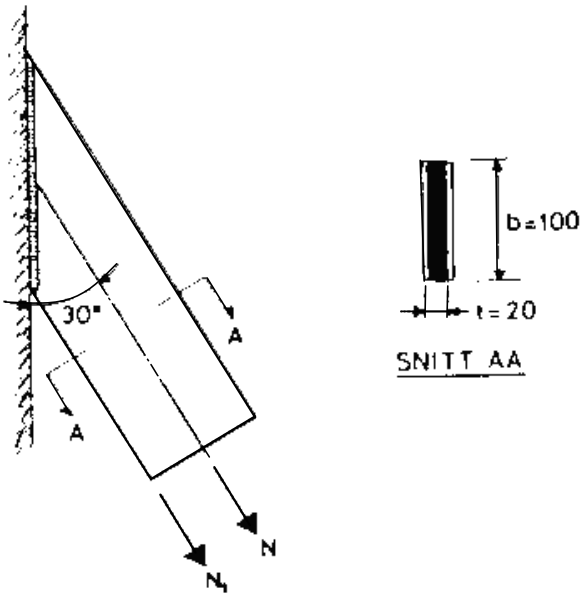
$$\sigma_\perp = \sigma_{\perp_{bA}} \le \frac{f_u}{\gamma_M}$$

$$53{,}9{,}1 \le \frac{360}{1{,}25}$$

$$53{,}9 \le 288{,}0 \quad \Rightarrow \text{OK!}$$

OPPGAVE 10

Figuren under viser et flattstål, 20 x 100mm, som er festet til en vegg med tosidig kilsveis.
Materialfasthet f_y (σ_F) = 235N/mm^2.
Sveisemetode benyttet er manuell buesveising.



Bruddgrenselasten (F_d) er:

I) Kraften N = 150kN
(Se figur) og virker sentrisk i flattstålet.

Ia) Kontroller grunnmaterialet

Normalspenning:

$$\underline{\sigma_{opptr}} = \frac{N \cdot \gamma_f}{b \cdot t} = \frac{150 \cdot 10^3 \cdot 1{,}5}{100 \cdot 20} = \underline{112{,}5 N/mm^2}$$

Kontroll:

$$\sigma_o = \sigma_j \le f_d = \frac{f_y}{\gamma_M}$$

$$112{,}5 \le \frac{235}{1{,}1} 213{,}6 \quad \Rightarrow \text{OK!}$$

Ib) Beregn kilsveisens a-mål (etter NS, kilsveisens kapasitet - metode b)

Sveisens kapasitet pr. lengdeenhet kan beregnes uavhengig av kraftens retning i forhold til sveisens orientering.

$$F_{W,d} = f_{W,d} \cdot a \ [N/mm]$$

Sveisens dimensjonerende skjærspenning:

$$\underline{f_{W,d}} = \tau_d = \frac{f_u}{\gamma_M \sqrt{3}} \frac{1}{\beta_W} = \frac{360}{1{,}25\sqrt{3}} \frac{1}{0{,}8} = \underline{207{,}8 N/mm^2}$$

$$F_{W,d} = \frac{\gamma_f \cdot F}{l_{sv}} = f_{W,d} \cdot a$$

$$\Rightarrow \underline{a} = \frac{\gamma_f \cdot F}{l_{sv} \cdot f_{W,d}} = \frac{\gamma_f \cdot F}{2 \cdot \frac{b}{\sin 30^0} \cdot f_{W,d}} = \frac{1{,}5 \cdot 150 \cdot 10^3}{2 \cdot \frac{100}{\sin 30^0} \cdot 207{,}8} = \underline{2{,}7mm}$$

Velger <u>a = 3mm</u>

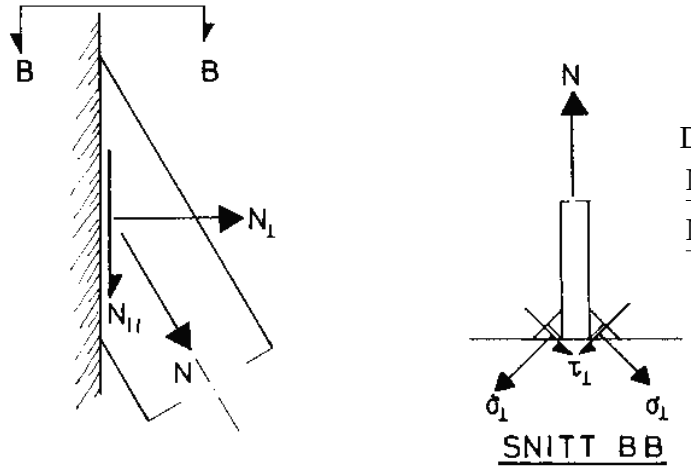
OPPGAVE 10, forts.

Ic) Kontroller sveisen(etter NS, kilsveisens kapasitet - metode a)

Antar sveisens a-mål, a=3mm

Sveisens areal:

$$\underline{A_{sveis} = 2 \cdot \left[\frac{b}{\sin 30^0} \cdot a \right] = 2 \cdot \left[\frac{100}{\sin 30^0} \cdot 3 \right] = 1200 mm^2}$$



Dekomponerer kraften N:

$$\underline{N_{\perp} = N \cdot \sin 30^0 = 150 \cdot \sin 30^0 = 75kN}$$

$$\underline{N_{||} = N \cdot \cos 30^0 = 150 \cdot \cos 30^0 = 129,9kN}$$

Spenninger normalt på sveisens lengderetning:

$$\underline{\sigma = \frac{N_{\perp} \cdot \gamma_f}{A_{sveis}} = \frac{75 \cdot 10^3 \cdot 1,5}{1200} = 93,8 N/mm^2}$$

$$\underline{\sigma_{\perp_N} = \tau_{\perp_N} = \frac{\sigma}{\sqrt{2}} = \frac{93,8}{\sqrt{2}} = 66,3 N/mm^2}$$

Skjærspenning parallelt med sveisens lengderetning:

$$\underline{\tau_{||} = \frac{N_{||} \cdot \gamma_f}{A_{sveis}} = \frac{129,9 \cdot 10^3 \cdot 1,5}{1200} = 162,4 N/mm^2}$$

Jevnførende spenning:

$$\sigma_j = \sqrt{\sigma_{\perp_N}{}^2 + 3\tau_{\perp_N}{}^2 \cdot 3\tau_{||}^2}$$

$$\underline{\sigma_j = \sqrt{66,3^2 + 3 \cdot 66,3^2 + 3 \cdot 162,4^2} = 311,0 N/mm^2}$$

Kontroll:

$$\sigma_j \le \frac{f_u}{\gamma_M \cdot \beta_W}$$

$$311,0 \le \frac{360}{1,25 \cdot 0,8} = 360,0 \quad \Rightarrow OK!$$

og

$$\sigma_{\perp} = \sigma_{\perp_N} \le \frac{f_u}{\gamma_M}$$

$$66,3 \le \frac{360}{1,25} = 288,0$$

$$66,3 \le 288,0 \quad \Rightarrow OK!$$

OPPGAVE 10, forts.

II) Kraften N_1= 75kN (Se figur) og virker i underkant av flattstålet, og a-målet er 5mm.

IIa) Kontroller grunnmaterialet

Bøyemoment p.g.a. eksentrisitet:

$$\underline{M_b} = N_1 \cdot \gamma_f \cdot \frac{b}{2} = 75 \cdot 10^3 \cdot 1{,}5 \cdot \frac{100}{2} = \underline{5{,}63 \cdot 10^6 \text{ Nmm}}$$

Maksimal spenning (normalspenning + bøyespenning):

$$\underline{\sigma_{maks.}} = \sigma_N + \sigma_b = \frac{N_1 \cdot \gamma_f}{A} + \frac{M_b}{W_x} = \frac{N_1 \cdot \gamma_f}{b \cdot t} + \frac{M_b}{\frac{t \cdot b^2}{6}}$$

$$\sigma_{maks.} = \frac{75 \cdot 10^3 \cdot 1{,}5}{20 \cdot 100} + \frac{5{,}63 \cdot 10^6}{\frac{20 \cdot 100^2}{6}} = 56{,}3 + 168{,}9 = \underline{225{,}2 \text{N/mm}^2}$$

Kontroll:

$$\sigma_{maks.} = \sigma_{opptr.} \le f_d = \frac{f_y}{\gamma_M}$$

$$225{,}2 \le \frac{235}{1{,}1} = 213{,}6 \quad \Rightarrow \text{IKKE OK!}$$

Må endre materiale eller dimensjoner.

Eksempel: Endre materiale til S275

Ny kontroll:

$$225{,}2 \le \frac{275}{1{,}1} = 250 \quad \Rightarrow \text{OK!}$$

IIb) Kontroller kilsveisen

Sveisens lengde:

$$\underline{l_{sveis}} = \frac{b}{\sin 30^0} = \frac{100}{\sin 30^0} = \underline{200\text{mm}}$$

Sveisens areal:

$$\underline{A_{sveis}} = 2 \cdot [l \cdot a] = 2 \cdot [200 \cdot 5] = \underline{2000\text{mm}^2}$$

Dekomponerer kraften N:

$$\underline{N_{1_\perp}} = N_1 \cdot \sin 30^0 = 75 \cdot \sin 30^0 = \underline{37{,}5\text{kN}}$$

$$\underline{N_{1_\parallel}} = N_1 \cdot \cos 30^0 = 75 \cdot \cos 30^0 = \underline{65{,}0\text{kN}}$$

OPPGAVE 10, forts.

Bøyemoment:

$$\underline{M_b} = N_1 \cdot \gamma_f \cdot \frac{b}{2} = 75 \cdot 10^3 \cdot 1{,}5 \cdot \frac{100}{2} = \underline{5{,}63 \cdot 10^6 \,\text{Nmm}}$$

Spenninger normalt på sveisens lengderetning:

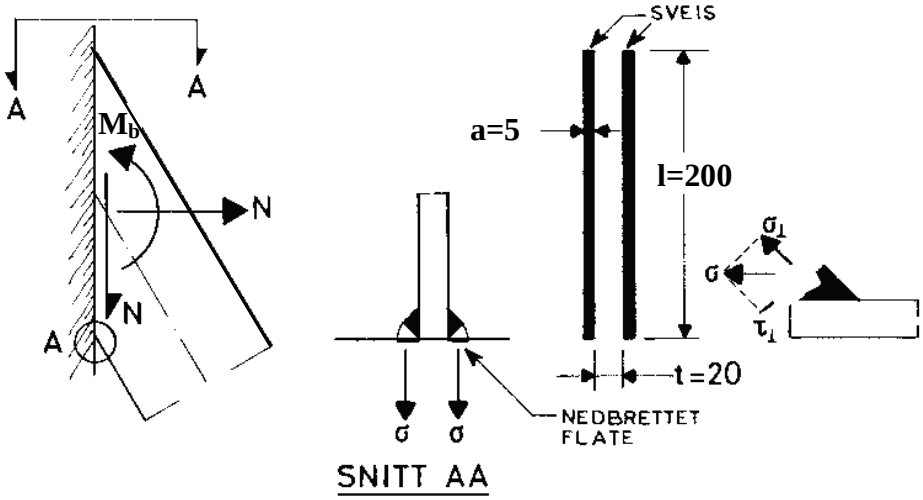
$$\underline{\sigma} = \frac{N_{1_\perp} \cdot \gamma_f}{A_{sveis}} = \frac{37{,}5 \cdot 10^3 \cdot 1{,}5}{2000} = \underline{28{,}1 \text{N/mm}^2}$$

$$\underline{\sigma_{\perp_{N_1}} = \tau_{\perp_{N_1}}} = \frac{\sigma}{\sqrt{2}} = \frac{28{,}1}{\sqrt{2}} = \underline{20{,}0 \text{N/mm}^2}$$

Skjærspenning parallelt med sveisens lengderetning:

$$\underline{\tau_{ll}} = \frac{N_{1_{ll}} \cdot \gamma_f}{A_{sveis}} = \frac{65{,}0 \cdot 10^3 \cdot 1{,}5}{2000} = \underline{48{,}8 \text{N/mm}^2}$$

For beregning av spenningene som opptrer p.g.a. bøyemomentet, M_b, tenkes sveisetverrsnittet brettet ned i det vertikale veggplanet.



SNITT AA

Treghetsmoment sveis:

$$\underline{I_{sveis}} = 2 \cdot \frac{a \cdot l^3}{12} = 2 \cdot \frac{5 \cdot 200^3}{12} = \underline{6{,}67 \cdot 10^6 \,\text{mm}^2}$$

Bøyespenning i pkt. A (i figur):

$$\underline{\sigma_b} = \frac{M_b}{I_{sveis}} \cdot \frac{l}{2} = \frac{5{,}63 \cdot 10^6}{6{,}67 \cdot 10^6} \cdot \frac{200}{2} = \underline{84{,}4 \text{N/mm}^2}$$

$$\underline{\sigma_{\perp_b} = \tau_{\perp_b}} = \frac{\sigma_b}{\sqrt{2}} = \frac{84{,}4}{\sqrt{2}} = \underline{59{,}7 \text{N/mm}^2}$$

OPPGAVE 10, forts.

Jevnførende spenning:

$$\sigma_j = \sqrt{\left(\sigma_{\perp_{N_1}} + \sigma_{\perp_b}\right)^2 + 3\left(\tau_{\perp_{N_1}} + \tau_{\perp_b}\right)^2 \cdot 3\tau_{II}^2}$$

$$\underline{\sigma_j} = \sqrt{(20{,}0 + 59{,}7)^2 + 3 \cdot (20{,}0 + 59{,}7)^2 + 3 \cdot 48{,}8^2} \underline{= 180{,}4 N/mm^2}$$

Kontroll:

$$\sigma_j \le \frac{f_u}{\gamma_M \cdot \beta_W}$$

$$180{,}4 \le \frac{360}{1{,}25 \cdot 0{,}8} = 360{,}0 \quad \Rightarrow \text{OK!}$$

og

$$\sigma_\perp = \left(\sigma_{\perp_{N_1}} + \sigma_{\perp_b}\right) \le \frac{f_u}{\gamma_M}$$

$$(20{,}0 + 59{,}7) \le \frac{360}{1{,}25}$$

$$79{,}7 \le 288{,}0 \quad \Rightarrow \text{OK!}$$