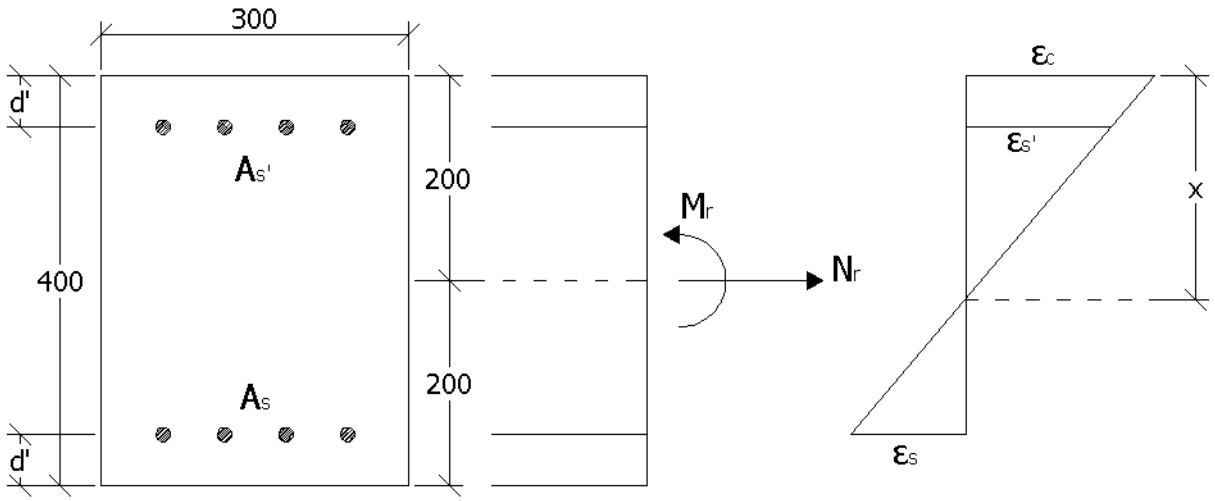
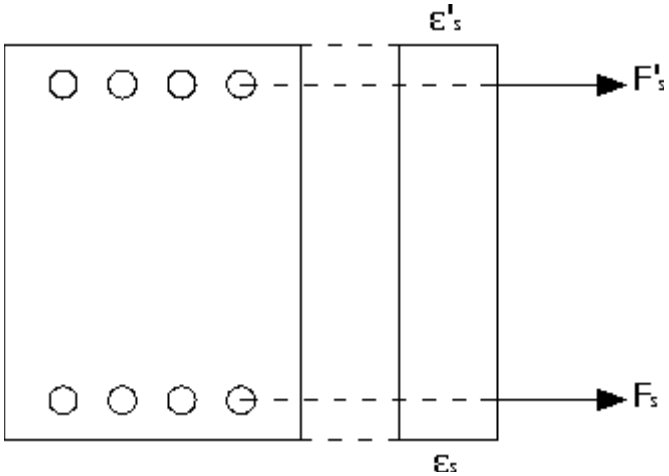


Given:

Material	C25/S420
b [mm]	300
h [mm]	400
$A_s=A'_s$ [mm^2]	$4\varphi 14 = 616$
f_{yd}	365
f_{cd}	$17\ \frac{N}{mm^2}$
d' [mm]	$h \times 10\% = 40$

a) Tension only,
($\varepsilon_s = \varepsilon'_s = \varepsilon_{su}$)



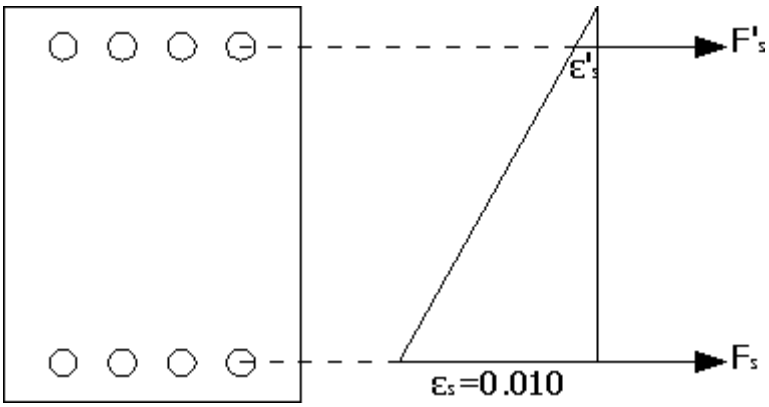
$F_s = F'_s = A_s \times f_{yd} = 616 \times 365 = 224840\ N$

$= 224.84\ kN$

N_r = -449.68 kN

M_r = 0

b) $x = 0\ (\varepsilon_c = 0, \varepsilon_s = \varepsilon_{su} = 0.010)$



$$\frac{\varepsilon'_s}{\varepsilon_s} = \frac{d'}{h-d'} = \frac{40}{400-40} = \frac{40}{360} = \frac{\varepsilon'_s}{0.010}$$

$$\varepsilon'_s = 1.111\times10^{-3}$$

$$F'_s = \varepsilon_c \times E_s \times A'_s = (1.111\times10^{-3})\times(200000)\times(616)$$

$$F'_s = 136.889\ \text{kN}$$

$$F_s = A_s \times f_{yd} = 616\times365 = 224840$$

$$F_s = 224.84\ \text{kN}$$

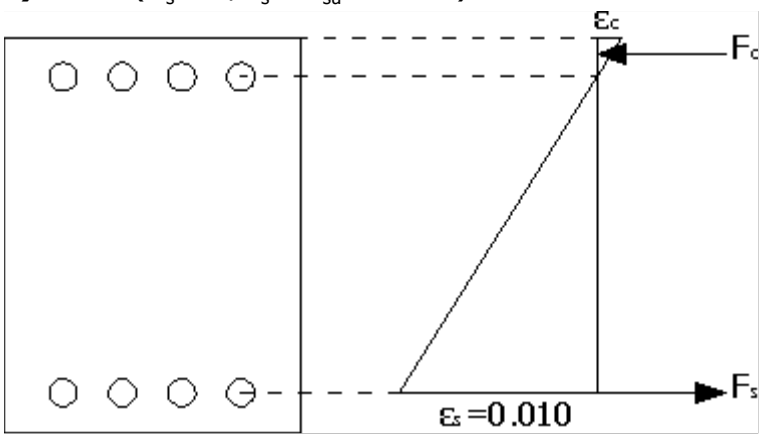
$$-N_r = F_s + F'_s$$

N_r = -361.729 kN

$$M_r = (F_s - F'_s)\left(\frac{h}{2} - d'\right) = (87.951)(160) = 14072.18\ \text{kNmm}$$

M_r = 14.072 kNm

c) $x = d'\ (\varepsilon'_s = 0, \varepsilon_s = \varepsilon_{su} = 0.010)$



$$F'_s = 0$$

$$F_c = 0.85(f_{cd})(0.85x)(b) = 0.85\times17\times0.85\times40\times300 = 147390\ \text{N}$$

$$F_c = 147.39\ \text{kN}$$

$$-N_r = F_s - F_c = 224.84 - 147.39$$

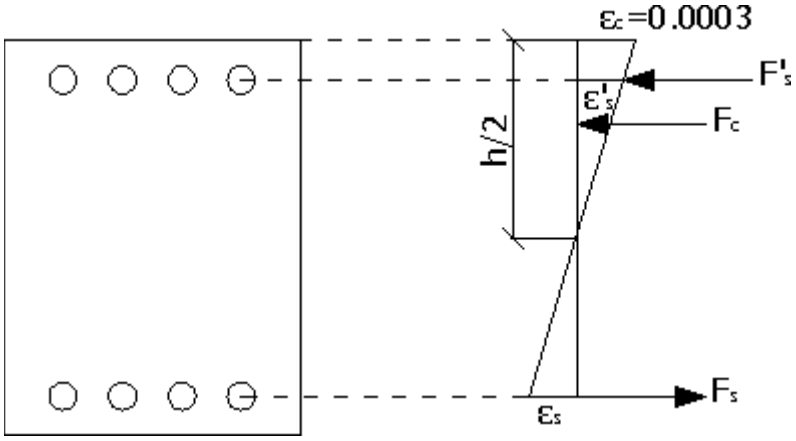
N_r = -77.45 kN

$$M_r = F_c\left(\frac{h}{2} - \frac{a}{2}\right) + F_s\left(\frac{h}{2} - d'\right)$$

$$= 147.39 \times \left(\frac{400}{2} - \frac{0.85 \times 40}{2}\right) + 224.84 \times \left(\frac{400}{2} - 40\right) = 62946.77 \text{ kNmm}$$

$M_r = 62.947$ kNm

d) $x = 0.5h$ ($\varepsilon_c = \varepsilon_{cu} = 0.0003$)



$$\frac{\varepsilon'_s}{\varepsilon_c} = \frac{x - d'}{x} \rightarrow \frac{\varepsilon'_s}{0.003} = \frac{200 - 40}{200}$$

$$\varepsilon'_c = 0.0024$$

$$\varepsilon_{yd} = \frac{f_{yd}}{E} = \frac{365}{200000} = 0.001825$$

$\varepsilon'_s > \varepsilon_{yd}$ (Yielded)

$$F'_s = A'_s \times f_{yd} = 616 \times 365 = 224840$$

$$F'_s = 224.84 \text{ kN}$$

$$F_c = 0.85(f_{cd})(0.85x)(b) = 0.85 \times 17 \times 0.85 \times 200 \times 300 = 736950 \text{ N}$$

$$F_c = 736.95 \text{ kN}$$

$$-N_r = F_s - F_c - F'_s = 224.84 - 736.95 - 224.84$$

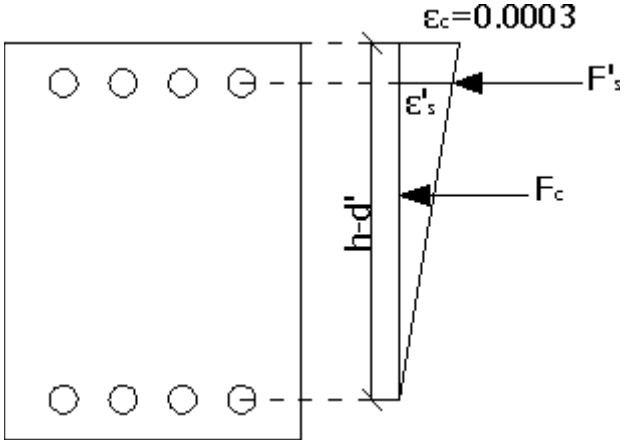
$N_r = 736.95$ kN

$$M_r = F_c\left(0.5h - \frac{a}{2}\right) + (F_s + F'_s)(0.5h - d')$$

$$= 736.95(115) + 449.68(160)$$

$M_r = 156.698$kNm

e) $x = h - d' \; (\varepsilon_c = \varepsilon_{cu} = 0.003)$



$$\frac{\varepsilon'_s}{\varepsilon_c} = \frac{x - d'}{x} \rightarrow \frac{\varepsilon'_s}{0.003} = \frac{360 - 40}{360}$$

$\varepsilon'_s = 0.002667$

$\varepsilon_{yd} = 0.001825$

$\varepsilon'_s > \varepsilon_{yd}$ (Yielded)

$F'_s = A'_s \times f_{yd} = 616 \times 365 = 224840$

$F'_s = 224.84 \text{ kN}$

$F_c = 0.85(f_{cd})(0.85x)(b) = 0.85 \times 17 \times 0.85 \times 360 \times 300 = 1326510 \text{ N}$

$F_c = 1326.51 \text{ kN}$

$F_s = 0$

$-N_r = F_s - F_c - F'_s = 0 - 1326.51 - 224.84$

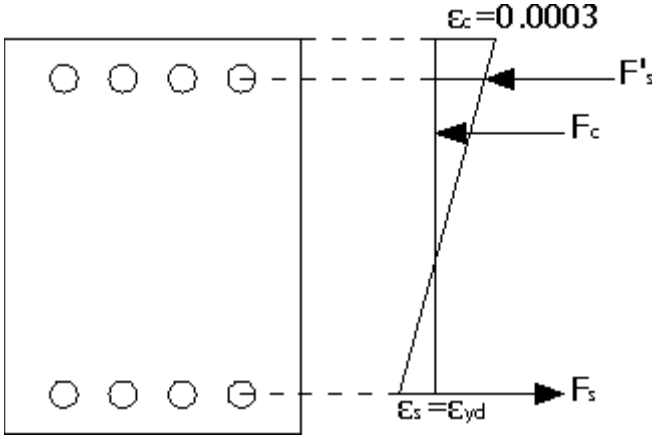
$N_r = 1551.35$ kN

$$M_r = F_c\left(0.5h - \frac{a}{2}\right) + (F'_s)(0.5h - d')$$

$= 1326.51(47) + 224.84(160)$

$M_r = 98.321$ kNm

f) $\varepsilon_c = \varepsilon_{cu} = 0.003, \; \varepsilon_s = \varepsilon_{yd} < \varepsilon_{su} = 0.010$



$$\frac{\varepsilon_c}{\varepsilon_s} = \frac{x}{h-(d'+x)} \rightarrow \frac{0.003}{0.001825} = \frac{x}{360-x}$$

$$x = 223.834$$

$$\frac{\varepsilon'_s}{\varepsilon_c} = \frac{x-d'}{x} \rightarrow \frac{\varepsilon'_s}{0.003} = \frac{223.834-40}{223.834}$$

$$\varepsilon'_s = 0.002464$$

$$\varepsilon'_s > \varepsilon_{yd} \quad \text{(Yielded)}$$

$$F'_s = A'_s \times f_{yd} = 616 \times 365 = 224840$$

$$F'_s = 224.84 \text{ kN}$$

$$F_c = 0.85(f_{cd})(0.85x)(b) = 0.85 \times 17 \times 0.85 \times 223.834 \times 300 = 824772.3 \text{ N}$$

$$F_c = 824.772 \text{ kN}$$

$$-N_r = F_s - F_c - F'_s = 224.84 - 824.772 - 224.84$$

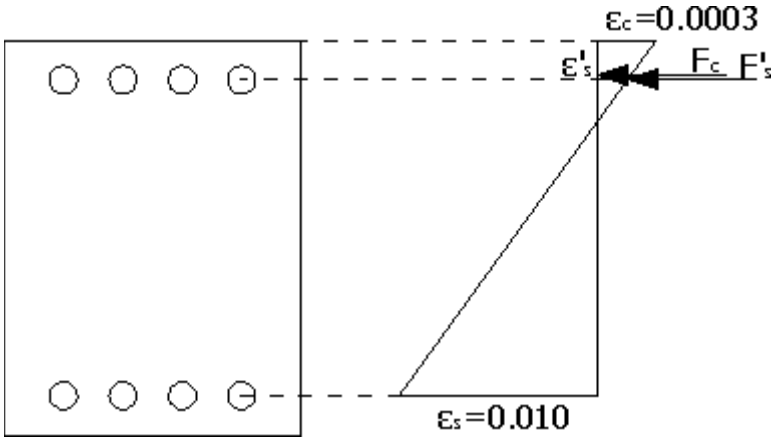
$$\mathbf{N_r = 824.772 \text{ kN}}$$

$$M_r = F_c\left(0.5h - \frac{a}{2}\right) + (F_s + F'_s)(0.5h - d')$$

$$= 824.772(104.87) + 449.68(160)$$

$$\mathbf{M_r = 158.443 \text{kNm}}$$

g) $\varepsilon_c = \varepsilon_{cu} = 0.003, \varepsilon_s = \varepsilon_{su} = 0.010$



$$\frac{\varepsilon_s}{\varepsilon_c} = \frac{360-x}{x} \rightarrow \frac{0.010}{0.003} = \frac{360-x}{x}$$

$$x = 83.077$$

$$\frac{\varepsilon'_s}{\varepsilon_c} = \frac{x-d'}{x} \rightarrow \frac{\varepsilon'_s}{0.003} = \frac{83.077-40}{83.077}$$

$$\varepsilon'_c = 0.001556$$

$$\varepsilon'_s < \varepsilon_{yd} \text{ (does not yield)}$$

$$F'_s = \varepsilon'_s \times E \times A_s$$

$$F'_s = 191.699 \text{ kN}$$

$$F_c = 0.85(f_{cd})(0.85x)(b) = 0.85 \times 17 \times 0.85 \times 83.077 \times 300 = 306117.98 \text{ N}$$

$$F_c = 306.118 \text{ kN}$$

$$-N_r = F_s - F'_s - F_c = 224.84 - 191.699 - 306.118$$

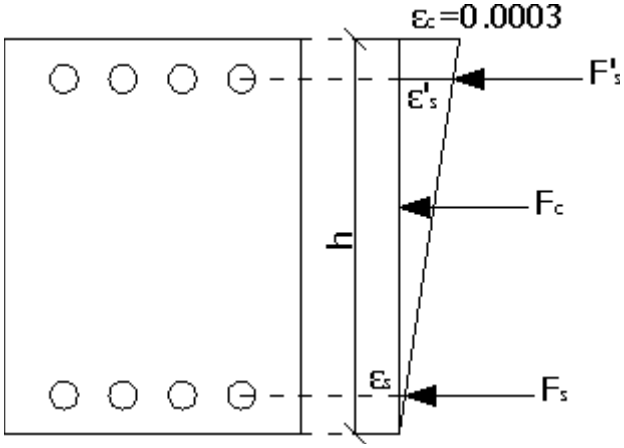
$$\mathbf{N_r = 272.977\ kN}$$

$$M_r = F_c\left(0.5h - \frac{0.85x}{2}\right) + (F_s + F'_s)(0.5h - d')$$

$$= 306.118(164.692) + 416.539(160)$$

$$\mathbf{M_r = 117.061\ kNm}$$

h) $x = h\ (\varepsilon_c = \varepsilon_{cu} = 0.003)$



$$\frac{\varepsilon'_s}{\varepsilon_c} = \frac{x - d'}{x} \rightarrow \frac{\varepsilon'_s}{0.003} = \frac{360}{400}$$

$$\varepsilon'_s = 0.0027$$

$\varepsilon'_s > \varepsilon_{yd}$ (Yielded)

$$F'_s = 224.84\ kN$$

$$\frac{\varepsilon_s}{\varepsilon_c} = \frac{d'}{x} \rightarrow \frac{\varepsilon_s}{0.003} = \frac{40}{400}$$

$$\varepsilon_s = 0.0003$$

$$F_s = \varepsilon_s \times E \times A_s = 0.0003 \times 200000 \times 616$$

$$F_s = 39.96\ kN$$

$$F_c = 0.85(f_{cd})(0.85x)(b) = 0.85 \times 17 \times 0.85 \times 400 \times 300 = 1473900\ N$$

$$F_c = 1473.9\ kN$$

$$-N_r = -F_s - F'_s - F_c = -39.96 - 224.84 - 1473.9$$

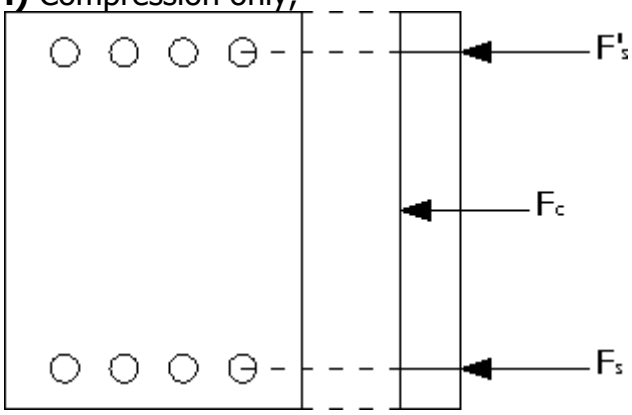
$$\mathbf{N_r = 1738.7\ kN}$$

$$M_r = F_c\left(0.5h - \frac{0.85x}{2}\right) + (F'_s - F_s)(0.5h - d')$$

$$= 1473.9(30) + 184.88(160)$$

$$\mathbf{M_r = 73.798\ kNm}$$

i) Compression only,



$\varepsilon_s = \varepsilon'_s = \varepsilon_c = \varepsilon_{su} = 0.003$

$\varepsilon_s = \varepsilon'_s > \varepsilon_{yd}$ (Yielded)

$F_s = F'_s = 224.84\ \text{kN}$

$F_c = 0.85(f_{cd})(h)(b) = 0.85 \times 17 \times 400 \times 300 = 1734000\ \text{N}$

$F_c = 1734\ \text{kN}$

$-N_r = -F_s - F'_s - F_c = -224.84 - 224.84 - 1734$

$N_r = 2183.68$ kN

$M_r = 0$ kNm