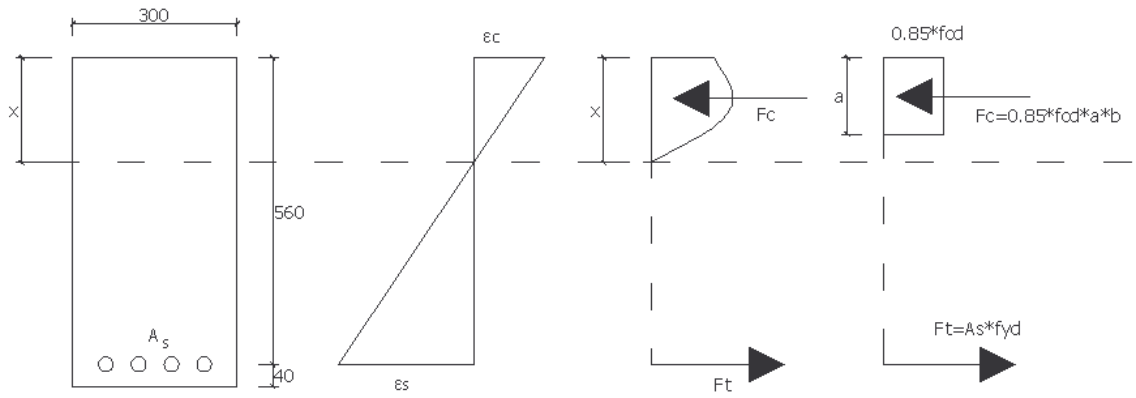

a) $\rho=\rho_{min}$

$$\rho_{min} = 0.8 \cdot \frac{f_{ctd}}{f_{yd}} = 0.8 \cdot \frac{1.00}{191} = 0.00419$$

$$\rho = \frac{A_s}{b_w \cdot d} \Rightarrow A_s = \rho \cdot b_w \cdot d = 0.00419 \cdot 300 \cdot 560 = 703.665 mm^2$$

$$A_s = 703.665 mm^2$$

$$F_c = F_t$$

$$0.85 \cdot 13 \cdot a \cdot 300 = 703.665 \cdot 191$$

$$a = 40.543 mm$$

$$M_r = M_d$$

$$F_c \cdot \left(d - \frac{a}{2} \right) = M_r$$

$$M_r = (703.665 \cdot 191) \cdot \left(560 - \frac{40.543}{2} \right)$$

$$M_r = 72539511.31 Nmm$$

$$M_r = 72.540 kNm$$

b) $\rho=\rho_b$

$$\varepsilon_{yd} = \frac{f_{yd}}{E} = \frac{191}{200000} = 0.000955$$

$$\varepsilon_{cu} = 0.003$$

$$k_{xb} = \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_{yd}} = 0.759$$

$$x = k_x \cdot d = 424.779$$

$$a = x \cdot k_1 = 361.062$$

$$F_c = F_t$$

$$F_c = 0.85 \cdot f_{cd} \cdot b \cdot k_1 \cdot k_{xb} \cdot d$$

$$F_t = \rho_b \cdot b \cdot d \cdot f_{yd}$$

$$\rho_b = \frac{0.85 \cdot f_{cd} \cdot b \cdot k_1 \cdot k_{xb} \cdot d}{b \cdot d \cdot f_{yd}} = \frac{0.85 \cdot f_{cd} \cdot k_1 \cdot k_{xb}}{f_{yd}} = 0.0373$$

$$\rho = \frac{A_s}{b \cdot d} \Rightarrow A_s = \rho \cdot b \cdot d = 0.0373 \cdot 300 \cdot 560 = 6266.599 mm^2$$

$$A_s = 6266.599 mm^2$$

$$F_c \cdot \left(d - \frac{a}{2} \right) = M_r$$

$$M_r = \left(6266.599 \cdot 191 \right) \cdot \left(560 - \frac{361.062}{2} \right) = 454194202 Nmm$$

$$M_r = 454.194 kNm$$

c) $\rho = \rho_{max} = 0.85\rho_b$

$$\rho_b = 0.0373$$

$$\rho = \rho_{max} = 0.85\rho_b = 0.85 \cdot 0.0373 = 0.0317$$

$$\rho = \frac{A_s}{b_w \cdot d} \Rightarrow A_s = \rho \cdot b_w \cdot d = 0.0317 \cdot 300 \cdot 560 = 5326.609 mm^2$$

$$A_s = 5326.609 mm^2$$

$$F_c = F_t$$

$$0.85 \cdot 13 \cdot a \cdot 300 = 5326.609 \cdot 191$$

$$a = 306.903 mm$$

$$M_r = M_d$$

$$F_c \cdot \left(d - \frac{a}{2} \right) = M_r$$

$$M_r = \left(5326.609 \cdot 191 \right) \cdot \left(560 - \frac{306.903}{2} \right)$$

$$M_r = 413615423.9 Nmm$$

$$M_r = 413.615 kNm$$

d) $\rho = \frac{\rho_{min} + \rho_{max}}{2}$

$$\rho = \frac{0.00419 + 0.0317}{2} = 0.01795$$

$$\rho = \frac{A_s}{b_w \cdot d} \Rightarrow A_s = \rho \cdot b_w \cdot d = 0.017945 \cdot 300 \cdot 560 = 3014.76 mm^2$$

$$A_s = 3014.76 mm^2$$

$$F_c = F_t$$
$$0.85 \cdot 13 \cdot a \cdot 300 = 3014.76 \cdot 191$$
$$a = 173.701\text{mm}$$
$$M_r = M_d$$
$$F_c \cdot \left(d - \frac{a}{2} \right) = M_r$$
$$M_r = \left(3014.76 \cdot 191\right) \cdot \left(560 - \frac{173.701}{2} \right)$$
$$M_r = 272448517.7\text{Nmm}$$
$$M_r = 272.449\text{kNm}$$

e) $\rho = \rho_1 = \dfrac{0.235 \cdot f_{cd}}{f_{yd}}$

$$\rho = \frac{0.235 \cdot 13}{191} = 0{,}015995$$
$$\rho = \frac{A_s}{b_w \cdot d} \Rightarrow A_s = \rho \cdot b_w \cdot d = 0{,}015995 \cdot 300 \cdot 560 = 2687.120\text{mm}^2$$
$$A_s = 2687.120\text{mm}^2$$

$$F_c = F_t$$
$$0.85 \cdot 13 \cdot a \cdot 300 = 2687.120 \cdot 191$$
$$a = 154.824\text{mm}$$
$$M_r = M_d$$
$$F_c \cdot \left(d - \frac{a}{2} \right) = M_r$$
$$M_r = \left(2687.120 \cdot 191\right) \cdot \left(560 - \frac{154.824}{2} \right)$$
$$M_r = 247683585.9\text{Nmm}$$
$$M_r = 247.684\text{kNm}$$

f) $\varepsilon_c = \varepsilon_{cu} = 0.003$, $\varepsilon_s = 0.003$

$$k_{xb} = \frac{\varepsilon_c}{\varepsilon_c + \varepsilon_s} = 0.5$$
$$x = k_{xb} \cdot d = 280$$
$$a = x \cdot k_1 = 238$$
$$F_c = 0.85 \cdot f_{cd} \cdot b \cdot k_1 \cdot k_{xb} \cdot d$$
$$F_c = 0.85 \cdot 13 \cdot 300 \cdot 0.85 \cdot 0.5 \cdot 560 = 788970$$

$$F_c \cdot \left(d - \frac{a}{2} \right) = M_r$$

$$M_r = 788970 \cdot \left(560 - \frac{238}{2} \right) = 347935770\text{Nmm}$$

$$M_r = 347.936\text{kNm}$$

$$F_t = A_s \cdot f_{yd}$$

$$F_c = F_t$$

$$A_s = \frac{F_c}{f_{yd}} = \frac{788970}{191} = 4130.733\text{mm}^2$$

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

$$k_{xb} = \frac{\varepsilon_c}{\varepsilon_c + \varepsilon_s} = 0.2308$$

$$x = k_{xb} \cdot d = 129.231$$

$$a = x \cdot k_1 = 109.846$$

$$F_c = 0.85 \cdot f_{cd} \cdot b \cdot k_1 \cdot k_{xb} \cdot d$$

$$F_c = 0.85 \cdot 13 \cdot 300 \cdot 0.85 \cdot 0.2308 \cdot 560 = 364140$$

$$F_c \cdot \left(d - \frac{a}{2} \right) = M_r$$

$$M_r = 364140 \cdot \left(560 - \frac{109.846}{2} \right) = 183918710.8\text{Nmm}$$

$$M_r = 183.919\text{kNm}$$

$$F_t = A_s \cdot f_{yd}$$

$$F_c = F_t$$

$$A_s = \frac{F_c}{f_{yd}} = \frac{364140}{191} = 1906.492\text{mm}^2$$

Given:

Property	Unit	C20/S220
b	mm	300
d	mm	560
d'	mm	40
f_{cd}	N/mm^2	13
f_{ctd}	N/mm^2	1.00
f_{yd}	N/mm^2	191