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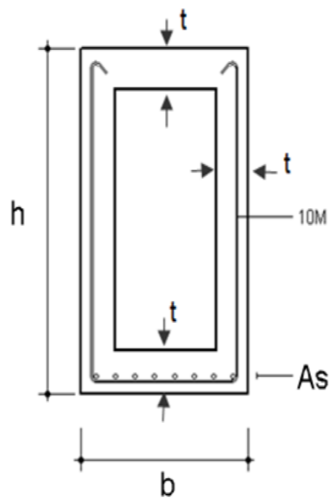
CVG 3148 – REINFORCED CONCRETE DESIGN 2022
ASSIGNMENT #3

Problem #1



NOTE:

- Use: **f'c = 30 MPa**, **fy = 400 MPa**
- Steel reinforcement: **As = 10-20M bars**
- Beam properties: **b = 400 mm**, **h = 800 mm**
- Clear cover = **40 mm** (bottom, top and side cover), **10M stirrups**
- Maximum aggregate size **(a_{max})= 20mm**, interior exposure **(not exposed)**

Givens

f_c'	30 MPa
f_y'	400 MPa
a_{max}	20 mm
A_s	10-20M
$Cover$	40 mm
b	400 mm
h	800 mm
t	100 mm Sides, 200 mm for top and bottom

Part a)

Step 1)

Determine the effective distance of the Steel.

$$d = 740mm$$

Step 2)

Determine the parameters of the concrete compression block

$$\alpha 1 = 0.81$$

$$\beta 1 = 0.90$$

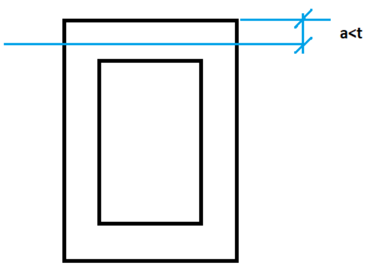
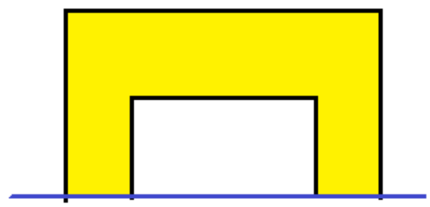
Step 3)

Determine the Area of Concrete Compression for the Steel Rebar.

$$A_{conc,comp} = 67591 mm^2$$

Step 4)

Determine whether rectangular analysis governs.

check if $a_{conc} < t_{top}$ governs	check if $a_{con} > t_{top}$ governs
 $A_{conc,comp} = 400 * a$ $a = 169 < 200\ o.k$ $\bar{a} = \frac{169}{2} = 84.5$	 $A_{conc,comp} = 400 * 200 + 2 * 100 * (a - 100)$ A=38<200 does not make sense

Step 5)

Determine distance between centroid of force blocks.

$$Z = d - \bar{a}$$

$$= 655.5 mm$$

Step 6)

Determine the Moment resistance (concrete or Steel)

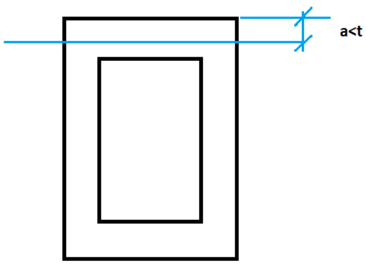
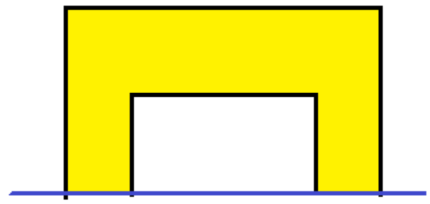
$$Mr = \emptyset_s . A_s . f_y . z$$

$$= 699.8\ kN.m$$

Part b)

<u>Step 1)</u>

Determine whether rectangular analysis governs.

check if $a_{conc} < t_{top}$ governs	check if $a_{con} > t_{top}$ governs
 $A_{conc,comp} = 400 * a$ $a = 169 > 100\ NO$	 $A_{conc,comp} = 400 * 100 + 2 * 100 * (a - 100)$ $a = 238 > 100$ OK $\bar{a} = 78.2mm$

<u>Step 2)</u>

Determine distance between centroid of force blocks.

$$Z = d - \bar{a}$$
$$= 661.8mm$$

<u>Step 3)</u>

Determine the Moment resistance (concrete or Steel)

$$Mr = \emptyset_s . A_s . f_y . z$$
$$= 706.5\ kN.m$$

Part c)

<u>Step 1)</u>

Check Yielding for Beam a:

$$\left(\frac{c}{d}\right) < \left(\frac{c}{d}\right)_{max}$$

$$0.25 < 0.64\ OK$$

Check Yielding for Beam b:

$$\left(\frac{\boldsymbol{c}}{\boldsymbol{d}}\right) < \left(\frac{\boldsymbol{c}}{\boldsymbol{d}}\right)_{\boldsymbol{max}}$$

$$0.36 < 0.64\ OK$$

Part d)

Step 1)

Check Steel Minimum and Spacing requirements Check $\boldsymbol{A_s} \geq\ \boldsymbol{A_{s_{min}}}$

$$A_{s_{min}} = \frac{0.2\sqrt{f'c}}{f_y}b\text{h}$$

$$= 876.4\ mm^2$$

$$A_s \geq\ A_{s_{min}}\ ,\ 3140 > 876.4\ \text{mm}^2\ OK$$

Step 2)

Check Spacing and Cover Requirements

$$spacing = \frac{b - 2(clear\ cover) - 2(d_{stirrup)} - n(d_{bar})}{n_{bars} - 1}$$

$$s_{min} \geq \max(1.4\ d_{bar}\ , 1.4\ \text{d}_{\text{agg}}, 30\text{mm})$$

$$= \max(28\text{mm}, 28\text{mm}, \mathbf{30mm})$$

$$s = 11.1 < 30\text{mm} \rightarrow \mathbf{NOT\ OK}$$

Step 3)

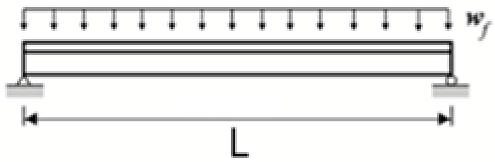
Check crack control

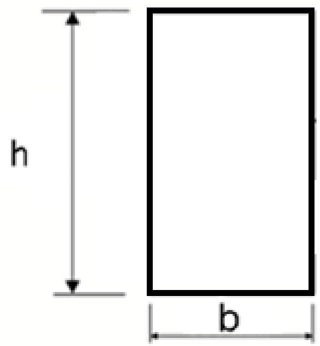
z = $f_s(d_c xA)^{1/3}$ = $240x(60x4800)^{1/3}$

=15849 N/mm < 30000 N/mm (interior exposure)

OK for interior exposure

Problem #2





NOTE:

- Beam dimensions are fixed: **b = 350 mm, h = 700 mm**
- Beam span, **L = 6 m**
- Use: **f'c = 30 MPa**, **20M bars** and **10M** stirrups
- Density of concrete for self-weight calculation: 24 KN/m^3
- Clear cover = 30 mm (bottom and side cover)
- Maximum aggregate size (a_{max})= 20mm
- Start by trying 1 layer (row) of rebar, if it does not work try 2 layers

Part a)

Step 1)

$$SW(Self - Weight) = 5.88\frac{kN}{m}$$

$$DL = 13.88\frac{kN}{m}$$

$$Wf = 84.85\frac{kN}{m}$$

$$Mf = 381.8\,kN.m$$

$$Mf = Mr$$

Step 2)

Determine the parameters of the concrete compression block

$$\alpha 1 = 0.81$$

$$\beta 1 = 0.90$$

Step 3)

Determine estimated depth for 1 Layer of Reinforcement

$$d_a = h - 70mm$$
$$= 630mm$$

OR

$$d_b = h - cover - d_{tie} - \frac{d_{rebar}}{2}$$
$$= 650mm$$

Step 4)
1st iteration

Estimate a;

$$a = 0.3 * d_a$$
$$= \ 189\ mm\ (195mm)$$

Determine A_s based on M_r;

$$M_r = \ \emptyset_s * A_s * f_y * \left(d - \frac{a}{2}\right)$$
$$A_{s1} = \frac{M_r}{\emptyset_s * f_y * \left(d - \frac{a}{2}\right)}$$
$$= 2097\ mm^2\ (2032.5\ mm^2)$$

Determine revised a;

$$a_1 = \frac{\emptyset_s . A_s . f_y}{\alpha 1 . \emptyset_c . f_c . b}$$
$$= 129mm$$
$$a_1 > 5\%\ difference$$

Step 5)
2nd Iteration 568.95

$$a_1 = 129mm$$
$$A_{s2} = 1985.7mm^2$$
$$a_2 = 122.1mm$$
$$a_2 > 5\%\ difference$$

Step 6)
3rd Iteration

$$a_2 = 122.1mm$$

$$A_{s2} = 1973.7mm^2$$

$$a_3 = 121.4mm$$

$$a_3 < 5\% \ difference! \ OK$$

Step 7)

Design

$$d_{bar} = 20mm, a_{bar} = 320mm^2, cover = 30mm$$

$$\#bar = A_{s2}/a_{bar}$$

$$= 6,17 \ bars$$

$$= round \ to \ 7 \ bars$$

$$a_{revised} = \frac{\emptyset_s.A_s.f_y}{\alpha 1.\emptyset_c.f_c.b}$$

$$= 137.77mm$$

$$M_r = \emptyset_s.A_s.f_y.\left(d - \frac{a_{revised}}{2}\right)$$

$$= 427.35 \ KN * m > M_f, O.K$$

Step 8)

Check Steel Minimum and Spacing requirements Check $\boldsymbol{A_s} \geq \boldsymbol{A_{s_{min}}}$

$$A_{s_{min}} = \frac{0.2\sqrt{f'c}}{f_y}b\text{h}$$

$$= 670.96 \text{ mm}^2$$

$$A_s \geq A_{s_{min}}, \ 2240 > 670.96 \text{ mm}^2 \ OK$$

Step 9)

Check Spacing and Cover Requirements

$$spacing = \frac{b - 2(clear\ cover) - 2(d_{stirrup)} - n(d_{bar})}{n_{bars} - 1}$$

$$s_{min} \geq \max(1.4\ d_{bar}, 1.4\ \text{d}_{\text{agg}}, 30\text{mm})$$

$$= \max(28\text{mm}, 28\text{mm}, \mathbf{30mm})$$

$$s = 21.67 > 30\text{mm} \rightarrow \textbf{NOT OK}$$

Bars are placed in two layers as $5 + 2$ (total 7)or as $4 + 4$(total 8)

Step 10)

Check for steel yielding

$$\left(\frac{\boldsymbol{c}}{\boldsymbol{d}}\right) < \left(\frac{\boldsymbol{c}}{\boldsymbol{d}}\right)_{\boldsymbol{max}}$$

$$0.24 < 0.64 \text{ OK}$$

Part b)

Step 1)

Setup Quadratic

$$0 = \left[\frac{\emptyset_s {f_y}^2}{2 * \alpha_1 * \emptyset_c * f_c * b}\right] * A_s^2 - [\emptyset_s * f_y * d] * A_s + M_r$$

$$A = 10.46$$

$$B = -214200$$

$$C = M_r$$

$$= 381.8\, Kn * m * (1e6)$$

$$A_s = 1972.4mm^2$$

$$d_{bar} = 20mm, a_{bar} = 320mm^2, cover = 30mm$$

$$\#bar = 6{,}16\ bars$$

$$= round\ to\ 7\ bars$$

Part c)

Step 1)

$$M_r = K_r * b * d^2$$

$$K_r = 2.75\ MPa$$

Check Table Table 2-1 @ f_c= 30 MPa

K_r= 2.7 MPa ➔ **$\boldsymbol{\rho}$= 0.88 %**

K_r= 2.8 MPa➔ **$\boldsymbol{\rho}$ = 0.91 %**

Interpolation ➔ $\boldsymbol{\rho} = \frac{(0.91\% - 0.88\%)}{(2.8-2.7)} * (2.75 - 2.7) + 0.88\% = 0.895\%$

$$A_s = \boldsymbol{\rho * b * d = 1973.5}\, mm^2$$

$$\#bar = 6.17$$

$$= round\ to\ 7\ bars$$

No need to check spacing and minimum reinforcement. Same # of bars.