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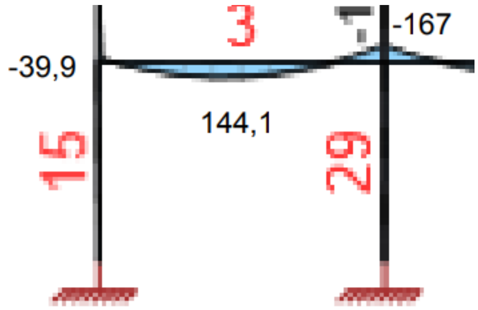
# 3rd TASK: DESING OF REINFORCEMENT




## 1. Reduction of the maximum values in the supports.

$$|M_{Ed,red}| = |M_{Ed,FEM}| - |V_{Ed,FEM}| \cdot \frac{b_{sup}}{2}$$

OUTER SUPPORT: $M_{Ed,FEM} = -39'9$ KN·m

$V_{Ed,FEM} = 147'6$ KN

$b_{sup} = 250$ mm $= 0'25$ m

$b_{sup}$ = width of the column

$$|M_{Ed,RED}| = 39'9 - 147'6 \cdot \frac{0'25}{2}$$

$$|M_{Ed,RED}|_{OUT} = 21'45 \text{ KN·m}$$

INNER SUPPORT: $M_{Ed,FEM} = -167$ KN·m

$V_{Ed,FEM} = 188'8$ KN

$$|M_{Ed,RED}|_{IN} = 167 - 188'8 \cdot \frac{0'25}{2}$$

$$|M_{Ed,red}|_{IN} = 143'4 \text{ KN·m}$$

$f_{yd} = 434'78$ MPa (from a B500)

MPa $\times 10^{3}$ = KN/mm²

## 2. DESING OF REINFORCEMENT

From task 1, the measures of my beam were:

$h_B = 600$ mm

$b_B = 400$ mm

And, $c = 20$ mm

I will suppose bars of 20 mm ⇒ $\varnothing = 20$ mm

$\varnothing_{sw}$ = stirrups = 10 mm

$$A_{s,rqd} = \frac{M_{Ed}}{0'9 \cdot d_B \cdot f_{yd}} \quad ; \quad d_B = h_B - \frac{\varnothing}{2} - \varnothing_{sw} - c$$

$$d_B = 600 - \frac{20}{2} - 10 - 20$$

$$d_B = 560 \text{ mm}$$

$$f_{yd} = 434'78e^{-3} \text{ KN/mm}^2.$$

## 2.1. OUTTER SUPPORT

$$A_{s,rqd} = \frac{21'45}{0'9 \cdot 0'56 \cdot 434'78 e^{-3}}$$

$$A_{s,rqd} = 97'88 \ mm^2$$

So with 2 bars of 8 mm → $A_{s,prov} = 101 \ mm^2$

DESING: $2 \times \phi 8$ ( $A_{s,prov} = 101 \ mm^2$ )

## 2.2. INNER SUPPORT

$$A_{s,rqd} = \frac{143'4}{0'9 \cdot 0'56 \cdot 434'78 e^{-3}}$$

$$A_{s,rqd} = 654'4 \ mm^2$$

DESING: $6 \times \phi 12$ ( $A_{s,prov} = 678'6 \ mm^2$ )

## 2.3. MIDSPAN

$$A_{s,rqd} = \frac{144'1}{0'9 \cdot 0'56 \cdot 434'78 e^{-3}} =$$

$$A_{s,rqd} = 657'6 \ mm^2$$

DESING: $6 \times \phi 12$ ( $A_{s,prov} = 678'6 \ mm^2$ )

# 3. Check of the desing

$$x = \frac{A_{s,prov} \cdot f_{yd}}{0'8 \cdot b \cdot f_{cd}} \ ; \quad z = d_B - 0'4 \cdot x \ ; \quad M_{Rd} = A_{s,prov} \cdot f_{yd} \cdot z \geq M_{Ed}$$

$f_{cd} = 16'67$ MPa

( C25/30 )

In supports $b = b_B$

$b_B = 400$ mm

In midspan $b = b_{eff}$

## 3.1. OUTTER SUPPORT

$$x = \frac{101 \ (mm^2) \cdot 434'78 \ (MPa)}{0'8 \cdot 400 \ (mm) \cdot 16'67 \ (MPa)} = 8'23 \ mm$$

$$z = 560 - 0'4 \cdot 8'23 = 556'7 \ mm$$

$$M_{Rd} = 101 e^{-6} (m^2) \cdot 434'78 e^{3} \ (KN/m^2) \cdot 0'5567 \ (m)$$

$$M_{Rd} = 24'45 \ KN \cdot m > M_{Ed,red} = 21'45 \ KN \cdot m$$ ✓

### 3.2. INNER SUPPORT

$$x = \frac{678'6 \cdot 434'78}{0'8 \cdot 400 \cdot 16'67} = 55'31 \text{ mm}$$

$$z = 560 - 0'4 \cdot 55'31 = 537'87 \text{ mm}$$

$$M_{Rd} = 678'6\, e^{-6} \cdot 434'78\, e^{3} \cdot 0'53787 = 158'7 \text{ KN}\cdot\text{m}$$

$$M_{Rd} = 158'7 \text{ KN}\cdot\text{m} > M_{Ed,RED} = 143'4 \text{ KN}\cdot\text{m} \quad ✓$$

### 3.3. MIDSPAN

#### 3.3.1. EFFECTIVE WIDTH. $b_{EFF}$

$$b_{eff} = \sum b_{eff,i} + b_B \le b \quad ; \quad b_{eff,i} = 0'2 b_i + 0'1 \cdot l_0$$

$l_B$ = span of the beam

$l_B = 5'6$ m

$$l_0 = 0'85\, l_B$$

$$l_0 \simeq 4'76 \text{ m}$$

$$b_1 = b_2 = l_B - b_B = 5600 - 400 = 5200 \text{ mm}$$

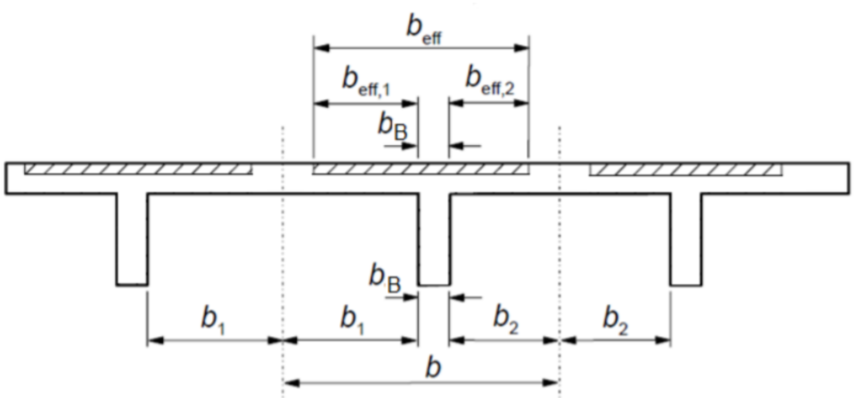
$$b_{eff,1} = b_{eff,2} = 0'2 \cdot 5'2 + 0'1 \cdot 4'76 = 1'516 \text{ m}$$

$$b_{eff,i} \le 0'2 \cdot l_0$$

$$0'2 \cdot 4'76 = 0'952 \not\ge b_{eff,1} = b_{eff,2} = 1'596 \text{ m}$$

So, $b_{eff,1} = b_{eff,2} = 0'952$ m

$$\rightarrow b_{eff} = 0'952 + 0'952 + 0'4 = 2'3 \text{ m}$$




$$x = \frac{678'6 \cdot 434'78}{0'8 \cdot 2300 \cdot 16'67} = 9'62 \text{ mm}$$

$$z = 560 - 0'4 \cdot 9'62 = 556'152 \text{ mm}$$

$$M_{Rd} = 678'6\, e^{-6} \cdot 434'78\, e^{3} \cdot 0'556152 = 164 \text{ KN}\cdot\text{m}$$

$$M_{Rd} = 164 \text{ KN}\cdot\text{m} > M_{Ed,FEM} = 144'1 \text{ KN}\cdot\text{m} \quad ✓$$

# 4. DETAILING RULES

1: $\xi = \frac{x}{d_B} \leq \min\left(\xi_{bal,1} = \frac{700}{700 + f_{yd}}\ ;\ 0'45\right)$

2. $A_{s,prov} \geq A_{s,min} = \max\left(0'26\ \frac{f_{ctm}}{f_{yk}}\ b_B d_B\ ;\ 0'0013 b_B d_B\right)$

3. $A_{s,prov} \leq A_{s,max} = 0'04\ b_B d_B$

4. $S_a \leq S_{a,max} = \min(2h_B\ ;\ 250\ mm)$

5. $S_c \geq S_{c,min} = \max(20\ mm,\ 1'2\ \emptyset)$

## 4.1. OUTTER SUPPORT

$f_{ctm} = 2'6\ MPa$
( C 25/30 )
$f_{yk} = 500 MPa$

1. $\xi = \frac{8'23}{560} = 0'014 \leq 0'45$ ✓

2. $A_{s,min} = \max\left(0'26 \cdot \frac{2'6}{500} \cdot 400 \cdot 560\ ;\ 0'0013 \cdot 400 \cdot 560\right)$

$A_{s,min} = \max(302'85\ ;\ 291'2)\ mm^2$

$A_{s,prov} = 101\ mm^2 \ngeq A_{s,min} = 302'85\ mm^2$

So the DESING would change. If it is needed
$A = 302'85\ mm^2$

DESING: $2 \times \emptyset 14$ ( $A_{s,prov} = 307'8\ mm^2$ )

And now, $A_{s,prov} = 307'8\ mm^2 \geq A_{s,min} = 302'85\ mm^2$ ✓

3. $A_{s,max} = 0'04 \cdot 400 \cdot 560 = 8960\ mm^2$

$A_{s,prov} = 307'8\ mm^2 \leq A_{s,max} = 8960\ mm^2$ ✓

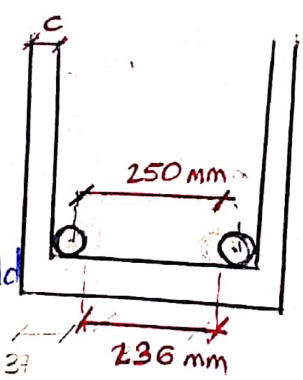
4. 4.11. $S_a = \frac{b_B - 2c - 2\emptyset_{sti}}{n-1}$

$S_a = \frac{400 - 2 \cdot 20 - 2 \cdot 14}{1} = 332 mm \nleq S_{a,max} = 250 mm$

So, $S_a = 250\ mm$

$S_c = 250 - 14 = 236\ mm \geq S_{c,min}$

$S_{c,min} = 20\ mm$ ✓




Now, the checking of the desing should be repeated with the new group of rebars.



Escaneado con CamScanner

$$X = \frac{307'8 \cdot 434'78}{0'8 \cdot 400 \cdot 16'67} = 25 \text{ mm}$$

$$z = 560 - 0'4 \cdot 25 = 550 \text{ mm}$$

$$M_{Rd} = 307'8\, e^{-6} \cdot 434'78\, e^{3} \cdot 0'55 = 73'6 \text{ KN·m}$$

$$M_{Rd} = 73'6 \text{ KN·m} > M_{Ed,red} = 21'45 \text{ KN·m}$$ ✓

4.2. INNER SUPPORT

1. $\xi = \frac{55'31}{560} = 0'098 \leq 0'45$ ✓

2. $A_{s,min} = 302'85 \text{ mm}^2 \leq A_{s,prov} = 678'6 \text{ mm}^2$ ✓

3. $A_{s,max} = 8960 \text{ mm}^2 \geq A_{s,prov} = 678'6 \text{ mm}^2$ ✓

4. $S_a = \frac{400 - 2 \cdot 20 - 2 \cdot 12}{6-1} \simeq 67 \text{ mm} \leq S_{a,max} = 250 \text{ mm}$ ✓

5. $S_c = 67 \text{ mm} - 12 = 55 \text{ mm} \geq S_{c,min} = 20 \text{ mm}$ ✓

4.3. MIDSPAN

1. $\xi = \frac{9'62}{560} = 0'017 < 0'45$ ✓

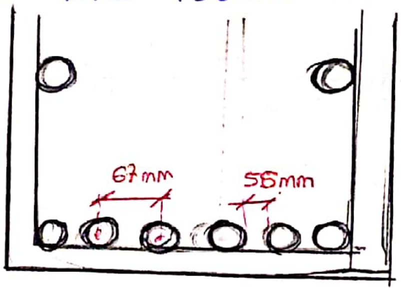
2. $A_{s,min} = 302'85 \text{ mm}^2 \leq A_{s,prov} = 678'6 \text{ mm}^2$ ✓

3. $A_{s,max} = 8960 \text{ mm}^2 \geq A_{s,prov} = 678'6 \text{ mm}^2$ ✓

4. $S_a = \frac{400 - 2 \cdot 20 - 2 \cdot 12}{6-1} = 67 \text{ mm} \leq S_{a,max} = 250 \text{ mm}$ ✓

5. $S_c = 67 - 12 = 55 \text{ mm} \geq S_{c,min} = 20 \text{ mm}$ ✓

Finally, because my $h_B > 500$ mm it is added $2 \times \varnothing 12$ rebars to the middle of the beam




2 Ø 12

6 Ø 12

# SHEAR REINFORCEMENT

1. Desing shear force

$$|V_{Ed,1}| = |V_{Ed,max,FEM}| \cdot \frac{V - \left(\frac{b_{sup}}{2} + d_B\right)}{V}$$

up to the draw: $V = 3\ m$

$b_{sup} = 400\ mm$

$d_B = 560\ mm$

so, for $V_{Ed,max,FEM} = 188'8\ KN$

$$|V_{Ed,1}| = 188'8 \cdot \frac{3 - \left(\frac{0'4}{2} + 0'56\right)}{3} = 140'9\ KN$$

2. Spacing of stirrups

Using rebars of 10 mm : $A_{sw} = \frac{n \pi \varnothing_{sw}^2}{4}$

$$A_{sw} = \frac{2 \cdot \pi \cdot 10^2}{4} = 157'1\ mm^2$$

$\cot g\theta = 1'5$

$z$ = from the bending

Then, $\Delta l = z \cdot \cot g\,\theta$

$$\Delta l = 537'87 \cdot 1'5 = 806'8\ mm$$

So, $S_1 \leq \frac{A_{sw} \cdot f_{yd}}{V_{Ed,1}} \Delta l$

$$S_1 \leq \frac{157'1\ (mm^2) \cdot 434'78 e^{3}\ (KN/mm^2)}{140'9\ (KN)} \cdot 806'8\ (mm)$$

$S_1 = 0'37 m \rightarrow S_1 = 0'3 m$

$S_1 \leq 0'75 d_B$ ; $S_1 \leq 300\ mm$ $S_1 \geq 100\ mm$

$S_1 = 300 mm \leq 0'75 \cdot 560 = 420\ mm$

CONCLUSION: Stirrup 10 mm per 300 mm

3. Check shear resistance

$$V_{Rd,sw,1} = \frac{A_{sw} \cdot f_{yd}}{S_1} \Delta l \geq V_{Ed,1}$$

$$V_{Rd,sw,1} = \frac{157'1 \cdot 434'78 e^{3}}{300} \cdot 806'8 \, e^{-6}$$

$$V_{Rd,sw,1} = 183'7 \text{ KN} \geq V_{Ed,1} = 140'9 \text{ KN}$$ ✓

4. Check shear reinforcement ratio

$$\rho_{sw,1} = \frac{A_{sw}}{b_B \cdot S_1} \geq \rho_{sw,min} = \frac{0'08 \sqrt{f_{ck}}}{f_{yk}}$$

$$\frac{157'1}{400 \cdot 400} = 0'00098 \geq \frac{0'08\sqrt{25}}{500} = 0'0008$$ ✓

$$\rho_{sw,1} \leq \rho_{sw,max} = \frac{0'5 \, \nu \, f_{cd}}{f_{yd}} = 0'5 \cdot (0'6 (1 - \frac{f_{ck}}{250})) \cdot \frac{16'67}{434'78}$$

$$\rho_{sw,max} = 0'0103 \geq \rho_{sw,1} = 0'00098$$ ✓

5. Stirrups in the middle part ($S_{max}$)

$$S_{max} \leq \min(0'75 d_B \, ; \, 400 \text{ mm})$$

$$S_{max} \leq \min(0'75 \cdot 560 \, ; \, 400) \text{ mm}$$

$$S_{max} \leq 400 \text{ mm}$$

5.1. Check shear reinforcement ratio

$$\rho_{sw,2} = \frac{A_{sw}}{b_B \cdot S_{max}} \geq \rho_{sw,min} \quad ; \quad \rho_{sw,2} \leq \rho_{sw,max}$$

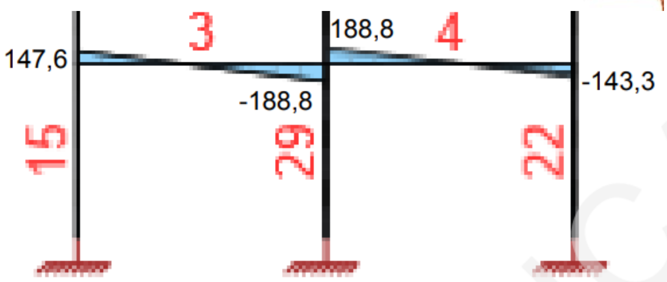
$$\frac{157'1}{400 \cdot 300} = 0'0013$$

$$0'0008 < 0'0013 < 0'0103$$ ✓

6. Shear force for which $S_{max}$ is sufficient

$$V_{Rd,mid} = \frac{A_{sw} \cdot f_{yd}}{S_{max}} \Delta l$$

$$V_{Rd,mid} = \frac{157'1 e^{-6} \cdot 434'78}{0'4} \cdot 0'8068 = 137'7 \text{ KN}$$




$y + v = l_B \;\Big|\; l_B = 5'6\,m$

$v = 3\,m$

$y = 5'6 - 3 = 2'6\,m$

$$\frac{V_{Ed,sup}}{y} = \frac{V_{Ed,max}}{v}$$

$$\frac{147'6}{2'6} = \frac{188'8}{v} \rightarrow v = 3m$$

$$V_{Rd,mid} = \frac{A_{sw} \cdot f_{yd}}{s_{max}} \cdot \Delta l$$

$$V_{Rd,mid} = \frac{157'1\,(mm^2) \cdot 434'78\,e^{-3}\,(KN/mm^2)}{400\,(mm)} \cdot 806'8\,(mm)$$

$$V_{Rd,mid} = 137'7\,KN$$

$$\frac{V_{Rd,mid}}{u} = \frac{V_{Ed,max}}{v} \rightarrow \frac{137'7}{u} = \frac{188'8}{3}$$

$u = 2'2\,m$

So the length of the area reinforced by stirrups with spacing $s_{max}$:

$w = u + \Delta l$

$w = 2'2 + 0'8068$

$w = 3\,m$