Example 2.3 [shear design, Ribbed slab]

Design the ribbed slab system in example 2 for shear using the same material properties and loading.

Solution

A. Rib shear design

Step 1. Material property

Concrete	f_{cu}=25Mpa	f_{ck}=20Mpa
	f_{cd}=11.33Mpa	f_{ctk}=1.5 Mpa
	f_{ctm}=2.2 Mpa	f_{ctd}=1.0 Mpa
Steel	f_{yk}=300 Mpa	f_{yd}=260.87Mpa
	ε_{yd}=1.3‰	E_s= 200 Gpa

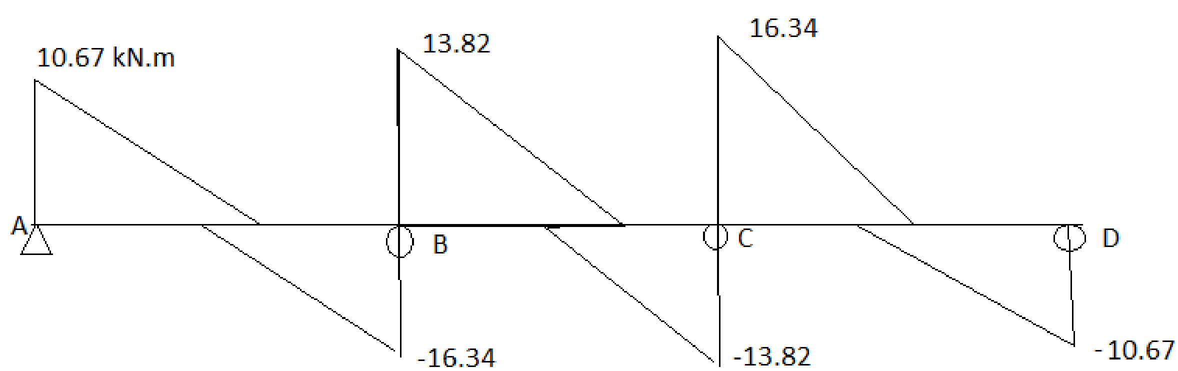
Step 2. Loading on Ribs

G_d= 4.17 KN/m

Q_d = 2.4 KN/m

Step 3. Analysis

- Shear envelope diagram



Step 4. Concrete shear capacity

$$V_{Rd,c} = \left[C_{Rd,c}.K.(100\rho_1.f_{ck})^{\frac{1}{3}} + K_1\sigma_{cp}\right]b_w.d \;>\; (V_{min} + K_1.\sigma_{cp})b_w.d$$

Where:

- $C_{Rd,c} = \frac{0.18}{\gamma_c} = \frac{0.18}{1.5} = 0.12$
- $K = 1 + \sqrt{\frac{200}{d}} \leq 2.0 \qquad d = 233$

  K=1.92

- $\rho_1 = \frac{A_s}{b_w.d} < 0.02$

$$\rho_1 = \begin{cases} \frac{226.19}{80x233} = 0.0121, & for\ sections\ with\ 2\emptyset 12 \\ \frac{157.07}{80x235} = 0.0085, & for\ sections\ with\ 2\emptyset 10 \end{cases}$$

- $f_{ck} = 20\ Mpa$
- K1= 0.15
- $\sigma_{cp} = \frac{N_{ED}}{A_c} < 0.2 f_{cd} = 0 \ldots \ldots \ldots (N_{ED} = 0)$
- $V_{min} = 0.035. K^{\frac{3}{2}}. f_{ck}^{\frac{1}{2}} = 0.416$

Therefore

$$For\ sections\ with\ 2\emptyset 12 \Longrightarrow V_{Rd,c} = 12.43\ KN > 7.75\ KN$$

$$For\ sections\ with\ 2\emptyset 10 \Longrightarrow V_{Rd,c} = 10.137\ KN > 7.75\ KN$$

Step 5: Diagonal compression check of concrete

$$V_{Rd,max} = \frac{\alpha_{cw}.b_w.Z.v.f_{cd}}{(\cot\theta + \tan\theta)}$$

$$V_{Rd,s} = \frac{A_{sw}}{S}.Z.f_{ywd}.\cot\theta$$

$$V_{Rd}(\text{minimum of}) = \begin{cases} V_{Rd,max} \\ V_{Rd,s} \end{cases}$$

where

$\alpha_{cw} = 1 \qquad recommended\ value\ for\ non-prestressed\ member$

$limit\ \theta \Longrightarrow 1 \leq \cot\theta \leq 2.5$

$Take \ldots .. \cot\theta = 2.5$

$bw = 80\ mm$

$$f_{cd} = 11.33\ Mpa$$

Z=0.9xd = 209.7

$$\Rightarrow V_{Rd,max} = \frac{1x80x209.7x0.6x11.33}{\left(2.5 + \frac{1}{2.5}\right)} = 39.325\ KN$$

Check this value with values form the shear envelop

$$\Rightarrow V_{Rd,max} > V_{ED} \ldots \ldots .\ at\ all\ locations, \qquad \boldsymbol{therefore\ Ok}!$$

Step 6. Calculate the required shear reinforcement

$$\frac{A_{sw}.f_{yd}}{b_w.S} \leq \frac{1}{2}.\alpha_c.v.f_{cd}$$

$$S_{max} = 0.75.d.(1 + \cot\alpha), \qquad \alpha = 90^0$$

$$S_{max} = 0.75\text{d}$$

$$\rho_{min} = \frac{0.08.\sqrt{f_{ck}}}{f_{yk}} = 0.00119$$

$$S = \frac{A_{sw}}{b_w.\rho_w.\sin\alpha} = \frac{2x(\emptyset 6^2\,\frac{\pi}{4})}{80x0.00119x1} = 593.99mm$$

- Check this value with S_{max}

Required: shear reinforcement

$$\frac{Asw}{S} = \frac{Ved}{0.78 * d * fyk * cot\theta} \qquad Asw = \frac{2 * \pi * 6^2}{4} = 56.54mm^2$$

$$S = \frac{Asw * 0.78 * d * fyk * cot\theta}{Ved}$$

V_{Ed}– d from the face of the columns but since the loads are small just take the values at the centre of the columns.

θ- since **$V_{Rd,max}$>V_{Ed}** lets take the conservative value

$$\theta = 22° \qquad cot\theta = 2.5$$

$$S = \frac{56.54 * 0.78 * 233 * 300 * 2.5}{Ved} = \frac{7706.68}{Ved} KNmm$$

span	Location	VEd(KN)	Scal (mm)	Sprovid
AB	near A	10.67	722	ϕ 6 C/C 175 mm
	near B	-16.34	471	ϕ 6 C/C 175 mm
BC	near B	13.825	557.44	ϕ 6 C/C 175 mm
	near C	13.825	557.44	ϕ 6 C/C 175 mm
CD	near C	16.34	471.64	ϕ 6 C/C 175 mm
	near D	10.67	722.27	ϕ 6 C/C 175 mm

S_{min} = 594 mm

S_{max} = 0.75 *d = 0.75 * 233 = 174.75 → 175mm

Provide ϕ 6 C/C 175 mm throughout

➔ Additional torsion force on the longitudinal reinforcement.

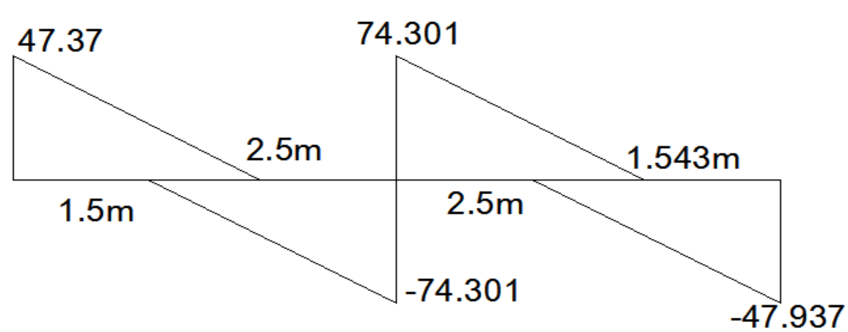
$$\Delta Ftd = 0.5 * \text{VEd} * \cot\theta \qquad \text{take VEd} = 16.34 \text{ (the largest value)}$$

$$\Delta Ftd = 0.5 * 16.34 * \cot(45) = \mathbf{20.425KN}$$

Note: this has to be added to the Flexural computation (on the tension reinforcements.)

Step 1: Shear envelope

- A and D
  - bw = 300, D= 300mm, d=259
  - ϕ8 stirrup, ϕ 16 rebar



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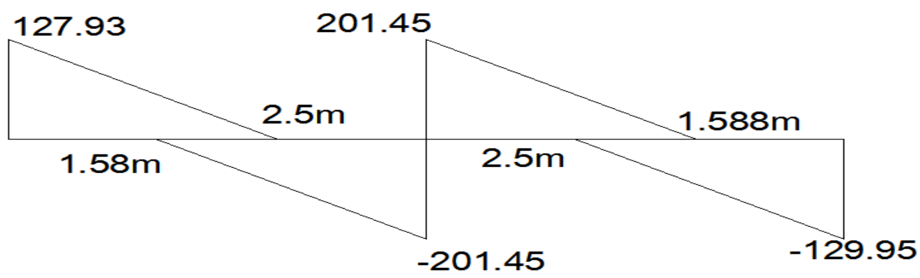
- B and C
  - b_w = 600, D= 300mm, d=257

- ϕ8 stirrup, ϕ 20 rebar



Step 2: concrete shear capacity

$$VRd,c = [CRd,c * k * \left(\log fck\right)^{\frac{1}{3}} + \mathrm{K1} * \rho\sigma\mathrm{cp}\Big] * \mathrm{bco} * \mathrm{d}$$
$$> [\mathrm{Vmin} + \mathrm{K1} * \sigma\mathrm{cp}] * \mathrm{bco} * \mathrm{d}$$

$$CRd,c = 0.12$$

$$\mathrm{K} = 1 + \sqrt{\frac{200}{d}} = 1 + \sqrt{\frac{200}{233}} \leq 2.0$$

$$K = 1.926$$

$$\rho = \frac{As}{bw * d} < 0.02$$

For A and D:

Support: 6ϕ16

$$\rho = \frac{1206.37}{300*259} = 0.0155$$

Span: 4ϕ16, $\rho = 0.01035$

For B and C:

Support: 10ϕ20 , $\rho = 0.02$

Span: 4ϕ16, $\rho = 0.0122$

$$fck = 20Mpa$$

$$\sigma cp = 0$$

$$Vmin = 0.035 * k^{\frac{3}{2}} * fck^{\frac{1}{2}} = 0.416$$

- **A and D**

- Span - $V_{RD,c}$ = 56.412 KN > 32.3 KN
- Support - $V_{RD,c}$ = 49.22 KN > 32.2 KN

- **B and C**
  - Span - $V_{RD,c}$ = 121.88 KN > 32.3 KN
  - Support - $V_{RD,c}$ = 103.36 KN > 32.3 KN

Step 3: Diagonal compression check of concrete

$$V_{Rd,max} = \frac{\alpha_{cw} * b_w * f * v * fcd}{\cot\theta + \tan\theta}$$

- **Girder A and D**
  - $\alpha_{cw} = 1$
  - $V = 0.6$
  - $b_w = 300mm$
  - $fcd = 11.33Mpa$
  - $\cot\theta = 2.5$
  - $z = 0.9 * d = 0.9 * 239 = 233.1$

    $V_{Rd\ max} = \frac{1 * 0.6 * 300 * 233.1 * 11.33}{2.5 * \frac{1}{2.5}}$

    $V_{Rd\ max} = 163.92KN$
  - $V_{Rd\ max} > V_{Rd}$…………***OK***

- **Girder A and D**
  - $\alpha_{cw} = 1$
  - $V = 0.6$
  - $b_w = 600mm$
  - $fcd = 11.33Mpa$
  - $\cot\theta = 2.5$
  - $z = 0.9 * d = 0.9 * 257 = 231.3$

    $V_{Rd\ max} = \frac{1 * 0.6 * 600 * 231.3 * 11.33}{2.5 * \frac{1}{2.5}}$

    $V_{Rd\ max} = 325.32KN$

  - $V_{Rd\ max} > V_{Rd}$…………***OK***

Step 4: Shear reinforcement required

$$\frac{A_{sw,max} * fyd}{b_w * s} < \frac{1}{2} * \alpha_c * Vyc$$

$$\frac{A_{sw}}{s} = \frac{V_{Ed}}{0.78 * 5 * fyd * \cot\theta}$$

$$A_{sw} = 2 * \frac{\pi * 8^2}{4} = 100.53$$

$$S = \frac{0.78 * d * fyk * A_{sw} * cot\theta}{Ved}$$

$$S_{max} = 0.75 * d * (1 + \cot\theta)$$

$$S_{max} = 194.25\ mm \quad for\ A\ and\ D$$

$$S_{max} = 192.74\ mm \quad for\ B\ and\ C$$

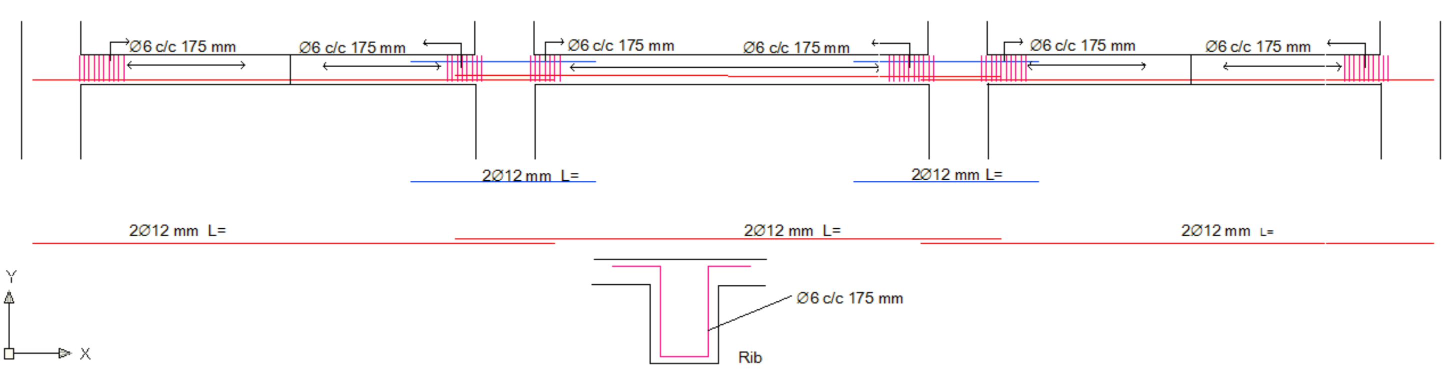
$$S_{min} = \frac{A_{sw}}{b_w * \rho_w * \sin x} = 281.59 \qquad for\ And\ D$$

$$S_{min} = 140.79\ mm \quad for\ B\ and\ C$$

Span	location	V_{Ed}(KN)	d	S_{cal} (mm)	S provided
A and D	near 1	39.67	259	767.92	ϕ 8 C/C 560 mm
	near 2	66.6	259	456.92	ϕ 8 C/C 450 mm
	near 2	66.6	259	456.92	ϕ 8 C/C 450 mm
	near 3	39.67	259	767.92	ϕ 8 C/C 560 mm
B and C	near 1	107.24	257	281.86	ϕ 8 C/C 280 mm
	near 2	180.74	257	167.24	ϕ 8 C/C 190 mm
	near 2	180.74	257	167.24	ϕ 8 C/C 190 mm
	near 3	107.24	257	281.86	ϕ 8 C/C 280 mm

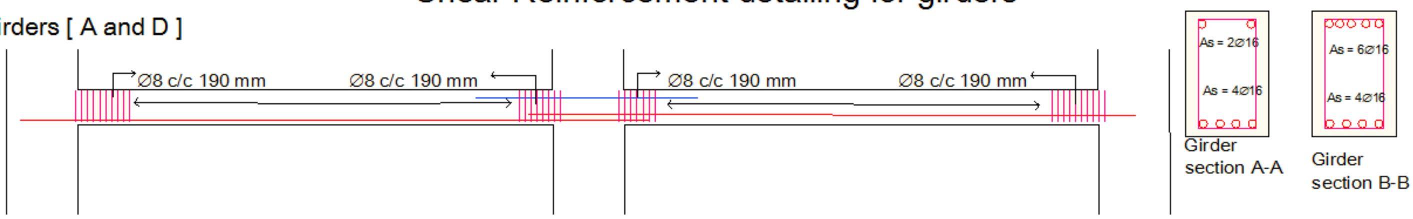
Step 7. Detailing

Shear Reinforcement detailing for Ribs

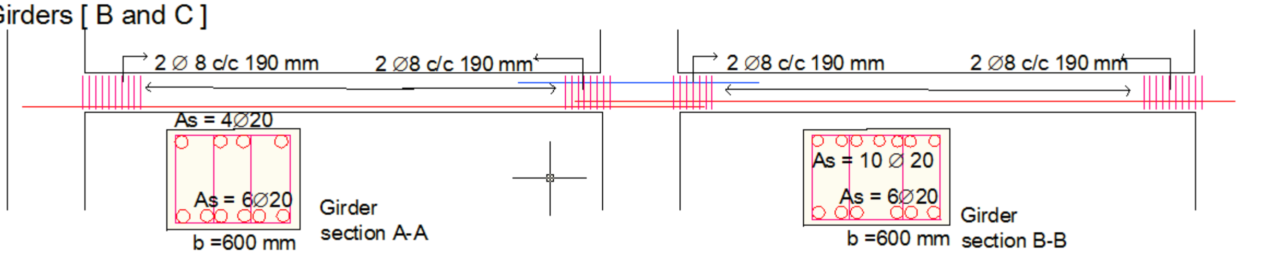


Shear Reinforcement detailing for girders

Girders [A and D]



Girders [B and C]



Shear Reinforcement detailing for Beams