EXAMPLE 1:

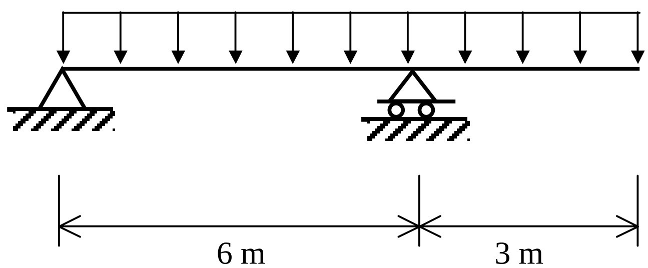
Given: The beam shown below.

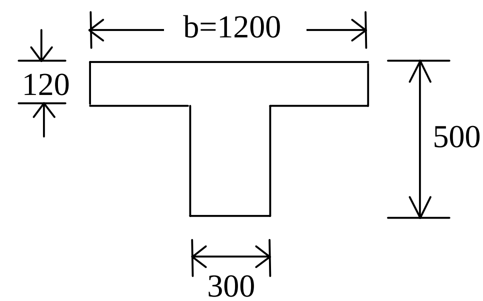
Materials: C16, S420 (f_{cd}=11 MPa, f_{ctd}=0.93 MPa, f_{yd}=365 MPa)

Stirrups S420 (f_{ywd}=365 MPa)

Cross-Section: T-Section (see the figure)

g=20 kN/m, q=20 kN/m

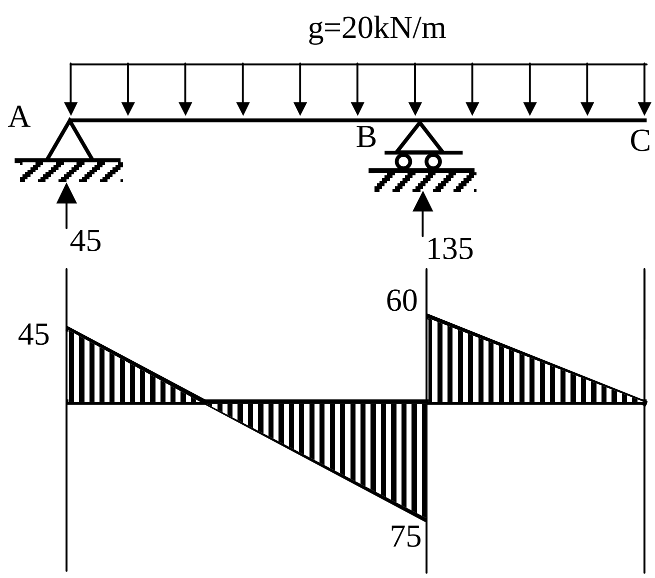




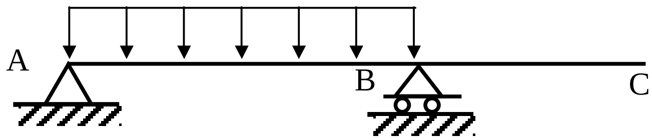
d= 465 mm

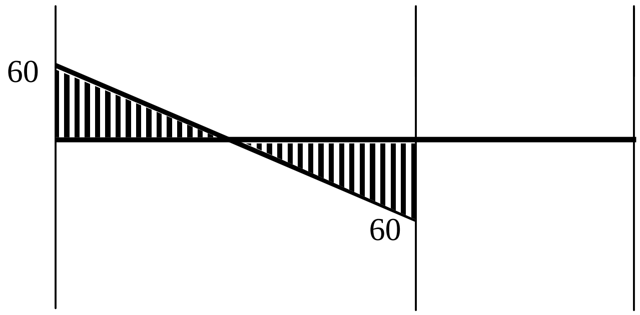
Find: Shear reinforcement.

SOLUTION:



Same moment diagram applies also for q=20kN/m





$p_d = 1.4(20) + 1.6(20) = 60\ kN/m$

Span A-B

Left support:

$V_d = 1.4(45) + 1.6(60) = 63 + 96 = 159\ kN$

At a distance "d", $V_d' = 159 - 60(0.465) = 131\ kN$

Right support:

$V_d = 1.4(75) + 1.6(75) = 225\ kN$

$V_d' = 225 - 60(0.465) = 197\ kN$

$$V_{cr} = 0.65 \times 0.93 \times 300 \times \frac{465}{1000} = 84\ kN$$

$V_c = 67\ kN$

$V_{\max} = 0.22 \times 0.011 \times 300 \times 465 = 337\ kN$

$V_{cr} < V_d' < V_{\max}$

Right support governs.

Cantilever

$V_d = 1.4(60) + 1.6(60) = 180\ kN$

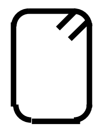
$V_d' = 180 - 60 \times 0.465 = 152\ kN \qquad V_{cr} < V_d' < V_{\max}$

$$\min \frac{A_{sw}}{s} = 0.3\frac{f_{ctd}}{f_{ywd}} \times b_w = 0.3\frac{0.93}{365} \times 300 = 0.23\, mm$$

<u>Span A-B (V_d'=197 kN)</u>

$$\frac{A_{sw}}{s} = \frac{V_d' - V_c}{f_{ywd}(d)} = \frac{(197-67)1000}{365 \times 465} = 0.766\, mm > \min \frac{A_{sw}}{s}$$

If ϕ10 is used, $A_{sw} = 2 \times 79 = 158\, mm^2$



$$s = \frac{158}{0.766} = 206\, mm \quad \max s = d/2 = 232\, mm$$

$\therefore$ Use ϕ10/200 mm

<u>Cantilever (V_d'=152 kN)</u>

$$\frac{A_{sw}}{s} = \frac{V_d' - V_c}{f_{ywd}(d)} = \frac{(152-67)1000}{365 \times 465} = 0.50\, mm > \min \frac{A_{sw}}{s}$$

If ϕ10 is used, $A_{sw} = 2 \times 79 = 158\, mm^2$

$$s = \frac{158}{0.5} = 316\, mm \quad \max s = d/2 = 232\, mm$$

$\therefore$ Use ϕ10/230 mm

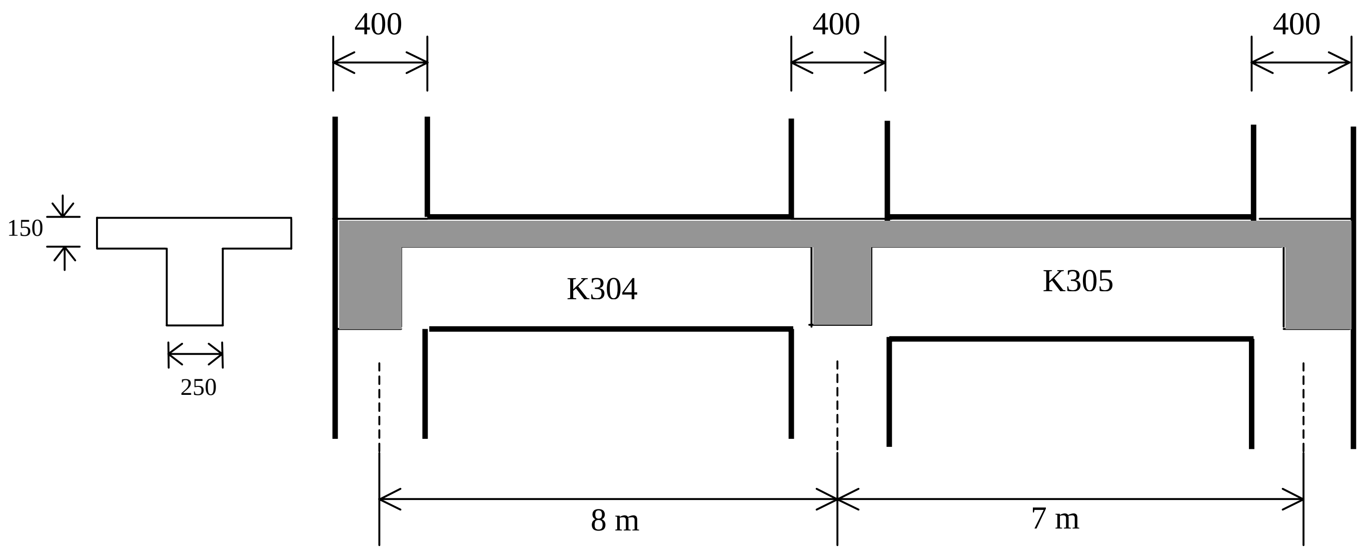
EXAMPLE 2:

Given: The continuous beam shown.

Materials: C20 & S420

Stirrups S220

$$K_\ell = 380\ mm^2 / kN$$



Find: (a) Preliminary Design

(b) Shear Design

SOLUTION:

(a) Preliminary Design

$g \approx 20\ kN/m,\ q \approx 12\ kN/m \Rightarrow p_d = 1.4(20) + 1.6(12) = 47\ kN/m \Rightarrow$ take $p_d = 50\ kN/m$

$$M_d \approx \frac{1}{9} \times p_d \times \ell^2 = \frac{1}{9} \times 50 \left(\frac{8+7}{2}\right)^2 = 312\ kN.m$$

(Interior support, Rectangular cross-section)

$$V_d \approx \frac{p_d \ell}{2} = \frac{50 \times 8}{2} = 200\ kN$$

$$b_w d^2 = K_\ell M_d = 380 \times 312000 = 118.56 \times 10^6 \ mm^3$$

If b_w=250 mm ⇒ d=689 mm

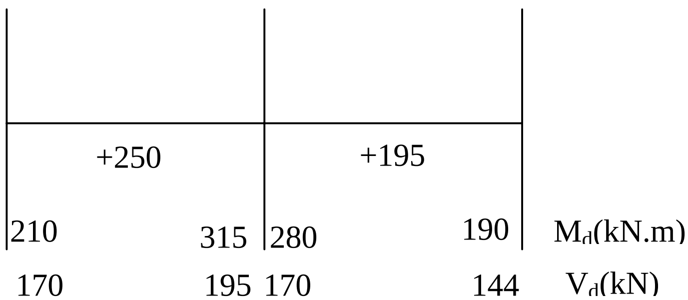
$$b_w d = \frac{0.9 V_d}{f_{ctd}} = \frac{0.9 \times 200000}{1.0} = 180000 \ mm^2$$

If b_w=250 mm ⇒ d=720 mm

Use 250×700 mm beam (d=660 mm)

(b) Final Design

$p_d = 45 \ kN/m$



<u>K304</u>

$$V_d' = V_d - p_d\left(\frac{a}{2} + d\right) = 195 - 45\left(\frac{0.4}{2} + 0.66\right) = 156 \ kN$$

$$V_{cr} = 0.65 \times 1 \times 250 \times 660 \frac{1}{1000} = 107 \ kN$$

$$V_c = 86 \ kN$$

$$V_{\max} = 0.22 \times 0.013 \times 250 \times 660 = 472 \ kN$$

$$V_{cr} < V_d' < V_{\max}$$

$$\min \frac{A_{sw}}{s} = 0.3 \frac{f_{ctd}}{f_{ywd}} \times b_w = 0.3 \frac{1}{191} \times 250 = 0.393 \ mm$$

$$\frac{A_{sw}}{s} = \frac{V_d' - V_c}{f_{ywd}(d)} = \frac{(156 - 86)1000}{191 \times 660} = 0.555 \ mm > \min \frac{A_{sw}}{s}$$

If ϕ8 is used, $A_{sw}=100 \ mm^2$, $s = \dfrac{100}{0.555} = 180 \ mm$

If ϕ10 is used, $A_{sw}=158\ mm^2$, $s = \dfrac{158}{0.555} = 285\ mm$

$d/2 = 330$

$\therefore$ Use ϕ10/280 mm

<u>K305</u>

$$V_d' = 170 - 45\left(\frac{0.4}{2} + 0.66\right) = 131\ kN$$

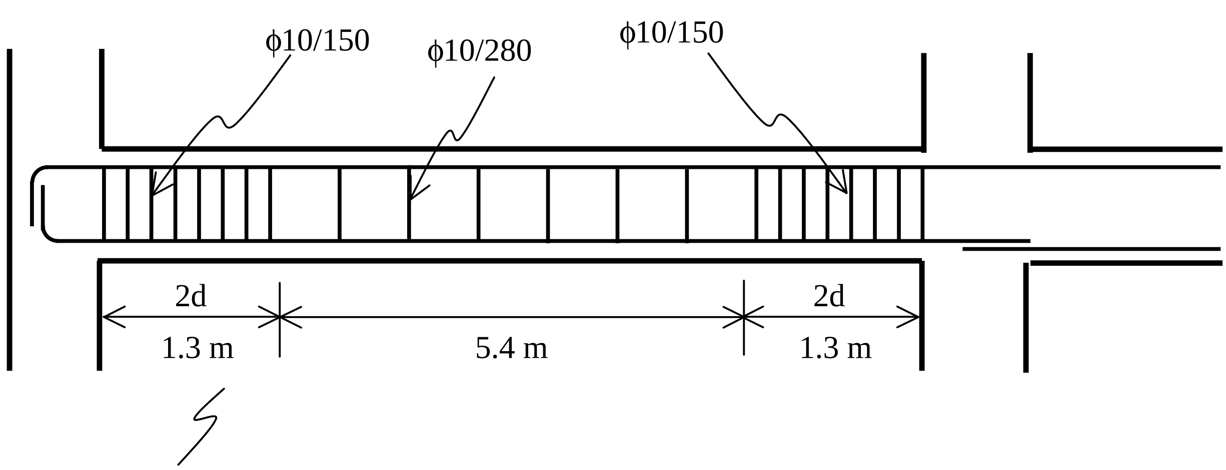
$$V_{cr} < V_d' < V_{\max}$$

$$\frac{A_{sw}}{s} = \frac{V_d' - V_c}{f_{ywd}(d)} = \frac{(131-86)1000}{191 \times 660} = 0.357\ mm < \min \frac{A_{sw}}{s}$$

$$\therefore \text{ Use } \min \frac{A_{sw}}{s} = 0.393\ mm$$

If ϕ10 is used, $A_{sw}=158\ mm^2$, $s = \dfrac{158}{0.393} = 402\ mm > d/2 \Rightarrow$ Use $d/2 = 330$ mm

$\therefore$ Use ϕ10/330 mm



Seismic code requirements

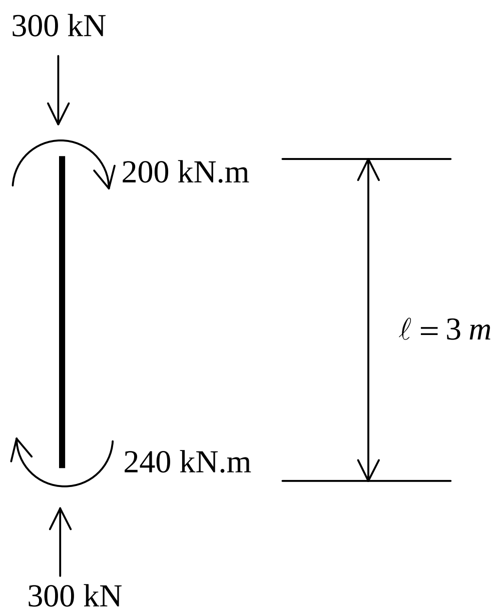
$s \leq 150\ mm = 150$

$\leq h/4 = 165$

$\leq 8\phi_\ell = 160$ (ϕ20 bars are used as longitudinal reinforcement)

EXAMPLE 3:

Given: Column 400×400 mm (d=360 mm)



Materials: C16 and S420

Ties S220

Find: Shear Reinforcement.

SOLUTION:

$$V_d = \frac{M_{d1} + M_{d2}}{\ell} = \frac{200 + 240}{3} = 147\ kN$$

$$V_{cr} = 0.65 f_{ctd}\, b\, d \left(1 + 0.07 \frac{Nd}{Ag}\right)$$

$$V_{cr} = 0.65 \times 0.93 \times 400 \times 360 \left(1 + 0.07 \frac{300000}{400 \times 400}\right) = 98.5\ kN$$

$$V_c = 78.8\ kN$$

$$V_{\max} = 0.22 \times 0.011 \times 400 \times 360 = 348.5\ kN$$

$$V_{cr} < V_d < V_{\max}$$

$$\frac{A_{sw}}{s} = \frac{(147 - 78.8)1000}{191 \times 360} = 0.991\ mm$$

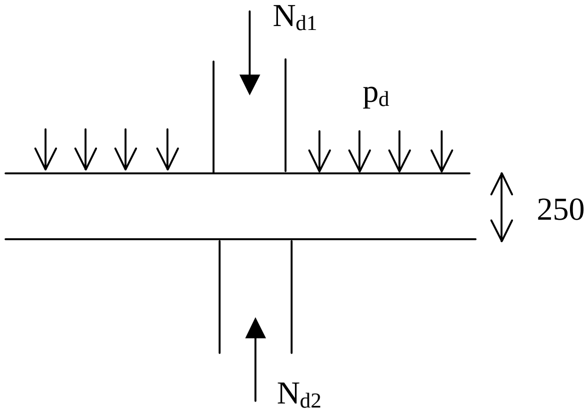
If $\phi 8$ ties are used, $A_{sw}=50\times 2=100\ mm^2$, $s=\dfrac{100}{0.991}=100\ mm$

EXAMPLE 4:

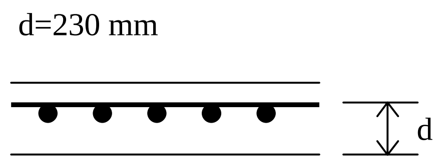
Given: Flat plate given below.

C20, S420

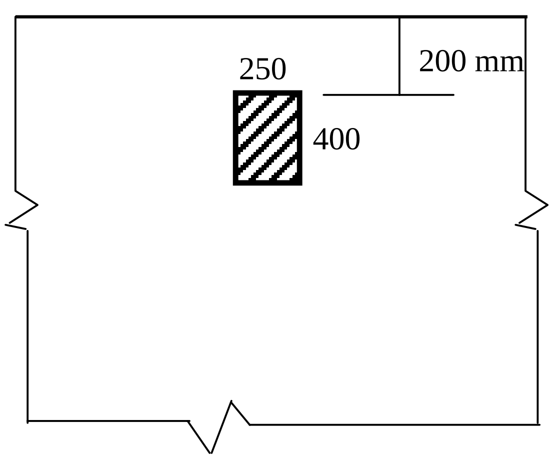
Find: Is the slab safe in punching?



SECTION

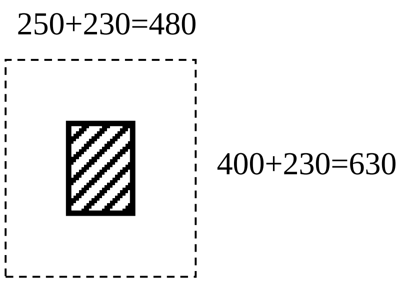


N_{d1}=900 kN
N_{d2}=1400 kN
P_d=14 kN/m^2



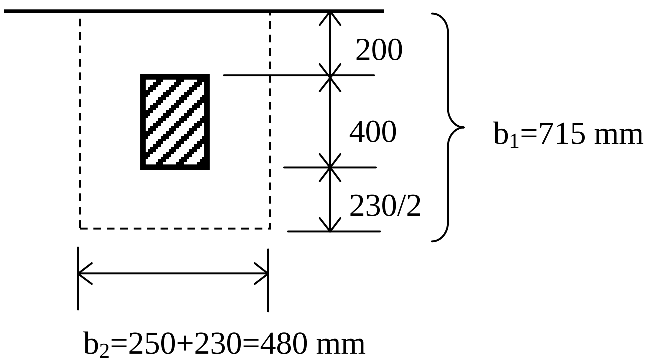
PLAN

SOLUTION:



$$u_p = 2(630 + 480) = 2220\ mm$$

Pattern-A



Pattern-B

$$u_p = 2(715) + 480 = 1910\ mm < 2220\ mm$$

More critical than 2220 mm

$$A_p = 0.715 \times 0.48 = 0.34\ m^2$$

$$F_a = 0.34 \times 14 = 4.8\ kN$$

$$V_{pd} = F_2 - F_1 - F_a = 1400 - 900 - 4.8 = 495.2\ kN$$

$$V_{pc} = (1 \times 1910 \times 230)\frac{1}{1000} = 439\ kN$$

$V_{pc} < V_{pd}$ Unsafe.