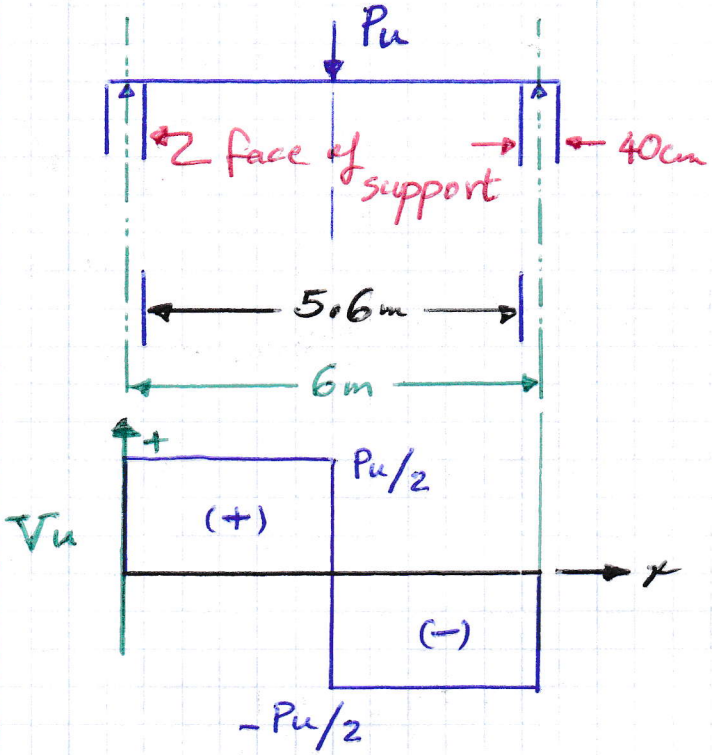
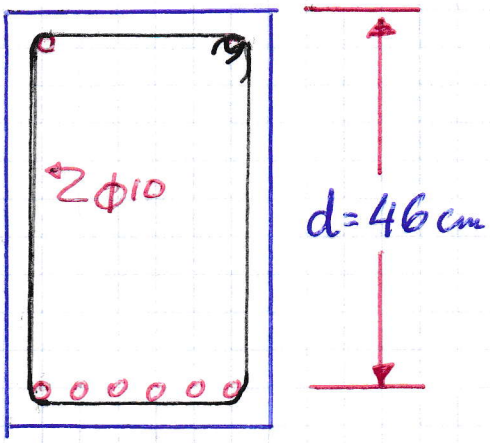
Examples:





b = 35 cm

$f_c' = 28$ MPa

$f_y = 420$ MPa

1) $P_u = 20$ t ϕ10 stirrups

$P_u/2 = 10$ t

$$\phi V_c = 0.75(0.17)\frac{\sqrt{28}}{100}(1.0)(35)(46)$$

$$= 10.86 \text{ t}$$

$$\frac{\phi V_c}{2} = 5.43 \text{ t}$$

Note: $V_u = 10$ t

∴ Category II $\frac{\phi V_c}{2} < V_u \leq \phi V_c$

Exceptions are not applicable,

∴ minimum shear reinforcement is required

$$s_{max} \leq \frac{(1.57)(420)}{0.062\sqrt{28}\,(35)} = 57.4\ cm$$

$$\leq \frac{(1.57)(420)}{0.35\,(35)} = 53.8\ cm$$

$$\leq d/2 = \underline{23\ cm} \quad \underline{\text{Controls}}$$

$$\leq 60\ cm$$

Note: $A_v = 2\phi 10$ (single stirrup)

$= 1.57\ cm^2$

Although not an ACI requirement, good engineering practice is:

for: $b \leq 40\ cm$ use single stirrups (2 legs)

$40cm < b \leq 80\ cm$ use double stirrups (4 legs)

$80\ cm < b \leq 120\ cm$ use tripple stirrups (6 legs)

∴ use single ϕ 10 stirrups at 23 cm c/c spacing along the entire length of the beam.

A total of 26 stirrups will be needed, the first one is placed at the face of the support.

2) $P_u = 30t$

$P_u/2 = 15t$ $\qquad V_u = 15t$

$\phi V_c = 10.86t$, $\qquad V_u > \phi V_c$

$< 3\phi V_c = 32.58t$

Is it III

or IV ?

Although not really necessary to determine which of these two categories it is, for clarity and complete understanding of these categories, this will be determined in two different ways.

A) From the previous example, $S_{max} = 23\,cm$

$$\phi V_{s\,min} = \frac{0.75\,(1.57\,cm^2)(4.2\,t/cm^2)(46\,cm)}{23\,cm}$$

$$= 9.89\,t$$

$$\therefore \phi V_c + \phi V_{s\,min} = 20.75\,t$$

$\phi V_c = 10.86t < V_u = 15t < \phi V_c + \phi V_{s\,min} = 20.75t$

$\therefore$ Category III

and minimum shear reinforcement is required (the same as in example 1)

B) Alternatively,

$$\phi V_{s\,req} = 15 - 10.86 = 4.14\,t$$

$$S_{req} = \frac{0.75\,(1.57)\,(4.2)\,(46)}{4.14^{t}}$$

(1.57 cm², 4.2 t/cm², 46 cm)

$$= 54.95\ cm$$

Since the minimum requirements control, i.e.,

$S_{max} = 23\ cm < S_{req} = 54.95\ cm$

∴ Category III

∴ use single Φ10 stirrups @ 23 cm C/C spacing along the entire length of the beam.

A total of 26 stirrups will be needed, the first stirrup is always placed at the face of the support to ensure that the critical part of the beam is not mistakenly missed.

3) $P_u = 50\,t$

$V_u = P_u/2 = 25\,t$

$\phi V_c = 10.86\,t$, $3\phi V_c = 32.58\,t$

Again, is it III or IV ?

A) From example 2, $\phi V_c + \phi V_{s\,min} = 20.75\,t$

[Category IV]

∴ procedure B must be used anyway,

B) $\phi V_{s\,req} = 25 - 10.86 = 14.14\,t$

$$S_{req} = \frac{0.75\,(1.57)(4.2)(46)}{14.14}$$

$$= 16.1\,cm$$

It would be clear when comparing this result to the S_{max} requirements that the beam is in the [Category IV] for shear design.

$S_{max} = 23\,cm$

∴ Use single $\phi 10$ stirrups @ 16 cm c/c spacing

4) $P_u = 80\,t$

$V_u = P_u/2 = 40\,t$

$\phi V_c = 10.86\,t,\ 3\phi V_c = 32.58\,t,\ 5\phi V_c = 54.3\,t$

$3\phi V_c = 32.58\,t < V_u (= 40\,t) < 5\phi V_c = 54.3\,t$

∴ Category V

$\phi V_{sreq} = 40 - 10.86 = 29.14\,t$

$$s_{req} = \frac{0.75(1.57)(4.2)(46)}{29.14} = 7.81\,cm$$

$S_{max} \leq 57.4\,cm$

$53.8\,cm$

$d/4 = 11.5\,cm$

$30\,cm$

∴ use $\phi 10$ stirrups @ 7.0 cm c/c spacing.

However, if double $\phi 10$ stirrups are used,

$A_v = 3.14\,cm$

$$s_{req} = \frac{0.75(3.14)(4.2)(46)}{29.14} = 15.61\,cm$$

$S_{max} \leq 114.8\,cm$

$\leq 107.6\,cm$

$d/4 = \underline{11.5\,cm}$ Controls

$30\,cm$

∴ use $2\phi 10$ stirrups @ 11.0 cm c/c spacing