DESIGN FOR SHEAR

Max. Shear due to loads, $V_u \leq$ Design Shear Capacity, $\varphi V_n$

Where $\varphi = 0.75$

Design Shear Capacity, $\varphi V_n = [\text{Design Shear strength of concrete, } \varphi V_c + \text{Design Shear strength of reinforcement, } \varphi V_s ]$

$\varphi V_n = \varphi V_c + \varphi V_s$

Therefore, $V_u \leq [ \varphi V_c + \varphi V_s ]$

Shear force that concrete can resist without web reinforcement, $V_c$

(ACI Eq. 11.3) \[ V_c = 2 \sqrt{f'_c} \times (b_w \times d) \]

where $f'_c$ is in psi; $b_w$ and $d$ are in inches

Fig. 1
\[ V_s = A_v \times f_y \times n \]

\[ \Rightarrow V_s = A_v \times f_y \times \frac{d}{s} \quad \text{(ACI Eq. 11-15)} \]

\[ \Rightarrow s = A_v \times f_y \times \frac{d}{V_s} \]

where \( A_v \) = cross-sectional area of each stirrup has crossed the crack

- \( A_v = 2 \) times the cross-sectional area of the stirrup bar.
- \( A_v = 3 \) times the cross-sectional area of the stirrup bar.
Fig. 4 Flow Chart
Vertical Shear Reinforcement Design
(Dr. Mohammed E. Haque, P.E.)

Known: $f'_{c}$, $f_{y}$, $d$, $b_{w}$ and $V_{u}$

$\phi = 0.75$

$\phi V_{c} = \lambda \cdot \phi \cdot 2\sqrt{f'_{c}} \cdot b_{w} \cdot d$

$\phi V_{s} = [V_{u} - \phi V_{c}]$

$8\phi \sqrt{f'_{c}} \cdot b_{w} \cdot d < [\phi V_{s}]$

Yes

Section should be enlarged.

No

Yes

$V_{u} > 0.5 \phi V_{c}$

Yes

$V_{u} > \phi V_{c}$

Determine required spacing of vertical U stirrups based on $\phi V_{s}$

No

Determine spacing of vertical U stirrups based on minimum shear reinforcement

$S = \phi A_{v} f_{y} d / [V_{u} - \phi V_{c}]$

$S$ must be

$S \leq d/2 \leq 24$ in

If $[V_{u} - \phi V_{c}] > 4\phi \sqrt{f'_{c}} \cdot b_{w} \cdot d$

$S \leq d/4$

$S$ is smaller of the two:

$S = A_{v} f_{y} / [50 b_{w}]$

$S = A_{v} f_{y} / [0.75 \sqrt{f'_{c}} \cdot b_{w}]$

$S$ must be

$S \leq d/2 \leq 24$ in

Draw the beam and show reinforcement and spacing
**Fig. 5 Shear Reinforcement requirements**

- **Support width** = $w_1$
- **Section A-A**
- **C.L. of Symmetry**
- **d**
- **$b_w$**
- **$w_u$**

**Equations:**

- $R_A = w_u \times \frac{L}{2}$
- $R_B = w_u \times \frac{L}{2}$

**Shear carried by concrete** $\varphi V_c$

**Minimum Shear reinforcement**

- $V_u - \varphi V_c$
- $\varphi V_c$
- $d + 0.5 w_1$

**Shear reinforcement required**

- $V_u$
- $0.5 \varphi V_c$

**Shear reinforcement not required**

- Support width = $w_1$
- C.L. of Symmetry
Summary (Vertical Stirrup or Web Reinforcement Design)

1. Draw Shear, $V_u$ Diagram (Fig. 5)

2. Calculate $V_u$ at a distance $d$ from the face of support

3. On the $V_u$ diagram, identify locations where (1) Shear Reinforcement required, (2) where shear reinforcement not required, (3) where shear carried by stirrups, $\varphi V_s$, and (4) where minimum shear reinforcement required (Shear carried by concrete, $\varphi V_c$). [Note: SEE Fig. 5]

4. Calculate $\varphi V_c = 2 \lambda \varphi \sqrt{f_c'} (b_w \times d)$, where

   $\varphi = 0.75$;
   $\lambda = 1$ for normal weight concrete; 0.85 for sand-lightweight concrete; 0.75 for all lightweight concrete.

5. Calculate $\varphi V_s = [V_u - \varphi V_c]$

   Check: If $8 \varphi \sqrt{f_c'} b_w d < [\varphi V_s]$, then SECTION SHOULD BE ENLARGED [STOP AT THIS STEP]

6. No Stirrups are needed if $V_u < 0.5 \varphi V_c$

DESIGN STIRRUPS

7. Determine required spacing of vertical U stirrups based on $\varphi V_s$

   Calculate theoretical stirrup spacing, $S = \varphi A_v \times f_y \times d / [V_u - \varphi V_c]$

   $S$ must satisfy

   $S \leq d/2 \leq 24$ inch

   If $[V_u - \varphi V_c] > 4\varphi \sqrt{f_c'} b_w d$ Then $S \leq d/4$
8. Determine spacing of vertical U stirrups based on minimum shear reinforcement.

S is smaller of the two:

\[ S = A_v f_y / [50 \, b_w] \]

\[ S = A_v f_y / [0.75 \sqrt{f_c} \cdot b_w] \]

S must satisfy

\[ S \leq d/2 \leq 24 \text{ inch} \]

9. Minimum practical stirrup spacing is 3 to 4 inches.

10. Draw the beam and show the shear reinforcements and spacing.