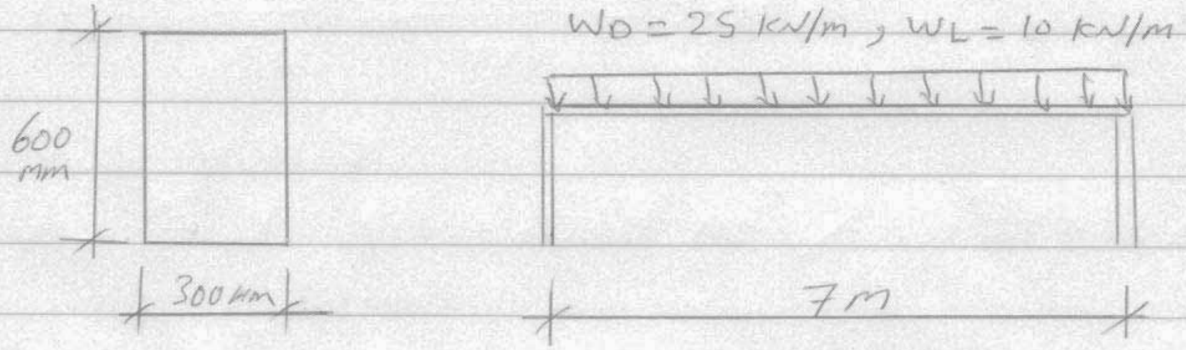
Problems

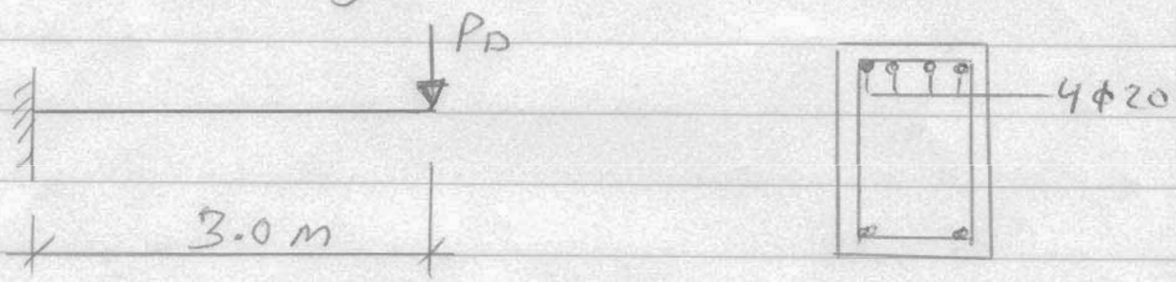
1- Design the following beam by ultimate design method, $f'_c = 21\ N/mm^2$, $f_y = 420\ N/mm^2$, $\gamma_c = 24\ kN/m^3$.



2- Analyze the following beam by using ultimate strength method, found maximum value of load (P_D) applied on the edge of cantilever.

$b = 300\ mm$, $h = 600\ mm$, $A_s = 4\phi 20\ mm$

$f'_c = 21\ MPa$, $f_y = 420\ MPa$



Design of Beams for Shear

Design of cross-sections subjected to shear shall be based on:

$$\phi V_n \geq V_u$$

where V_u is the factored shear force, and V_n is the nominal shear force.

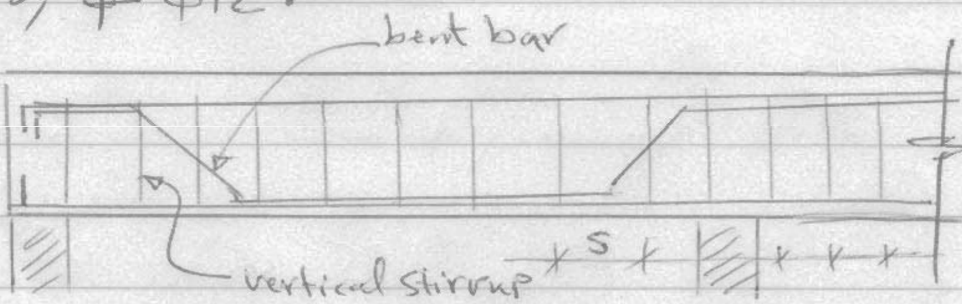
$$V_n = V_c + V_s$$

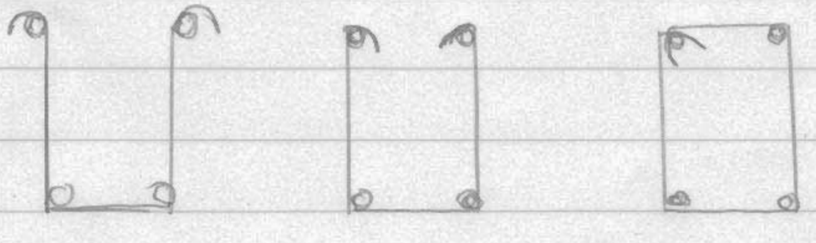
V_c = shear force provided by concrete.
V_s = shear force provided by shear reinforcement

Types of Shear (web) Reinforcement :-

Web reinforcement is provided in the form of vertical or inclined stirrups, spaced at varying intervals along the beam.

Relatively small size bars are used, generally $\phi 8$, $\phi 10$, & $\phi 12$.





open stirrup

Closed stirrup

$$V_c = \frac{1}{6}\sqrt{f'_c}\cdot b_w\cdot d$$ (Shear force provided by concrete)

$$\simeq 0.17\sqrt{f'_c}\, b_w\cdot d$$

or

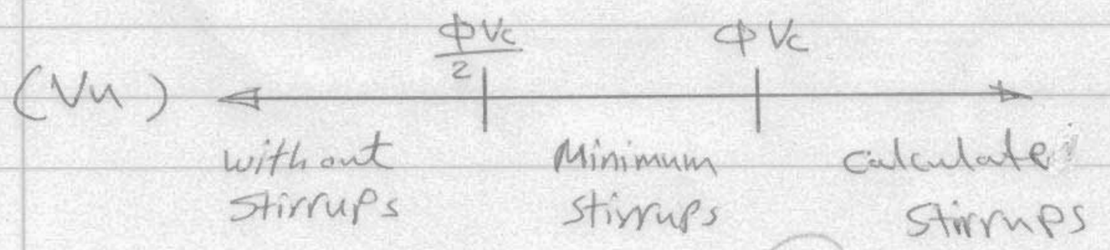
$$V_c = \left(0.16\sqrt{f'_c} + 17.2\,\rho_w \frac{V_u\cdot d}{M_u}\right) b_w\cdot d \leq 0.3\sqrt{f'_c}\, b_w\cdot d \quad \text{with } \frac{V_u\cdot d}{M_u} \leq 1.0$$

$$V_s = \frac{A_v\cdot f_y\cdot d}{s}$$ (Shear force provided by vertical stirrups)

$$\therefore V_n = V_c + V_s = \frac{1}{6}\sqrt{f'_c}\, b_w\cdot d + \frac{A_v\cdot f_y\cdot d}{s}$$

ACI code 318 requirements of minimum stirrups and maximum spacing.

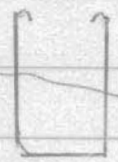
If V_u (shear force at factored loads) is not larger than (ϕV_c) calculated, theoritically no web reinforcement is required, however the cod requires to provision at least a minimum web steel to be used, unless (V_u) smaller than one half of (ϕV_c) in this case no need to web reinforcement (beam will be without web reinforcement).



$$Av_{min.} = \frac{bw \cdot S}{3 fy} \simeq 0.33 \frac{bw \cdot S}{fy}$$

Av for two legs

$A_v = 2 \cdot A_b$



$$V_u = \phi (V_c + V_s) \quad ; \phi = 0.85$$

If ;

$$V_s \leq \frac{1}{3} \sqrt{f'_c} \cdot bw \cdot d$$

$$S_{max} = \frac{d}{2} \text{ or } 600 \text{ mm}$$

If ;

$$V_s > \frac{1}{3} \sqrt{f'_c} \cdot bw \cdot d$$

$$S_{max.} = \frac{d}{4} \text{ or } 300 \text{ mm}$$

In all cases V_s must be taken not greater than $\left(\frac{2}{3} \sqrt{f'_c} \cdot bw \cdot d \right)$.

Notes :

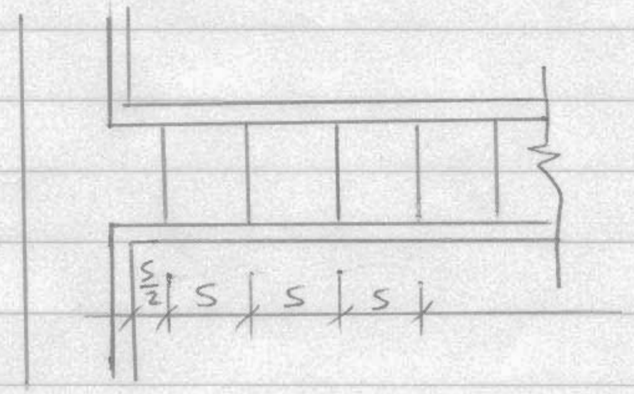
1- first stirrup should be placed at $\frac{S}{2}$ from the face of support.

2- The maximum shear for design is calculated at a distance (d) from face of the support when the following conditions are satisfied;

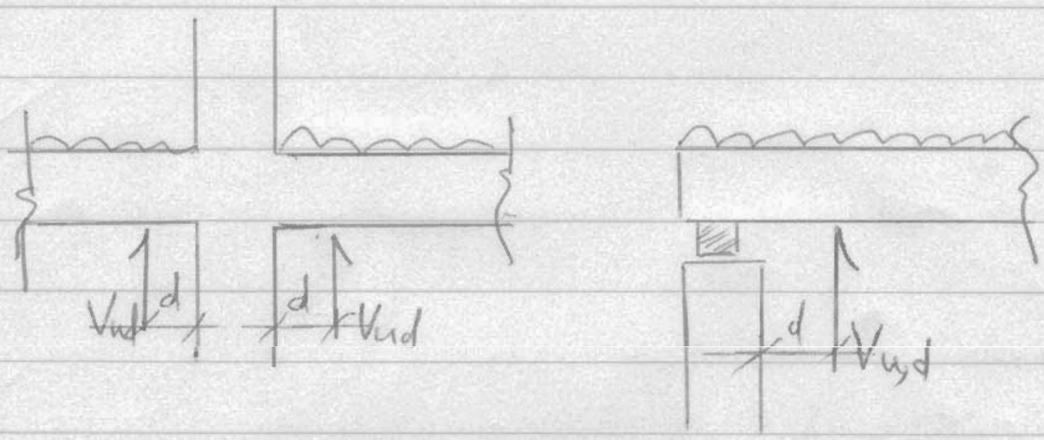
a - Support reaction in direction of applied shear introduces compression into the member.

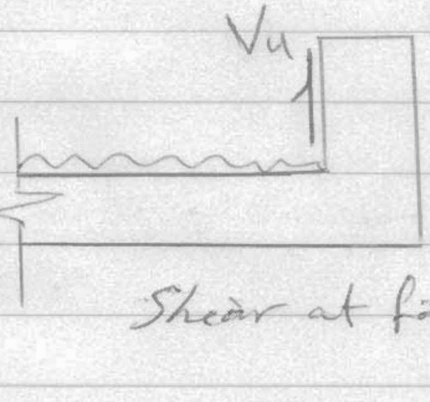
b - No concentrated load exsists between face of support and location of critical section at distance (d).

(1)



(2)





Shear at face

Summary of limits for design of vertical stirrups under the ACI code :-

Region	V_n Boundaries (kN)	A_v (mm^2)	$S_{max.}$ (mm)
I	$0 \leq V_n \leq \frac{1}{2} V_c$ $0 \leq V_n \leq \frac{1}{12}\sqrt{f'_c} \cdot b_w \cdot d$	/	/
II	$\frac{1}{2} V_c \leq V_n \leq V_c$ $\frac{1}{12}\sqrt{f'_c} \cdot b_w \cdot d \leq V_n \leq \frac{1}{6}\sqrt{f'_c} \cdot b_w \cdot d$	$A_{v_{min.}} = \frac{b_w \cdot S}{3 f_y}$	$\frac{3 A_{v_{min}} \cdot f_y}{b_w}$
III	$V_c \leq V_n \leq V_c + V_s$ & $V_s \leq \frac{1}{3}\sqrt{f'_c} \cdot b_w \cdot d$ $\frac{1}{6}\sqrt{f'_c} b_w \cdot d \leq V_n \leq \frac{1}{6}\sqrt{f'_c} \cdot b_w \cdot d + \frac{1}{3}\sqrt{f'_c} \cdot b_w \cdot d$ $\frac{1}{6}\sqrt{f'_c} b_w \cdot d \leq V_n \leq \frac{1}{2}\sqrt{f'_c} b_w \cdot d$	$A_v = \frac{V_s \cdot S}{f_y \cdot d}$	d/2 or 600 mm
IV	$V_n > \frac{1}{2}\sqrt{f'_c} \cdot b_w \cdot d$ & $V_s > \frac{1}{3}\sqrt{f'_c} \cdot b_w \cdot d$	//	d/4 or 300 mm