ALMUSTAQBAL UNIVERSITY COLLEGE

DEPARTMENT OF BUILDING & CONSTRUCTION ENGINEERING TECHNOLOGY

ANALYSIS AND DESIGN OF REINFORCED CONCRETE STRUCTURES II

ADDITIONAL EXAMPLES IN PUNCHING SHEAR

EXAMPLE SIX: check the two-way shear action (punching shear) only around an interior column (440x440) mm in a flat plate floor of a span (6.3x6.3) m. Also, find the spacing of closed stirrups of vertical shear reinforcement if required. Loading conditions Wu=15kn/m^2. Slab thickness h=210mm. d= 160mm. Use Ø10mm for closed stirrups, fy=400MPa, fc'=35MPa.

SOLUTION:

$$B_O = (440 + 160) \times 4 = 2400mm$$

$$V_u = 15 \times (6.3 \times 6.3 - 0.6 \times 0.6) = 589.95kN.$$

$$v_u = \frac{V_u}{b_o d} = \frac{589.95 \times 10^3}{2400 \times 160} = 1.536MPa.$$

$$\beta = \frac{440}{440} = 1$$

$$v_c = \begin{cases} 0.33\sqrt{f_c'} = 0.33\sqrt{35} = \mathbf{1.952MPa} \\ 0.17\left(1 + \frac{2}{\beta}\right)\sqrt{f_c'} = 0.17\left(1 + \frac{2}{1}\right)\sqrt{35} = 3.017MPa \\ 0.083\left(2 + \frac{\alpha_s d}{b_o}\right)\sqrt{f_c'} = 0.083\left(2 + \frac{40 \times 160}{2400}\right)\sqrt{35} = 2.291MPa \end{cases}$$

$$\therefore v_c = 1.952MPa$$

$\emptyset v_c = 0.75 \times 1.952 = 1.464MPa < v_u = 1.536MPa$ ..... Not ok

$v_u \le \emptyset 0.5\sqrt{f_c'} \rightarrow 1.536 < 2.218$ .... Ok.

$$v_c = 0.17\sqrt{f_c'} = 0.17\sqrt{35} = 1.0057MPa$$

$$v_s = \frac{v_u}{\emptyset} - v_c = \frac{1.536}{0.75} - 1.0057 = 1.0423MPa$$

$$A_v = 2 \times 4 \times \frac{\pi}{4} \times 10^2 = 628.3mm^2$$

$$v_s = \frac{A_v f_y}{b_o s} \rightarrow s = \frac{628.3 \times 400}{1.0423 \times 2400} = 100.431mm$$

$$s_{max} = \frac{d}{2} = \frac{160}{2} = 80mm < s = 100.431mm$$

∴ use s=80mm.

EXAPMLE 7: Check the two-way shear action (punching shear) only around an interior column having the diameter of 500mm in a flat plate floor system of a span 6m in all directions from centre to centre of column. Find the vertical shear reinforcement if required. Assume that the effective depth is 190mm, total ultimate load 19kPa (including self-weight of the slab), fc'=25MPa, and fy=414MPa.

SOLUTION:

$$b_o = (500 + 190) \times \pi = 2168mm$$

$$V_u = 19 \times \left(6 \times 6 - \frac{\pi}{4} \times 0.69^2\right) = 678kN.$$

$$v_u = \frac{V_u}{b_o d} = \frac{678 \times 10^3}{2168 \times 190} = 1.645MPa$$

$$v_c = \begin{Bmatrix} 0.33\sqrt{25} = 1.65MPa \\ 0.17\left(1 + \frac{2}{1}\right)\sqrt{25} = 2.55MPa \\ 0.083\left(2 + \frac{40 \times 190}{2168}\right)\sqrt{25} = 2.284MPa \end{Bmatrix}$$

$\therefore$ $\boldsymbol{v_c = 1.65MPa}$

$$\emptyset v_c = 0.75 \times 1.65 = 1.2375MPa$$

$$v_u = 1.645MPa > \emptyset v_c = 1.2375MPa$$

$\therefore$ shear reinforcement is required.

$v_u < 0.5\emptyset\sqrt{f_c{}'} \rightarrow 1.645MPa < 0.5 \times 0.75 \times \sqrt{25} = 1.875MPa$ **o.k.**

$$v_c = 0.17\sqrt{25} = 0.85MPa$$

$$v_s = \frac{v_u}{\emptyset} - v_c = \frac{1.645}{0.75} - 0.85 = 1.343MPa$$

$$v_s = \frac{A_v f_y}{b_o s} \rightarrow A_v = \frac{v_s b_o s}{f_y} \quad , \quad s = s_{max} = \frac{d}{2} = \frac{190}{2} = 95mm.$$

$$A_v = \frac{v_s b_o s}{f_y} = \frac{1.343 \times 2168 \times 95}{414} = 668.13mm^2.$$

$\therefore$ The required area of vertical shear reinforcement = $668.13mm^2$

EXAMPLE 8: Check the two-way shear action (punching shear) only around an edge circular column having a diameter of 500mm in a flat plate floor system with a span of 6m from centre to centre of column in all directions. Find the area of the vertical shear reinforcement if required. Assume that the effective depth is 190mm, total ultimate weight is 25kPa (self-weight is included), fc'=25MPa, fy=414MPa.

SOLUTION:

$$b_o = (250 \times 2 + \pi \frac{690}{2}) = 1584mm$$

$$V_u = 25 \times \left(6 \times 3.25 - (0.69 \times 0.25 + \frac{\pi}{8} \times 0.69^2\right) = 478.5kN.$$

$$v_u = \frac{V_u}{b_o d} = \frac{478.5 \times 10^3}{1584 \times 190} = 1.589MPa$$

$$v_c = \begin{Bmatrix} 0.33\sqrt{25} = 1.65MPa \\ 0.17\left(1 + \frac{2}{1}\right)\sqrt{25} = 2.55MPa \\ 0.083\left(2 + \frac{30 \times 190}{1584}\right)\sqrt{25} = 2.323MPa \end{Bmatrix}$$

$\therefore$ $\boldsymbol{v_c = 1.65MPa}$

$\emptyset v_c = 0.75 \times 1.65 = 1.2375MPa$

$v_u = 1.589MPa \ > \ \emptyset v_c = 1.2375MPa$

$\therefore$ shear reinforcement is required.

$v_u < 0.5\emptyset\sqrt{f_c{}'} \rightarrow 1.645MPa \ < \ 0.5 \times 0.75 \times \sqrt{25} = 1.875MPa$ **o.k.**

$v_c = 0.17\sqrt{25} = 0.85MPa$

$$v_s = \frac{v_u}{\emptyset} - v_c = \frac{1.589}{0.75} - 0.85 = 1.268MPa$$

$v_s = \frac{A_v f_y}{b_o s} \rightarrow A_v = \frac{v_s b_o s}{f_y}$, $s = s_{max} = \frac{d}{2} = \frac{190}{2} = 95mm.$

$$A_v = \frac{v_s b_o s}{f_y} = \frac{1.268 \times 1584 \times 95}{414} = 460.89mm^2.$$

$\therefore$ The required area of vertical shear reinforcement = $460.89mm^2$

EXAMPLE 9: Check the two-way shear action (punching shear) around an edge polygon column having the dimensions of 500mm in a flat plate floor system with the span of 6m from centre of columns. Find the area of vertical shear if required. Assume that d= 190mm, total weight Wu= 25kPa (including the slab's delf-weight), fc'=25MPa, and fy=414MPa.

SOLUTION:

$$b_o = (690 \times 2 + 353.55 \times 2) = 2087.1mm$$

$$V_u = 25 \times \left(6 \times 3.35355 - \left(0.9758 \times 0.35355 + \frac{0.9758}{2} \times 0.4879\right)\right)$$

$$=25 \times \left(20.1213 - (0.583)\right) = 488.46kN.$$

$$v_u = \frac{488.46 \times 10^3}{2087.1 \times 190} = 1.231MPa.$$

$$v_c = \left\{ \begin{array}{c} 0.33\sqrt{25} = 1.65MPa \\ 0.17\left(1 + \frac{2}{1}\right)\sqrt{25} = 2.55MPa \\ 0.083\left(2 + \frac{30 \times 190}{2087.1}\right)\sqrt{25} = 1.96MPa \end{array} \right\}$$

$\therefore$ $\boldsymbol{v_c = 1.65MPa}$

$\emptyset v_c = 0.75 \times 1.65 = 1.2375MPa$

$v_u = 1.231MPa < \emptyset v_c = 1.2375MPa$

$\therefore$ No shear reinforcement is required.