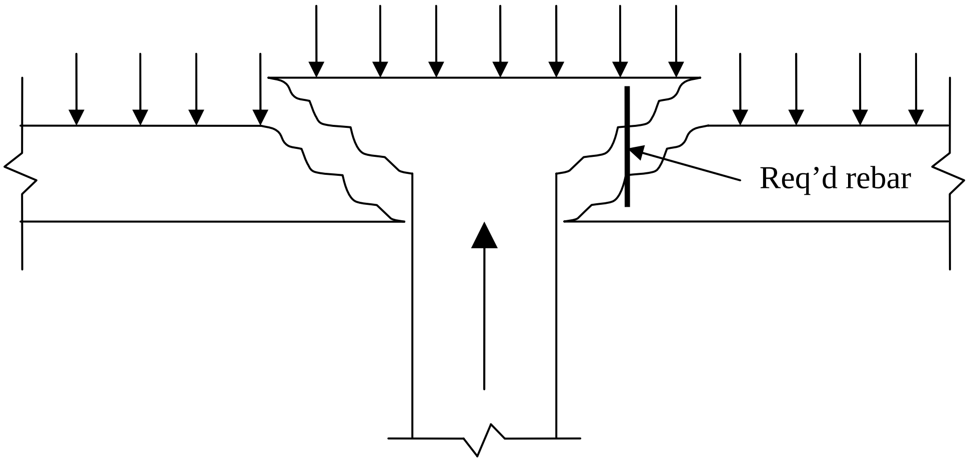
# Punching Shear

## What is Punching Shear?

Punching shear is a type of failure of reinforced concrete slabs subjected to high localized forces. In flat slab structures this occurs at column support points. The failure is due to shear:




*Piper's Row Car Park, Wolverhampton, UK, 1997 (built in 1965).*

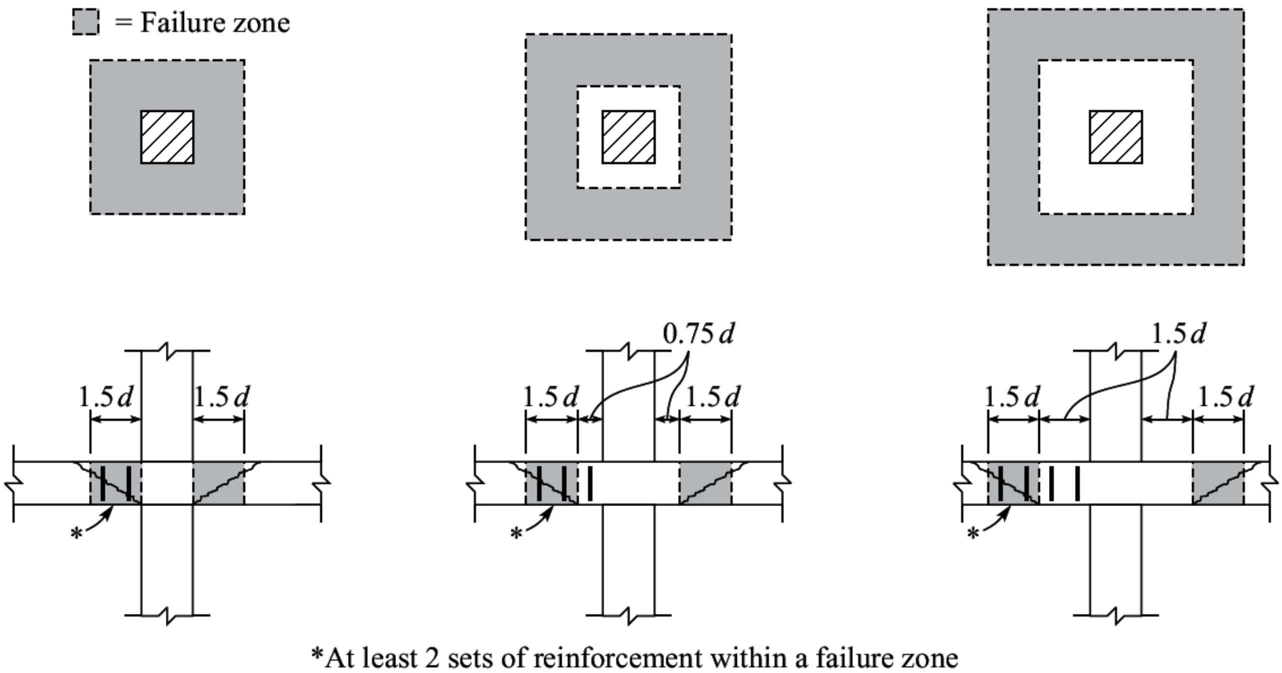
**Punching Shear Design**

The design to prevent punching shear failure proceeds as:

1. Check if the concrete is strong enough alone;
2. If not, check if the amount of reinforcement is reasonable;
3. Design reinforcement if reasonable, if not, change form of structure.

Changing the form of structure includes deepening the slab, making the column larger, introducing drop panels or flared column heads. There is also the possibility to adapt foreign codes of practice which are more liberal!

The reinforcement put in is usually vertical and traverses the potential failure line. Of course, we don't know where the failure plane might be, so we must reinforce each possible failure plane as shown:



(a) First failure zone (b) Second failure zone (c) Third failure zone

Note that bars may be common to two failure planes and that as we move away from the column the (shaded) area over which the load is spread increases and so the stress reduces. Eventually we reach a point where the concrete is sufficiently strong alone.

## Preliminary Design

The column reaction, $V_t$, is modified as follows to take account of moment transfer:

- Internal Columns: $V_{eff} = 1.15V_t$;
- Edge/Corner Columns: $V_{eff} = 1.4V_t$.

1. Check maximum shear at column face:

$$v_{\max} = \frac{V_{eff}}{u_0 d} \leq 0.8\sqrt{f_{cu}} \text{ or } 5 \text{ N/mm}^2$$

   where $u_0$ is the perimeter of the column.

2. Shear stress at the critical section, 1.5*d* from the face of the column:

$$v = \frac{V}{ud}$$

$$u = 2a + 2b + 8\mu d$$

   where *a* and *b* are the plan dimensions of a rectangular column and $\mu$ is the perimeter multiplier of *d*: in this case, $\mu = 1.5$. If:

   $v \leq v_c$: No shear reinforcement required.

   $v \leq 2v_c$: Link reinforcement may be used.

   $v > 2v_c$: Alternative proven system to be used.

For preliminary design, it is sufficient to pass Step 1 and to know that $v \leq 2v_c$ at the critical perimeter.

For preliminary purposes for the design of flat slabs buildings in 40N concrete, take:

$$v_c = 0.65 \text{ N/mm}^2$$

**Example:**

Taking an Internal Column from the Load Takedown Example - (refer to page 43 of the Quantitative Design Notes).

**Solution:**

$$V_t = 6.25 \times 6.7 \times 17.24 = 722 \text{ kN}$$

$$\therefore V_{eff} = 1.15 V_t = 830 \text{ kN}$$

Maximum shear at face of column:

$$u_0 = 2a + 2b = 4 \times 300 = 1200 \text{ mm}$$

$$v_{\max} = \frac{830 \times 10^3}{1200 \times 237} = 2.92 \text{ N/mm}^2$$

$$\begin{aligned} v_{\max} &\le 0.8\sqrt{40} \text{ or } 5 \text{ N/mm}^2 \\ &\le 5.06 \text{ or } 5 \le 5 \therefore OK \end{aligned}$$

Shear at critical perimeter, 1.5*d* from column face:

$$u_{1.5d} = 2a + 2b + 8\mu d = 4 \times 300 + 8 \times 1.5 \times 237 = 4044 \text{ mm}$$

$$v_{1.5d} = \frac{830 \times 10^3}{4044 \times 237} = 0.87 \text{ N/mm}^2$$

If we take $v_c = 0.65 \text{ N/mm}^2$, then $v_c \le v_{1.5d} \le 2v_c$ and shear reinforcement is to be provided.

<u>Result:</u>

Punching shear reinforcement will be required but there will only be 1 or 2 perimeters as $v_{1.5d}$ is nearly at $v_c$.