

Calculation method

Design

The design and layout of the HDB system has been independently approved by UK CARES. It is based on BS 8110 and uses technical reports and test data to adapt the Standard from reinforcement links as specified, to the HDB proprietary double headed stud system.

The calculation first checks the shear stress at the column face. The area of HDB shear reinforcement is then calculated at the first shear perimeter, 1.5d from the column face. This determines the diameter of the HDB stud required. The calculation then checks the perimeter where $v = v_c$, after which no further shear studs are required. This determines the length of the shear rail arm.

Punching shear load (piercing load)

The Halfen calculation software allows the user to input the design load in two ways

V^{eff} = the design effective shear, which should include the effect of any moment transferred to the column, or

V_t = design shear transferred to the column, which is then multiplied by the appropriate factor for moment transfer, dependent on the column type as shown below

Using V_t the program defaults to the following simplified multiplication factors, which in the absence of calculation will be satisfactory to use for braced structures with approximately equal spans and approximately equal loading to all spans surrounding the column.

Interior column: 1.15
 Corner column: 1.25 (BS 8110 cl. 3.7.6)
 Edge column: 1.40

These simplified factors may be changed if more rigorous analysis is carried out.

Design concrete shear stress, v_c (BS 8110 table 3.8)

$$v_c = \frac{0.79}{1.25} \left(\frac{100 A_s}{b_v d} \right)^{1/3} \left(\frac{400}{d} \right)^{1/4} \left(\frac{f_{cv}}{25} \right)^{1/3}$$

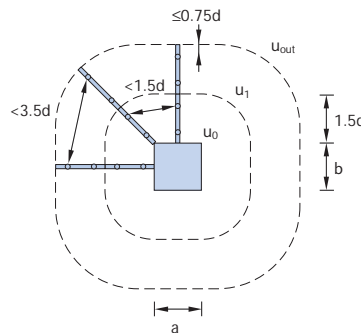
where

100 $A_s / (b_v d)$: reinforcement ratio, ρ
 A_s : area of tension reinforcement
 d : effective depth
 b_v : width of slab under consideration
 f_{cv} : characteristic strength of concrete

Perimeters

The perimeters used in the calculation have radius corners rather than the rectangular perimeters given in BS 8110,

For rectangular column
 $u_1 = 2(a+b) + 2 \prod (1.5d)$



Perimeters:

U_0 = perimeter of loaded area (usually the column)
 U_1 = first critical perimeter at 1.5d from the column face
 U_{out} = perimeter where $v \leq v_c$

Calculation of shear stress

The shear stress (v_0) at the column face (u_0 perimeter) is first checked to ensure it does not exceed v_{max} , if $v_0 > v_{max}$ then the concrete slab and/or column should be redesigned.

$$v_0 = \frac{V_{eff}}{u_0 d}$$

$$v_{max} = 0.8 \sqrt{f_{cu}} \text{ or } 5.6 \text{ N/mm}^2$$

where $f_{cu} \leq 50 \text{ N/mm}^2$

The next check on the shear stress is carried out at the first perimeter (u_1), 1.5d from column face.

$$v_1 = \frac{V_{eff}}{u_1 d}$$

If $v_1 < v_c$ then no shear studs are required. If $v_1 > v_c$ shear studs are provided based on the following equations

$$v_c \leq v \leq 2.0v_c \quad \sum A_{sw} = \frac{(1.57v - v_c) u_1 d}{0.87 f_y}$$

minimum stud reinforcement

$$\sum A_{sw} = \frac{0.46 u_1 d}{0.87 f_y}$$

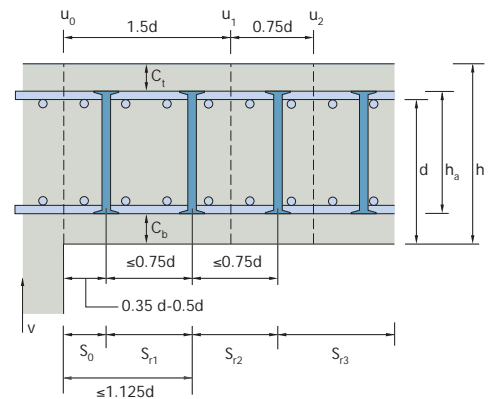
where

$f_y = 500 \text{ N/mm}^2$
 A_{sw} = cross sectional area of shear studs

At the first and subsequent perimeters v is limited to $2v_c$. If v exceeds this value then the concrete slab and/or the column should be redesigned $v \leq 2v_c$

The first perimeter is critical in deciding the size and arrangement of studs to be used. The length of the stud arm is determined by the perimeter where $v = v_c$ after which no more studs are required.

The program will automatically select the appropriate number and diameter of shear studs, however the user can select different sizes and arrangements to rationalise the design.

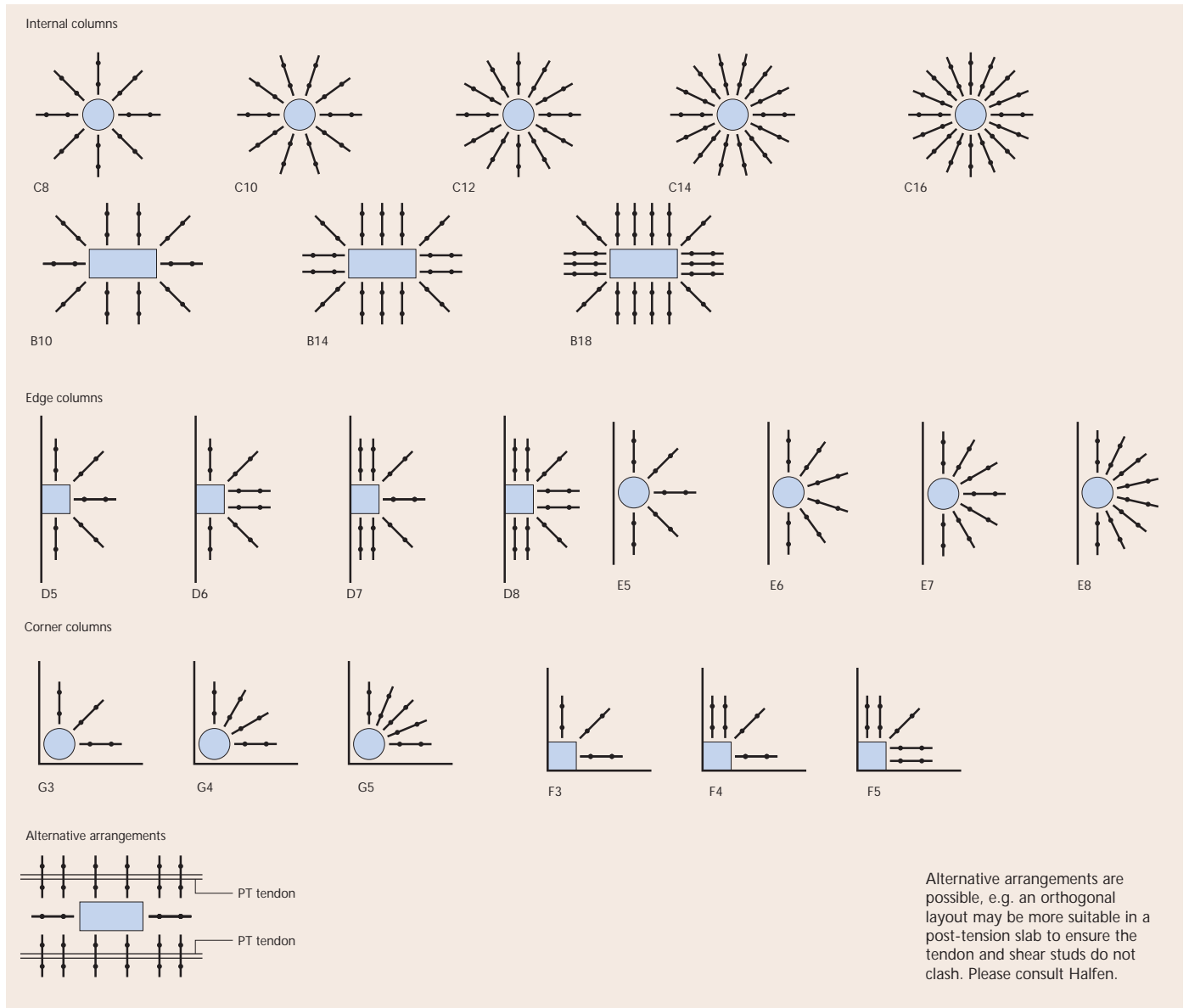


Detailing

The program automatically checks the geometry of the shear stud arrangement to ensure the following requirements are met.

- The first stud is placed between 0.35d and 0.5d from the face of the column ($0.35d \leq S_0 \leq 0.5d$).
- Subsequent studs are placed at centres $\leq 0.75d$. The exact spacings are dependent on the particular HDB unit selected.
- The maximum distance from the column face to the second stud = 1.125d ($S_0 + S_{r1} \leq 1.125d$)
- The maximum tangential spacing of the second studs is 1.5d.
- The absolute maximum tangential spacing of any studs is 3.5d, however this can be less depending on the reinforcement ratio, effective depth and type of column.

Typical arrangements of HDB elements/arms



Increased shear strength: membrane action

For internal columns where $\rho \leq 1.0\%$ increased shear strength is available due to membrane action with v up to $2.2v_c$. However the absolute maximum tangential spacing of any studs is reduced to $1.5d$ therefore this option may only be viable for highly loaded columns.