The general procedure to be adopted is as follows:

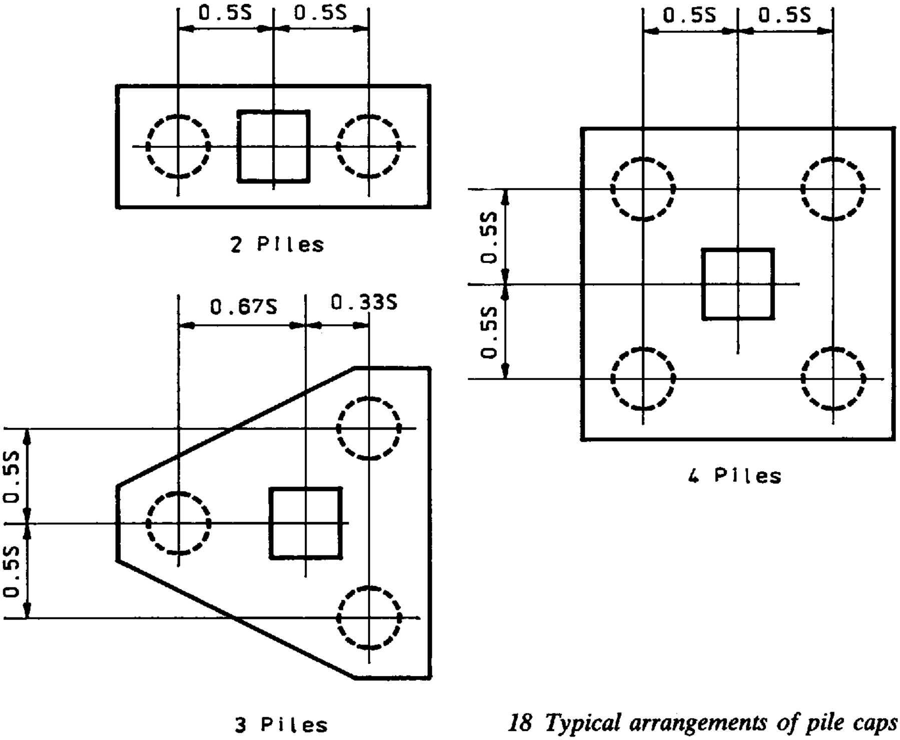
(f) Using the unfactored loads and moments calculate the number of piles required under each column

(g) Proportion the pile caps on plan in accordance with the above general principles. Typical arrangements are shown in Fig. 18 where *S* is the spacing of the piles

(h) Determine the initial depth of the pile cap as equal to the horizontal distance from the centreline of the column to the centreline of the pile furthest away

(i) Check the face shear as for reinforced pad footings, using factored loads, and increase the depth if necessary

(j) Calculate the bending moments and the reinforcement in the pile caps using the factored loads.



18 Typical arrangements of pile caps

4.10.10 Reinforcement in pile caps

All pile caps should generally be reinforced in two orthogonal directions on the top and bottom faces with not less than 0.0013 *bh* for Grade 460 or 0.0025 *bh* for Grade 250 in each direction.

The bending moments and the reinforcement should be calculated on critical sections at the column faces, assuming that the pile loads are concentrated at the pile centres. This reinforcement should be continued past the piles and bent up vertically to provide full anchorage past the centreline of each pile.

In addition, fully lapped, circumferential horizontal reinforcement consisting of bars not less than size 12 at a vertical spacing not more than 250mm, should be provided.

4.11 Robustness

4.11.1 General

If the recommendations of this *Manual* have been followed, a robust structure will have been designed, subject to the reinforcement being properly detailed[2].

However, in order to demonstrate that the requirements for robustness have been met, the reinforcement already designed should be checked to ensure that it is sufficient to act as:

(a) peripheral ties
(b) internal ties
(c) external column or wall ties
(d) vertical ties.

The arrangement of these (notional) ties and the forces they should be capable of resisting are stated in clause 4.11.2.

Reinforcement considered as part of the above ties should have full tension laps throughout so as to be effectively continuous. For the purpose of checking the adequacy of the ties, this reinforcement may be assumed to be acting at its characteristic strength when resisting the forces stated below and no other forces need to be considered in this check. Horizontal ties, i.e. *(a)*, *(b)* and *(c)* above, should be present at each floor level and at roof level.

4.11.2 Tie forces and arrangements

Forces to be resisted by horizontal ties are derived from a 'tie force coefficient'

$F_t = (20 + 4n)$ kN for $n \leq 10$, or
$F_t = 60$ kN for $n > 10$,

where n is the number of storeys.

(a) **Peripheral ties**
Peripheral ties should be located in zones within 1.2m from the edges; they should be capable of resisting a tie force of 1.0 F_t and should be fully anchored at all corners.

(b) **Internal ties**
Internal ties should be present in two directions approximately at right-angles to each other. Provided that the floor spans do not exceed 5m and the total characteristic load does not exceed 7.5 kN/m^2, the ties in each direction should be capable of resisting a tie force of 1.0 F_t kN per metre width. If the spans exceed 5m and/or the total load exceeds 7.5 kN/m^2, the tie force to be resisted should be increased *pro rata*. Internal ties may be spread evenly in the slabs or may be concentrated at beams or other locations, spaced at not more than 1.5 times the span. They should be anchored to the peripheral ties at each end.

In spine or crosswall construction the length of the loadbearing wall between lateral supports should be considered in lieu of the spans when determining the force to be resisted by the internal ties in the direction of the wall.