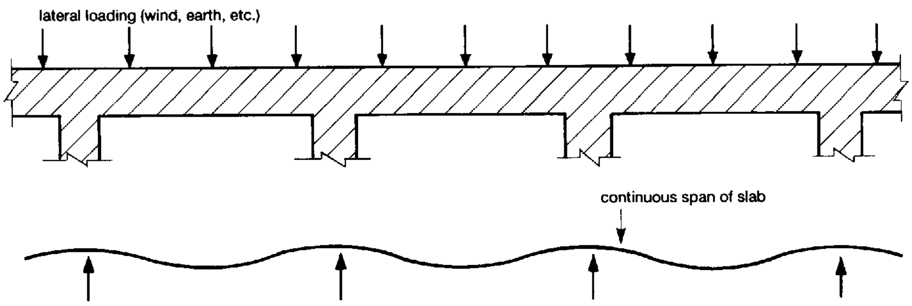

Figure 12: Spacing of cross-ribs: condition (a)

G_k	characteristic dead load
g_A	design vertical load per unit area
g_d	design vertical dead load per unit area
h	clear height of wall or column between lateral supports
h_{ef}	effective height
*I	second moment of area
*K_a	$\frac{1-\sin\theta}{1+\sin\theta}$ (Rankine's formula for retained earth pressure)
*K_1	shear stress coefficient
*K_2	stability moment trial section coefficient
*M	applied bending moment
*MR	design moment of resistance
*MR_s	stability moment of resistance
*M_w	applied moment in height of wall
*P_{ubc}	allowable flexural compressive stress
*P_{ubt}	allowable flexural tensile stress
Q_k	characteristic imposed load
*q	dynamic wind pressure
*SR	slenderness ratio
t_{ef}	effective thickness
*t_f	leaf (or flange) thickness
*V	design shear force
v_h	design shear stress
*W	load
W_k	characteristic wind load
*w_s	minimum width of stress block
*y	distance from centroid of section to centroid of stressed area
Z	section modulus
β	capacity reduction factor for walls allowing for effects of slenderness and eccentricity
γ_f	partial safety factor for load
γ_m	partial safety factor for materials
γ_{mv}	partial safety factor for materials in shear
*ρ	density

2.2 Lateral loading

2.2.1 Determination of centres of cross-ribs

The spacing of the cross-ribs is generally governed by one of the following four conditions:

(a) The flanges must act as continuous slabs spanning between the cross-ribs, as shown in Figure 12, when subjected to wind or other lateral loading, e.g. earth pressure in the case of a retaining wall.

(b) The flanges must not buckle under vertical loading. (Their slenderness is generally determined by the restraint provided by the intersecting cross-ribs as shown in Figure 13.)

(c) The flanges and cross-ribs must act together compositely as shown in Figure 14. The length of flange must be restricted in accordance with Clause 36.4.3, BS 5628 : Part 1.

(d) In developing the bending resistance of the composite box section, the interface between flange and cross-rib must not fail in flexural shear, as shown in Figure 15.

Note: Condition (c) does not limit the maximum centres at which the cross-ribs may be spaced but does limit the extent of the leaves which can be considered as contributing to the flange of the **I** section for structural purposes.

Typical calculations for the cross-rib centres from these limiting conditions for a tall single-storey building give the following:

Condition (a) (refer to Figure 12):

$M = P_{ubt}Z$

in which

M = applied bending moment due to wind
$= \gamma_f W_k B_d^2/10$ (reduced moment for continuity)

P_{ubt} = allowable flexural tensile stress $= f_{kx}/\gamma_m$

Z = section modulus $= t_f^2/6$ per unit height

Then, typically, assuming

$W_k = 0.6$ kN/m^2

$t_f = 0.1$ m

B_d = cross-rib centres required

$f_{kx} = 0.6$ N/mm^2 i.e. 7 N/mm^2 block set in a designation (iii) mortar (see BS 5628 : Part 1, Table 3)

$\gamma_m = 3.5$ (BS 5628 : Part 1, Table 4) and $\gamma_f = 1.4$

$M = \gamma_f W_k B_d^2/10 = 1.4 \times 0.6 \times B_d^2/10 = 0.084\, B_d^2$ kNm

$P_{ubt} = f_{kx}/\gamma_m = 0.6/3.5 = 0.17$ N/mm^2

$Z = t_f^2/6 = 0.1^2/6 = 1.67 \times 10^{-3}$ m^3

But $M = P_{ubt}Z$

$0.084 B_d^2 = 0.17 \times 10^3 \times 1.67 \times 10^{-3}$ (kN and m units)

$\therefore B_d = 1.84$ m

For a retaining wall, subjected to greater lateral loading, this condition can be the most critical and it is often necessary to increase the leaf and cross-rib thicknesses and/or reduce the cross-rib spacing from those normally encountered in tall single-storey buildings.

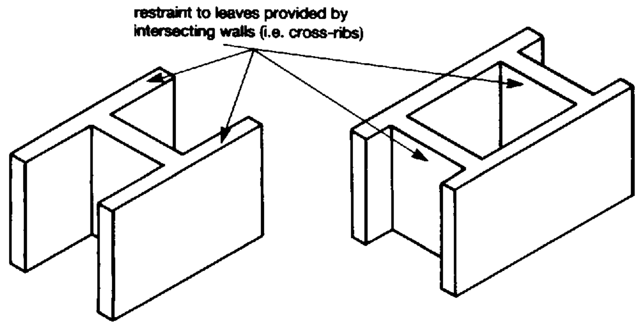

Figure 13: Spacing of cross-ribs: condition (b)

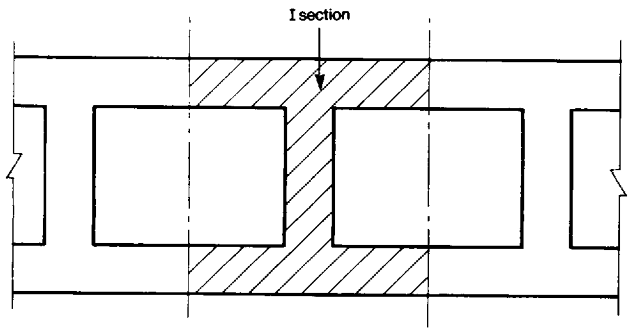

Figure 14: Spacing of cross-ribs: condition (c)

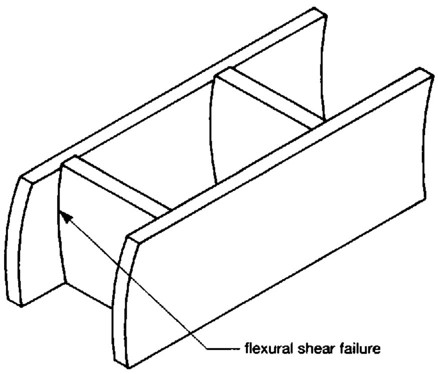

Figure 15: Spacing of cross-ribs: condition (d)

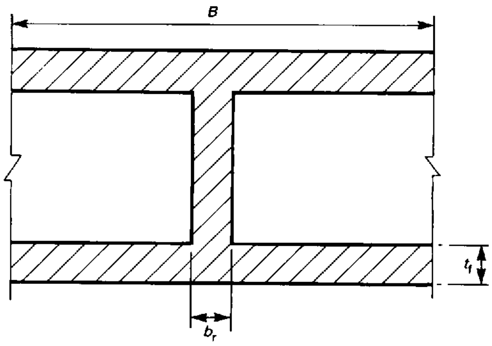

Figure 16: Symbols used for diaphragm wall geometry

Condition (b) (refer to Figure 13):

Slenderness ratio $= h_{ef}/t_{ef} = B_d/t_f$

Maximum permitted slenderness ratio = 27 (BS 5628 : Part 1, Clause 28.1)

$B_d/t_f = 27$

$\therefore B_d = 27 \times 0.1 = 2.7$ m

Condition (c) (refer to Figure 14):

BS 5628 : Part 1, Clause 36.4.3 states that, in assessing the section modulus of a wall including piers, the outstanding length of the flange from the face of the pier should be taken as six times the thickness of the flange where the flange is continuous, but in no case more than half the distance between the piers – in this design the cross-ribs may be taken to be the piers.

Then, typically, for a 6 m high diaphragm wall constructed throughout in 100 mm thick units,

$B_d = 6t_f + 6t_f + b_r$

$t_f = b_r$ (see Figure 16)

$\therefore B_d = 1.30$ m

It is considered that the effective flange width should also be limited to a proportion of the height of the wall even though no such limitation is provided for in BS 5628 : Part 1. It is therefore proposed that one-third of the wall height, as was applicable in CP 114 : 1969, Clause 311 (e), would be an acceptable limit and will be used here.
Then:

$B_d = h/3 = 6/3 = 2.0$ m

Condition (d) (refer to Figure 15):

There are two methods of achieving shear resistance between the leaf and the cross-rib, i.e. by bonding the brick and block courses or by using designed metal shear ties to maintain the composite action of the box section (see Figure 17). The choice of method is determined by a number of considerations which are discussed in Section 1.2.3.

2.2.2 Typical design dimensions

Experience has shown that in the case of single-storey buildings with wind forces of around 0.6 kN/m^2 and wall heights in the order of 8 m, the cross-rib centres are generally 1.0 to 1.3 m. The cross-ribs may be spaced at wider centres provided that only a restricted length of flange is considered as the effective section in resisting the bending, and that all other stress criteria are satisfied.

The greater the overall thickness of the wall, the greater is its resistance to lateral wind forces. Increasing its overall thickness also improves the wall's slenderness ratio, and thus its axial loadbearing capacity. Again, experience has shown that with the wind forces and wall heights quoted above, the overall thickness of the wall needs to be 0.4 to 0.7 m as shown in Figure 18, although the actual dimensions must be determined by calculation as shown later in the worked example.

2.3 Properties of sections

The range of overall thicknesses which can be achieved with concrete masonry diaphragm walls is considerable and affords the designer maximum flexibility.

In order to simplify the presentation of section properties a selected number of wall profiles have been calculated and their properties tabulated in Tables 1 and 2. Table 1 deals with concrete blockwork diaphragms in