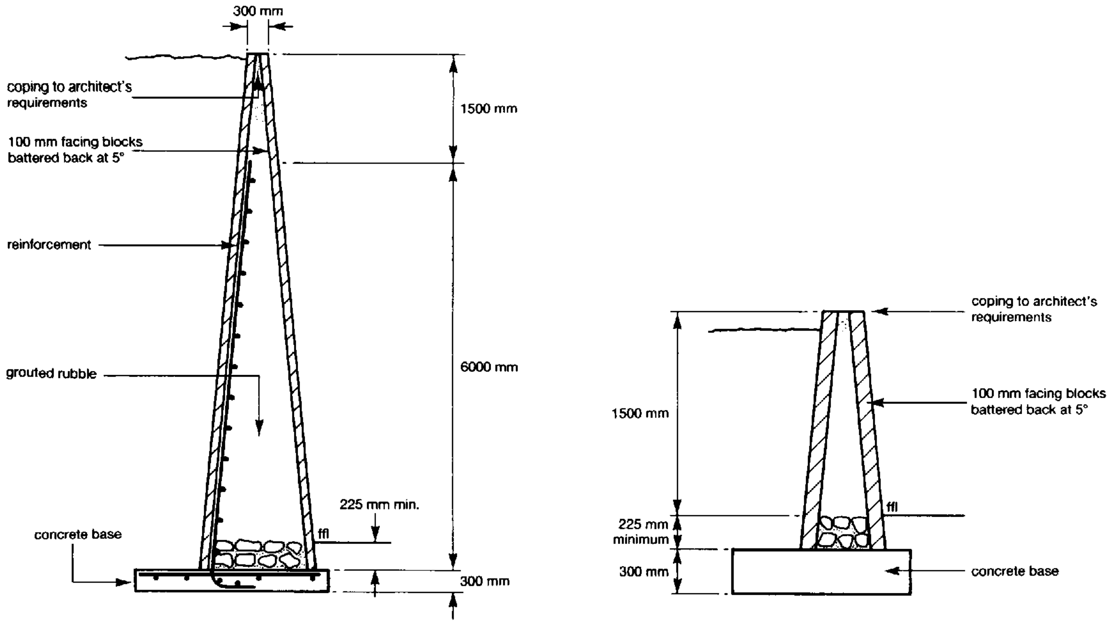
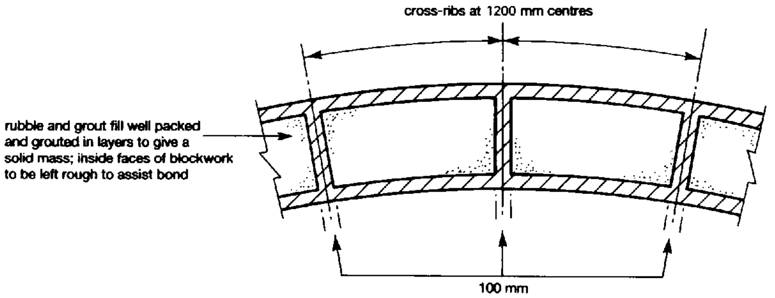


Section through reinforced wall

Section through unreinforced wall



Plan

Figure 10: Example of diaphragm wall used as a retaining wall

tendering procedures are simplified, and dependence on a variety of materials, subcontractors and separate site operations is eliminated, thus enabling the general contractor to work to a tighter programme under his own close control.

1.5 Other applications

At first, diaphragm walls were mainly used for tall single-storey buildings, in particular sports halls in schools and leisure centres. Their success has led to architects, engineers, developers and contractors applying the technique to numerous other types of buildings. Among these are now included factories, warehouses (with and without overhead travelling cranes), garages, churches, theatres, assembly halls, squash courts and retaining walls.

There are many applications in other fields, particularly where lateral loading is more significant than vertical loading. A diaphragm wall has been used as a mass retaining wall on a site which was covered with a large amount of demolition rubble. The rubble was used to fill the voids, and a cheap, strong, mass-retaining wall was achieved as shown in Figure 10.

A variation on this basic application for retaining walls is shown in Figure 11. The design can use a plain diaphragm wall, or further benefits may be derived by post-tensioning or reinforcing a similar wall section.

Sound reflectors on motorways in urban areas are another application for diaphragm walls. At present some reflectors are constructed in precast concrete, steel or timber. It is believed that concrete masonry diaphragm walls would be cheaper and more durable, and provide greater aesthetic appeal and potential for such applications. They may also be used for fire barriers in industrial buildings, and in farm buildings as silos or bins for the storage of grain, potatoes, etc.

Post-tensioned diaphragm walls were used in the Oak Tree Lane Community Centre, Mansfield, Nottinghamshire, which was subjected to massive ground subsidence due to coal extraction. The stiff composite structure performed excellently where other forms of construction might have suffered considerable damage due to the subsidence. This particular technique was recognized by the receipt of a Certificate of Merit for the project in the 1982 Structural Design Awards Scheme organized by the Brick Development Association.

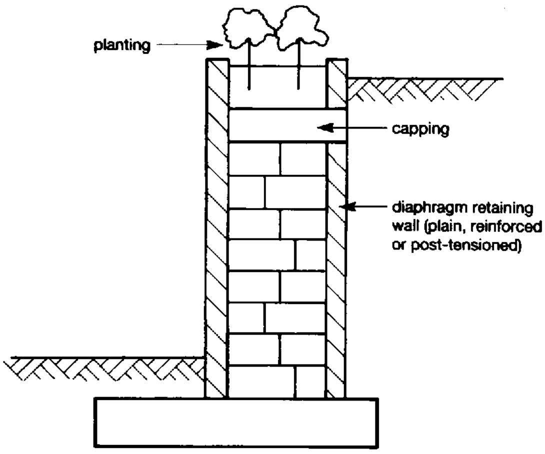


Figure 11: Alternative application as retaining wall

A similar post-tensioning technique was used in a concrete blockwork diaphragm wall project where the architect required clerestory windows around the full perimeter of the building. This meant that propping the wall by means of the roof structure was not possible and thus the wall was designed as a free cantilever. Post-tensioning the diaphragm helped it to cope with the higher stresses from the increased bending moment.

Whilst most of the applications of diaphragm walls have tended to concentrate on their effectiveness in resisting lateral loading, they also possess ideal properties to carry heavy axial loads. This results from their robustness for resisting buckling, thus allowing them to be designed at efficient stress levels to support a heavy axial load.

1.6 Potential for development and requirements for research

The development potential of the basic diaphragm wall technique is only now beginning to be realized. The diaphragm section with its high Z/A ratio and high radius of gyration make it ideal for prestressing. By prestressing masonry sections, further advantage can be made of masonry's high compressive strength whilst overcoming the disadvantage of its low tensile strength. Several prestressed masonry diaphragm walls have now been constructed, some including the use of concrete blockwork.

Concrete blockwork, in particular, lends itself to reinforcing and there is considerable potential for the development of this technique. Reinforcement may be applied to the wall as a whole or to strengthen one leaf of the wall, for instance in a retaining wall, to enable a comparatively thin leaf to span between the cross-ribs to support high lateral pressures.

The ease of construction and comparative lack of sophistication make concrete masonry diaphragm walls particularly effective in producing a highly engineered structure with a work force possessing normal trade skills. This obviously has considerable potential when considering agricultural buildings, construction in remote areas, and developing countries.

There are a number of aspects where engineering research is required to enable the diaphragm wall technique to be more fully exploited and extended in its use and range of applications. One such aspect concerns the shear at the junction of the cross-rib and flange. In bonded forms of construction, data are required for concrete bricks and more particularly concrete blocks, so that where very high shear stresses occur, for example in retaining walls, more accurate assessments of the shear strength may be made. In tied construction, where hollow or cellular blocks are used, information is required on the shear resistance which may be developed with the metal ties built into the external shell of those hollow units.

2 Design principles

This design guide is written in limit state terms and follows BS 5628 where appropriate. However, the design of more complex geometric masonry elements, such as the diaphragm wall, is not fully covered in BS 5628 and supplementary design procedures have been introduced. These are discussed and developed in the text before applying them later to the worked examples.

The design of the earliest diaphragm walls was made using fundamental engineering principles. The research work which has been completed to date has confirmed the logic of early assumptions and engineers can approach future designs of diaphragm walls with confidence.

It is only rarely that compressive stresses in the masonry are the governing factor in the design of diaphragm walls in tall single-storey buildings. The limiting condition is bending tensile stress due to wind loading, and this consideration determines the spacing of the leaves (or flanges). As a result, concrete masonry of low compressive strength is usually adequate for loadbearing purposes and the final choice of masonry type is more generally related to aesthetics, durability and to thermal, sound and fire resistance properties.

The structural calculations are carried out by selecting a trial section which is then checked for the various stress conditions. Full discussion and worked examples are included in Section 3 of this design guide.

2.1 Design symbols

The design procedure introduces additional symbols to those provided in BS 5628 : Part 1. A full list of all the symbols used in the text and the worked examples is given below. The additional symbols have been marked with an asterisk * for identification.

A	horizontal cross-sectional area
$*B_d$	distance between centres of cross-ribs
$*b_r$	thickness of cross-rib
$*b_v$	length of void between cross-ribs
$*C_{pe}$	external pressure coefficient (wind)
$*C_{pi}$	internal pressure coefficient (wind)
$*D$	overall thickness of diaphragm wall
$*d$	width of void between flanges
e_x	eccentricity at top of wall
f_k	characteristic compressive strength of masonry
f_{kx}	characteristic flexural strength (tension) of masonry
f_v	characteristic shear strength of masonry
$*f_{ubc}$	applied flexural compressive stress at design load
$*f_{ubt}$	applied flexural tensile stress at design load