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# Design of concrete masonry diaphragm walls

Report of a Concrete Society Working Party

## Summary

This Report is a design guide which provides the information required by structural engineers to design concrete masonry diaphragm walls. The sizes and types of concrete units which may be used for these walls are discussed and information is provided on aspects such as appearance, moisture penetration, movement joints, openings, services and acoustic and thermal properties. Key points on construction and economy are noted. Design principles are comprehensively explained and the background to the design method is fully detailed. Worked examples are provided covering a single-storey warehouse and a retaining wall. Design graphs and tables are provided and the report is illustrated by numerous sketches and figures.

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# 1 Introduction, general arrangements and details

## 1.1 Introduction

Developments in structural masonry, particularly the introduction of diaphragm and fin walls over the past 20 years, have provided economically viable alternatives to reinforced concrete, structural steel and structural timber for certain applications. Diaphragm walls are now acknowledged as having many advantages to offer the client together with benefits for designers, developers, contractors and users, compared with framed solutions. Nor is their use limited to tall single-storey buildings; diaphragm walls have been successfully applied to other types of construction such as retaining walls and boundary/barrier walls. Indeed, wherever large lateral loadings or moments are combined with minimal vertical loading, the diaphragm wall is worthy of consideration.

Diaphragm walls fulfil the functions of structure, cladding, insulation and lining in one operation, using only one trade, which can be carried out by the main contractor. Experience has shown that diaphragm walls are well suited to the building types mentioned in the foreword, having proved to be more economic, speedier and simpler to construct, and more durable than the traditional steel frame and sheet cladding type of building. There is scope to exploit the aesthetic qualities of concrete masonry and its robustness offers vandal resistance as a further bonus.

Generally, diaphragm walls become more economic compared to framed construction, as the height of the wall increases. On recent projects relatively narrow diaphragm walls with a 100 mm wide cavity have also proved to be economic both in construction time and financial terms for buildings with wall heights of only about 4.5 m. This wall height is ideally suited to small factory units and numerous such projects, some incorporating crane gantries, have been built throughout the country. To date, diaphragm walls with heights of up to 10 m have been designed and there is no reason to suppose that this is either the structural or the economic limit. Diaphragm walls have no advantage however where normal cavity walls can meet all the structural requirements.

Diaphragm walls used in tall single-storey buildings illustrate many of the advantages of the technique. They also demonstrate the overall design approach which can produce structural economies by considering the interaction of different parts of the structure, for example walls and roof, as opposed to considering these elements in isolation. This is extremely important in the design of structural masonry. The design and construction of tall single-storey buildings using diaphragm walling is therefore considered in some detail to illustrate these principles.

The correct and economical engineering use of any material requires a full understanding of its properties. Concrete masonry is no exception. It is strong in compression and comparatively weak in tension and it is therefore ideal for supporting axial compressive loads, but cannot so readily resist lateral loads which induce tensile bending stresses. The development of diaphragm walls began with the realization of the importance of the use of a high ratio of section modulus to area ($Z/A$) and the need to take advantage of the gravitational forces involved. Both of these requirements involve an appropriate geometric distribution of the material, that is to distribute the material to its largest practical lever arm. It is also necessary of course to provide adequate resistance to shear forces and to the buckling tendency of the compression portion of the section.

By applying the basic principles of high $Z/A$ ratio and large lever arm and by using a minimum thickness for leaves and cross-ribs, as appropriate to the loading condition, diaphragm wall construction has evolved and developed into an economic structural medium.

From the practical point of view, the geometric arrangements of the various wall profiles should be consistent with standard block or brick dimensions. In this regard concrete masonry diaphragm wall sections offer an almost unlimited combination of profiles resulting from the wide range of sizes and thicknesses of commonly available standard units. Hence, with a careful combination of bonding requirements and structural design requirements, the designer should be able to achieve maximum efficiency and economy from a diaphragm wall design in concrete masonry.

## 1.2 General arrangements and details

### *1.2.1 Wall section*

A diaphragm wall is basically a wide cavity wall with the leaves of concrete masonry connected together with perpendicular cross-ribs (diaphragms) to form a series of 'box' or I sections as shown in Figure 1.

The two leaves of the wall act as flanges in resisting