SELECTION OF SHAPES OF CEMENT BLOCKS BETTER SUITED TO SRI LANKAN CONDITIONS

by

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Abstract

Although a vast array of block shapes is available, not all blocks are suitable for local use in Sri Lanka. Hence, information on selection of suitable block shapes is opportune and useful. In order to select shapes suitable for local use, a survey was conducted on various block shapes which are successfully used in other countries. These block shapes were then assessed against important considerations that affect production of blocks, and construction and performance of block walls under local conditions. Plain ended two-core block was found to be the best suited with half blocks supplied separately, and full potential of Architectural blocks was found to be yet unutilised in Sri Lanka.

1.0 Introduction

Concrete block is a widely used material for building construction. It is made of a cement sand mix or a concrete mix. Poor quality and variability of bricks in Sri Lanka as well as easy availability of necessary raw materials, technology and equipment for block production, favour further exploitation of this material.

Concrete masonry is hand-made with concrete blocks which are precast. These blocks are proportioned so that their size enables delivery and laying manually. Over the years many shapes of blocks were evolved to suit various specific situations which resulted in a baffling array of block shapes to select from.

A situation in which selection of block shapes becomes important is when a new block-making machine and moulds are to be purchased. Most often machine and moulds are imported and those moulds may be designed to suit the demand in that country. Sometimes local fabricators produce replicas of imported machines and moulds. Thus, prior knowledge of block shapes suitable for local conditions will facilitate procurement of the best equipment for the local needs.

Absence of freezing and thawing, smaller range of temperature variation, low roof loads due to the absence of snow, abundance of single storey buildings and ready acceptance of thicker walls, give opportunities to use low strength blocks with adequate durability in masonry construction. In fact the main demand in Sri Lanka is for blocks suited for buildings of two storeys or less. For satisfactory performance, these low strength blocks require compatible low strength mortars. The combination of weak block and compatible weak mortar rule out the use of face shell mortar bedding (Figure 1). Hence, block shapes better suited for full mortar bedding are desired.

As mortar is generally more porous than the block, head joints are often the weak spots allowing greater rain penetration. Hence, head joints with mortar across the entire thickness of the wall is desired, as cavity walls are uncommon. This, not only favours certain block shapes, but also requires a block-laying technique where mortar in the head joint is compacted by slicing with a trowel. The widely used technique of buttering the head joint surface of the block with mortar and pushing the block sideways so that mortar oozes out is ineffective, due to the low cement mortar used and greater area of the head joint. Thus, the block-laying technique adopted also favours certain block shapes as block can be gripped by hand differently.

Information is easily available on selection of block size, block strength and mortar mix. Lack of guidance on selection of shapes and availability of a wide variety of block shapes to choose from, create confusion in the user's mind. Hence, consideration of more suitable block shapes for use will be opportune and beneficial.

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2.0 Different Types of Blocks and their Usefulness

2.1 General -

Blocks are available in a variety of shapes which have been developed over the years and each shape is the result of overcoming some shortcomings in either production or construction. More recently, many studies (1,2) were conducted to modify the shape of the block in order to improve the structural performance of masonry. There were also other studies (3,4) aimed to improve productivity of installation, out-of-plane bending behaviour and rain penetration resistance. These studies have widened our understanding of the influence of block shape in masonry structures and also have produced some shapes with only a few changes to the common block as well as other shapes which are radically different. Various block shapes and their functional advantages and disadvantages are presented below.

2.2 Conventional blocks and blocks resembling them -

Solid block is probably the oldest type of concrete masonry unit. Now, its use is limited to special applications such as, at the top or bearing course of loadbearing walls, for increased fire protection for manhole construction, or for boundary walls. It provides better fire protection and sound insulation while it is easy to cast especially by hand casting, and economical for single storey buildings (with 100 mm block width). Its disadvantages are higher weight, difficulty in handling, extra material required to cast the block and extra mortar required for block-laying.

Hollow block is one of the most important developments in concrete masonry and it is the most widely used block with many variations of shape. Its advantages are reduction in weight, better thermal insulation, consumption of less material for block as well as mortar, and easier handling. Disadvantages are the need for better quality control to prevent cracking during production and the need for mixes with higher cement content for casting blocks.

A very common shape is a hollow block with two cores (Figure 2). The cores of the hollow unit are tapered to permit ready stripping in the moulding process. The taper also gives a broader base for mortar bedding and for better gripping by the mason. Sometimes the junctions of the central web and face shell are thickened (Figure 2-a, c). This strengthens both the web and the face shell, and also minimizes cracking during stripping. However, the unit consumes more material and gripping the block with the centre web becomes a little difficult.

Multicellular units contain more than two cores and the more common arrangement consists of three cores (Figure 16). It is particularly useful when the length of the unit is more than twice its width, easier to handle and more robust against breakage during handling. Its disadvantages are that it consumes more material, needs greater care in stripping and, often, results in a heavier unit than a two core unit.

Hollow unit with flanged ends (Figure 1) is tailor-made for block-laying with face shell bedding. Its advantages are easy handling by masons and possibility of reinforcing. Difficulty in stripping from moulds, susceptibility to breakage, need for special blocks (at corners, stopped ends, door jambs, window jambs or piers), and greater misalignment of webs (Figure 17) in a wall are some shortcomings.

Hollow block with plain ends (Figure 7) is more common (5) with smaller unit size such as the 100mm width and the 150mm width sizes. Its advantages are: (i) it can be used for stretcher, stopped end, corner or pier units, thus minimizing the need for special blocks; (ii) greatly reduced misalignment of webs in a wall; (iii) easy to strip from the moulds; (iv) lesser likelihood of breakage during handling; and (v) provides greater area at head joint and hence it is better suited for block-laying with weak mortars. For larger units (200mm width or more) used with strong mortar where face shell bedding is used, this unit may give rise to lower productivity and wastage of mortar.

Block with tongue and grooves, or grooves (Figure 3) minimizes cracking and provides good bond at head joints (12). It improves rain penetration resistance, sound insulation and thermal insulation too. Its disadvantages are that stripping from the mould is difficult and placement of mortar at the head joint requires greater care and consumes more time.

Some core designs include a degree of flaring of the face and web (Figure 4) to give a broader base for mortar bedding, better gripping by the mason, and easy stripping from the mould. However, it consumes more material in forming the block.

Compared to two-core hollow unit, the three-core hollow unit provides a weaker wall section at a head joint. To overcome this, face shells are sometimes thickened at the centre (Figure 5) to provide greater tensile strength at mid-section.

To obtain half blocks, sometimes an easily split slotted or kerfed (Figure 6) two-core unit is available. Convenience in obtaining half blocks from one stack of full blocks is offset by the fact that these full units provide a weaker wall section at a head joint in spite of utilizing
similar quantity of material in making the block. Also, it is expensive to produce due to difficulty in stripping and shorter life span of the mould. Hence, use of special half length units and cutting of shorter length units from full units with a masonry saw are preferred.

2.3 Special (accessory) blocks for use with stretcher blocks

Half blocks are units one-half the length of full stretcher blocks and are required at an end or an opening. Corner blocks (Figure 7-a) have one end cast plain for use in pilasters, piers or exposed corner construction. Double-corner blocks (Figure 7-b) are similar but have both ends plain, and are used for piers or columns single block long. Bullnose blocks (Figure 8) are corner blocks having one or more small radius-rounded corners which are used instead of square-edged corner units to minimize chipping during service. Return or corner-angle blocks (Figure 9) are used at corners, when block width is unequal to half the length of the block, to maintain horizontal coursering with the appearance of full length and half length units. Jamb or sash blocks (Figure 10) are used to facilitate the installation of windows or other openings with different kinds for steel and wooden frames. Capping blocks (Figure 11) have solid top faces for use as a bearing surface in the finishing course of a wall. Control joint blocks (Figure 12) are used to provide shear resisting control joints, particularly for retaining walls. Bond beam blocks (Figure 13) serve as shuttering for reinforced bond beams embedded in a wall. Plumbing or conduit units (Figure 14) are useful to install services.
Figure 1 - Types of mortar bedding (5)

a) 4 in. Block

b) 6 in. Block

c) 8 in. Block
d) 12 in. Block

Figure 2 - Hollow blocks with two cores
Figure 3 - Tongues and grooves

Figure 4 - Flared webs and face shells

Figure 5 - Thickened face shells
Figure 6 - Block for easy splitting

One plain end (single corner)  
Both ends plain (double corner or pier)

Figure 7 - Corner blocks

One plain end (single corner)  
Both ends plain (double corner or pier)

Figure 8 - Bullnose units

Bullnose radius varies 1 to 3 in
The need for most types of these units can be substantially reduced with plain ended blocks and cutting (Figure 15) will help further.

2.4 Blocks differing from conventional blocks -

The core-aligned block (Figure 18-a) is an improvement of the conventional block (1,6) where block shape is altered to attain alignment of webs for running bond construction. This is done by minimizing the taper of the webs and face shells and increasing and reducing, respectively, the thickness of the middle and end webs. The wavy-core block (Figure 18-b) is a further improvement (1) of the above block where further thickening of the webs along the block's centre line has the effect of strengthening the block and postponing the onset of cracking along the head joints.

Fin block (Figure 18-c) is lighter and stronger, and it is laid in a full bed of mortar unlike face shell bedding (2). It consumes less mortar for block-laying, produces vertically aligned cores and can be grouted with vertical reinforcement. Its disadvantages are that horizontal reinforcement is difficult to be placed and, due to reduction of compression zone, it has poor out-of-plane moment capacity.

Slotted acoustical blocks (Figure 19) are suited for places like gymnasiums and factories where noise generation is high (5). The block absorbs sound in the middle and high frequencies by acting as damped resonators, where the slotted openings moulded into the face of the unit conduct sound into the cores. The disadvantages are that the structural strength is reduced, insects may form colonies inside, and cleaning the surface is difficult.

Ivany block (7) and H block (5) (Figure 20) are developed in the United States specifically for reinforced grouted masonry, and they facilitate easy placement of both vertical and horizontal steel. The blocks act like forms and rely more on the grouted area and reinforcement for structural action, and hence, they are not suitable for unreinforced masonry construction or lightly reinforced walls. These blocks are not as long and not as high as common blocks.

Interlocking blocks (Figure 24-a,b,c) are designed to improve productivity of installation and out-of-plane flexural capacity, and provide effective rain penetration resistance. These blocks rely on vertical and horizontal interlocking for stability during erection. The walls, made of these blocks, are fully grouted or surface bonded to provide flexural strength. These blocks may be worthwhile for massive construction projects, or where skilled labour is expensive.

Even units or ground units (8) have also been developed. These units are similar to conventional solid blocks, but the height tolerance is reduced to 1mm. The structural purpose of embedding the units in mortar is to adjust unevenness of the unit surfaces, so as to avoid large local tensile stresses in the unit, and the usual bed joint thickness is 10mm. These units require only a thin layer of mortar, less than 3mm thick having a maximum particle size of 1mm. The mortar is applied by a special trowel or some mechanised means. To achieve any significant economy, block-laying machines are required where several blocks are laid at once.

A single wythe masonry unit (Figure 22), was developed (4) to provide good rain penetration resistance. It has dimensions similar to the conventional block. As the webs are arched between the faceshells, conventional wall reinforcing cannot be used.

Insulated block which provides improved insulation and dry block which provides improved protection from moisture are not very useful in the Sri Lankan context.

2.5 Architectural blocks -

Architectural concrete masonry units offer opportunities for almost unlimited architectural expression. The selection of the unit profile, or even the unit dimensions, may be closely related to the architectural design of the building. Architect may also decide on surface colour and texture, whether or not aggregate will be exposed, and the type of aggregate to be exposed.

Split block (Figure 21-a) is fractured (split) lengthwise by the machine to produce a rough stone-like texture. The fractured face, which is exposed when the unit is laid, is irregular but sharp, breaking through and exposing the aggregates in the various planes of fracture. By casting a bigger row of holes initially, ribbed split blocks (Figure 21-b) can be obtained. These are also used for load-bearing work.

Patterns and profiles in the block can be made (Figure 23) with vertical scoring, fluted or ribbed faces, moulded angles or curves, projected or recessed faces, or combination of these surfaces. The designer can select virtually any shape that can be moulded vertically within the bounds of the 450 x 650mm metal pallet under the block machine.

Other effects can also be made by using the same block design in different pattern bonds. Furthermore, by use of Architectural units in combination with plain units many interesting designs can be created.

Another alternative is the prefaced concrete masonry unit. Here facings can be applied either on the hardened block as in the case of resin-aggregate mixtures
or as the block is cast with facing and block forming an integral bond as in the case of cement-aggregate mixtures. Here too, many shapes are possible.

Slump block (Figure 25) is shorter than a normal block and it is produced by using a concrete mixture finer and wetter than usual. After removal of the mould, the block as cast is squeezed to give a bulging effect and a shorter block.

3.0 Important Considerations in Selection of Blocks for Local Use

3.1 General

All the different types of blocks presented above, are known to be in satisfactory use around the world, but are not suitable for Sri Lankan conditions. Also the practice of making special blocks for a variety of situations is undesirable, and the normal block that can meet most of such situations is preferred. In the succeeding sections, important considerations which govern the selection of blocks most suited for local use are discussed, with special reference to the two main types of blocks available in Sri Lanka: plain-ended (Figure 7-b) and flange-ended (Figure 1).

3.2 Structural considerations

As mentioned previously, blocks and mortar used locally are weaker compared to those used elsewhere. Further, many researchers (2,6) have established that full mortar bedding increases load bearing capacity significantly. As cement is the costliest material in a block wall, use of full mortar bedding is also the most economical way of optimising the load bearing capacity and such optimisation is most welcome in low strength walls. Hence, full mortar bedding is extremely beneficial and blocks better suited for face shell bedding (Figure 1-b) are not desirable.

Units with less misalignment of webs in a wall provide improved structural performance (2,9). Hence, blocks with plain ends (Figure 7-b) are more desirable than blocks with flanged ends (Figure 1-b).

Use of low consistency lean mortar and full mortar bedding requires a different block-laying technique consisting of applying a full bed of mortar, placing the block in position, and placing and compacting mortar at the head joint by slicing movements of the trowel. Rain penetration resistance is improved by this technique as it involves minimum movement of the block after it has been placed in contact with fresh mortar (10). This block-laying technique also favours plain ended blocks as mortar wastage is considerable with flange ended blocks.

As amount of cement used locally in blocks or mortar is low, drying shrinkage and wetting expansion are only of minor importance in selection of the block shape. In unreinforced block walls tensile strength parallel to bed joints helps the wall to span horizontally between cross walls or pilasters or in unexpected situations of differential settlement. Fully mortared head joints of plain ended blocks will be preferred as they provide greater tensile strength.

Cracking of block shell can be minimized by concentrating the main area of the block in the face shells (9). Strong blocks induce stepwise cracking around the blocks and multicellular blocks resist diagonal cracking of the block better (9). Cracking of mortar bed joints by tension or shear forces gives rise to tensile debonding or shear debonding along the mortar-block interfaces, and full mortar bedding and greater area of blocks minimise such cracking. Thus multicellular blocks will perform better in such a situation.

Cracking at head joints can be minimised by provision of grooves or tongues and grooves on end faces or end flanges of the block. As a full head joint is more advantageous against head joint cracking, plain ended blocks even without grooves will perform better.

Although the most common application in Sri Lanka is blockwork with cavities unfilled, there is some scope for blockwork with cavities filled and for reinforced blockwork. For the latter two applications, plain ended blocks are better than flange ended blocks as misalignment of cores is smaller giving continuous grout cores of larger sectional area. In addition, compaction of grout is easier with the absence of smaller cavities at the head joints (Figure 17).

Simple movement joints can be made with any block shape, and special blocks (Figure 12) are usually used for movement joints that transfer shear. However, it is also possible to make the latter type of joints with flange ended blocks (Figure 12) without the use of special blocks.

3.3 Other Considerations

Most of the block walls in Sri Lanka are single-wythe walls, where water is kept off the wall by roof overhangs, drips, plaster and other details as well as low driving wind. Walls built with mortars with high water retentivity such as lime mortars and walls constructed with full head and bed joints with well compacted mortar perform better (11,12). Generally, head joint is more vulnerable to leakage than bed joint as the latter is likely to receive better compaction due to dead weight of blocks. As plain ended blocks give rise to deeper head joints and since these head joints can be compacted better, these blocks are preferred over flange ended blocks as regards rain penetration resistance.
NOTE: SLOTS MAY BE CAST IN UNIT WHEN MOLDED OR CUT OUT WITH A MASONRY SAW AFTER UNIT HAS BEEN CURED.

SLOTTED UNITS

UNITs WITH SECTIONS REMOVED

Channel bond beams
Single C
Double C

Open-end bond beams

Figure 13 - Bond beam blocks (5)

Figure 14 - Plumbing or conduit units (5)
Figure 15 - Corner layout with cut blocks (5)

Figure 16 - Units with more than two cores (5)

Figure 17 - Misalignment of webs (2)
(a) The core-aligned block.  
(b) The wavy-core block.

(c) The fin block system.

Figure 18 - Core-aligned block, wavy-core block and fin block (2)

Figure 19 - Slotted accoustical blocks (5)
Consumption of mortar for block-laying differs with shape of the block, in case of full mortar bedding. As regards economy by reduced mortar consumption, flange ended block is superior to plain ended block, and two core block is better than multicellular block of same width.

Productivity of block-laying depends mainly on efficiency in spreading of mortar, laying blocks in position, and adjustment of blocks to line, level and plumb. Both the main types of blocks are similar with none having an edge over the other. Flange ended block is easier to position but, difficult to form the head joint and the opposite is true for plain ended block.

Production of all the common block types can be done by machine casting with equal ease, but flange ended block requires greater quality control to prevent cracking at demoulding. Plain ended block is preferred for hand casting.

Plain ended block requires very few special blocks for use in buildings while flange ended block requires a vast array of special blocks for corners, stopends, jambs, etc. Hence, former is more convenient for building construction.

Provision of services in a block wall is not easy whatever the block shape, unless special blocks (Figure 14) are used. However, it is more difficult with multicellular blocks and even more so with blocks where cavities do not occur throughout the depth.

Fire resistance does not appreciably change with block shape, provided aggregate type is the same. The unit’s fire resistance depends on volume of solid materials on the heat path which is usually expressed as the equivalent solid thickness.

Control of heat flow, air flow or water vapor flow in a blockwall is generally not an important consideration in Sri Lanka. Concrete masonry is an excellent sound barrier because of its density, but block shape in itself is not a significant variable if block density is the same.

For blocks of similar compressive strength, plain ended block is superior to flange ended block as regards likely damage during transportation and handling.

Influence of block shape on cost is not so significant as the mix proportion, the cost of materials used, the efficiency of the block-making machine, the rate of block production or the effectiveness of the block plant management. However, multicellular blocks or blocks in which cavities do not go throughout the block height, are costlier due to greater consumption of material.

4.0 Conclusions

The following conclusions can be made from this study:

(a) A vast array of blocks shapes can be used, but not all are effective in local conditions;
(b) The full potential of architectural block shapes still remains to be exploited in Sri Lanka;
(c) Plain ended blocks are better suited for local conditions;
(d) Two-core arrangement is preferable to the multi-core arrangement; and
(e) Provision of half blocks, separately, is preferable than providing blocks that can be readily split into half blocks.

5.0 References


Figure 20 - Blocks for heavily reinforced masonry (5,7)

Figure 21 - Split block (5)
(a) Masonry unit.

(b) Typical wall section.

Figure 22 - Rain resistant unit (4)
(a) Scored, ribbed and fluted faces.

(b) Reesed faces

(c) Angular and curved faces

Basket weave  Taper block  Bevel siding  Serpentine

Figure 23 - Architectural blocks (5)
Epoxy-based mortar is extruded into the joints after dry stacking.

Figure 24 - Interlocking blocks (3)

Figure 25 - Slump block (5)