ABSTRACT

Concrete hollow blocks for use in masonry have been produced in a large variety of shapes and sizes. Within the limits of codal requirements, it is possible to vary the overall size of blocks, face and web shell thickness. However, when these blocks are used in load bearing masonry, all the shapes with a certain void/solid ratio cannot be said to be equally efficient. In this study, it is demonstrated that the wall to block strength ratio considerably vary with different shapes of blocks and types of mortar bedding. Theoretical analysis also indicate the presence of stress concentrations in certain shapes and arrangement of blocks leading to reduction in the capacity of masonry. An efficient shape is suggested to eliminate these shortcomings when used in common running bond.

INTRODUCTION

Precast concrete hollow and cellular blocks have been widely used for masonry work in developed countries but their use in India has been limited. Bricks continue to be extensively used. However, it is observed that clay suitable for making high strength bricks are not available in southern parts of India (1). Consequently, clay bricks produced and presently used in construction are non-uniform in quality. Of late, there has been a steep rise in the cost of bricks and clay products. These factors have encouraged the investigations in the use of hollow concrete blocks, especially for load bearing walls...
of low-rise constructions like residential houses. It is also realised that in a developing country like India, scarce resources should be put to optimum utilisation and hence it is imperative that maximum possible capacity of masonry is achieved with a given block unit.

SHAPES AND SIZES OF HOLLOW BLOCKS
A hollow block is defined as one having one or more large holes or cavities which either pass through the block (open cavity) or do not effectively pass through the block (closed cavity) and having the solid material between 50 and 75 percent of the total volume of the block calculated from the overall dimensions. Codes specify the block properties such as block density and compressive strength (2). Within the limits of these requirements, it is possible to vary the overall size of blocks and thickness of face and web shells. A large variety of shapes and sizes have been developed in various countries. Some examples (3 to 7) are shown in Fig.1. All these blocks are shaped to conform to the codal requirements of the respective countries.

STRENGTH OF MASONRY UNIT/WALL PANEL
The compressive strength of the individual hollow block depends on the cross sectional area, height, concrete mix and moulding methods used. The strength of the wall panel depends upon several factors such as strength of the unit, strength of jointing mortar, deformation characteristics of the unit and mortar and type of bonding of units.

In most conventional constructions with concrete blocks running (stretcher) bond is adopted. Mortar can be spread out on both the web and face shells of the hollow block (full bedding) or on the face shells only (face shell bedding). Full bedding is applicable when the webs of the blocks laid in a course bear fully or partially on the webs of blocks in the lower course.

For the three-cored blocks and many other types of blocks only face shell bedding of mortar is used in running bond. In such arrangement, the web shells of these blocks virtually do not carry any load except wherever they get supported partially or fully. In the case of a typical two-cored unit having three webs of equal thickness when used in running bond as shown in Fig.2, its mid-web rests over the end webs joined by mortar. Even in this arrangement, however, all the webs of all blocks do not get uniformly good bearing support.

Studies were undertaken at the Building Technology Laboratory, I.I.T.,
1.1. 3 CORED WITHOUT END PROJECTIONS.

1.2. 3 CORED WITH PROJECTIONS AT ONE END.

1.3. 3 CORED WITH PROJECTIONS AT BOTH ENDS.

1.4. 3 UNEQUAL CORES.

1.5. PEAR SHAPED CORES.

1.6. TAPERED CORES.

Fig. 1. Different types of blocks.
Madras on the performance of three different types of blocks and walls made with them (8,9). The details of blocks are shown in Fig.3. The ratios of wall to block strength observed for these blocks with full mortar bedding and with face shell bedding only are given in Table-1. As seen from the table, this ratio is about 0.44 for the case of face shell bedding and goes up to about 0.60 to 0.65 for full bedding. Similar results have also been observed in studies reported by others. In tests reported by Read and Clements (10) this ratio varies from 0.38 to 0.45 average (0.415). The unit used is similar to Type A block (Fig.3) and possibly used in face shell bedding. Tests by Richart, Woodworth and Moorman (11) on walls built with 8" (200 mm) thick units with three oval cores indicated an average ratio of 0.53 and the ratio of axial compressive strength with face shell bedding to that with full bedding was 0.8.

PROPOSED DESIGN OF UNIT TO IMPROVE STRUCTURAL EFFICIENCY

As seen from the above, it is apparent that the use of blocks of different shapes and core sizes but keeping all the web thicknesses uniform, results in obtaining face shell bedding only in the walls, and partial bedding of the webs also in a few cases. These shapes, therefore, are inefficient structurally. This shortcoming can be avoided if stack bond is used instead of running bond. On the other hand, stack bond in masonry walls is undesirable owing to the presence of continuous vertical joints. Thus there is a real need for development of a suitable shape for the block to obtain full bedding in running
Fig. 3. PLAN OF BLOCKS USED IN EXPERIMENTAL INVESTIGATIONS. (Vide Table. 1)

Fig. 4. REDESIGNED BLOCK - TYPE D
bond. With this objective, the two-cored hollow unit was redesigned to have a rationalised shape with a mid-web thickness equal to twice the end web thickness plus one joint mortar thickness (10 mm), the dimensions of which are shown in Fig.4. This block when used in running bond with a 200 mm stagger, results in the mid-web resting on the two end webs joined by mortar and vice versa in consecutive layers of masonry. By this arrangement (Fig.5) all the webs get full bearing support throughout the length/height of the wall. The total core area of the redesigned hollow unit is retained to be almost equal to that of Type C block (Fig.3).

**Fig.5. MASONRY ARRANGEMENT WITH TYPE-D BLOCKS.**

**COMPARISON OF THE PERFORMANCE OF HOLLOW BLOCKS**

To compare the performance of the redesigned unit and the unit with equal web thickness, which has been adopted in most earlier studies (and which is normally adopted in practice, a theoretical analysis of walls under axial compression using finite element method has been developed (12). The three dimensional analysis of walls makes use of the two dimensional membrane elements, idealizing the face and web shells of the block as membrane elements (as plane stress elements in different planes).

Wall panels of size 1200 x 1200 mm (Fig.6), using the redesigned block, (Type D) and Type C block were analysed. Type C blocks were chosen for comparison since the proposed redesigned block has almost the same core area and the same volume of material. The finite element analysis has been carried out for different loading conditions. The details of the wall panel analysed is shown in Fig.6.
Typical graphs showing the comparison of vertical stresses in face and web panels at two different layers of the walls using both the blocks are given in Fig. 7 and 8 respectively for a concentrated vertical load. Tables 2 and 3 show the percentage deviations of vertical stresses in face and web panels respectively for a uniformly distributed load on the wall using the two types of blocks.

**CONCLUSIONS**

1. The available experimental results of wall to block strength indicate the advantage of full mortar bedding over face shell bedding for obtaining increased strength of walls in axial compression. The increase varies from 25 to 50%.

2. The comparative study of walls by theoretical analysis using two types of blocks one with uniform web thickness and the other with the rationalised dimensions indicate the additional advantage of having 100% bedding of the blocks which help to realise the full potential capacity of the blocks in walls.

3. The results of the analysis (Fig. 7 and 8) indicate stress concentration and sharp variation in stresses in masonry using conventional blocks, whereas
Fig. 7. COMPARISON OF VERTICAL STRESS IN FACE PANELS

Fig. 8. COMPARISON OF VERTICAL STRESS IN WEB PANELS
### TABLE 1
Ratios of wall to block strength

<table>
<thead>
<tr>
<th>Type of block</th>
<th>Block strength, Q, kg/sq.cm.</th>
<th>Wall strength on gross area, P, kg/sq.cm.</th>
<th>Ratio P/Q</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A+</td>
<td>33.0</td>
<td>14.6</td>
<td>0.442</td>
<td>Wall size 1200x800 mm</td>
</tr>
<tr>
<td>Type B++</td>
<td>51.0</td>
<td>33.3</td>
<td>0.653</td>
<td>-do-</td>
</tr>
<tr>
<td>Type C++</td>
<td>49.4</td>
<td>29.1</td>
<td>0.590</td>
<td>Average values for different wall sizes</td>
</tr>
</tbody>
</table>

+ Face shell bedding  ++ Full bedding  vide Fig.3 for details of blocks

### TABLE 2
Comparison of vertical stresses in face panel (percentage deviation)

<table>
<thead>
<tr>
<th>Layer No.</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>F4</th>
<th>F5</th>
<th>F6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-11.38</td>
<td>-4.20</td>
<td>-4.33</td>
<td>-4.33</td>
<td>-4.20</td>
<td>-11.36</td>
</tr>
<tr>
<td>2</td>
<td>4.73</td>
<td>-6.57</td>
<td>-5.96</td>
<td>-5.96</td>
<td>-6.57</td>
<td>4.73</td>
</tr>
<tr>
<td>3</td>
<td>-13.23</td>
<td>-4.33</td>
<td>-6.00</td>
<td>-6.00</td>
<td>-4.33</td>
<td>-13.23</td>
</tr>
<tr>
<td>4</td>
<td>5.19</td>
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<td>-6.10</td>
<td>-6.10</td>
<td>-6.61</td>
<td>5.19</td>
</tr>
<tr>
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<td>-6.59</td>
<td>-6.59</td>
<td>-4.81</td>
<td>-12.67</td>
</tr>
<tr>
<td>6</td>
<td>6.07</td>
<td>-7.46</td>
<td>-6.59</td>
<td>-6.59</td>
<td>-7.46</td>
<td>6.07</td>
</tr>
</tbody>
</table>

F1-F6 are elements in each layer.

### TABLE 3
Comparison of vertical stresses in web panel

<table>
<thead>
<tr>
<th>Layer No.</th>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>W4</th>
<th>W5</th>
<th>W6</th>
<th>W7</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>-8.57</td>
<td>17.64</td>
<td>-31.94</td>
<td>19.17</td>
<td>-31.94</td>
<td>17.64</td>
<td>-8.57</td>
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<tr>
<td>3</td>
<td>0.09</td>
<td>-26.48</td>
<td>16.86</td>
<td>-29.80</td>
<td>16.86</td>
<td>-26.48</td>
<td>0.09</td>
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<tr>
<td>4</td>
<td>-6.88</td>
<td>16.44</td>
<td>-30.30</td>
<td>17.10</td>
<td>-30.30</td>
<td>16.44</td>
<td>-6.88</td>
</tr>
<tr>
<td>5</td>
<td>2.36</td>
<td>-27.52</td>
<td>16.88</td>
<td>-30.74</td>
<td>16.88</td>
<td>-27.52</td>
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<tr>
<td>6</td>
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<td>15.27</td>
<td>-29.76</td>
<td>16.99</td>
<td>-29.76</td>
<td>15.27</td>
<td>-3.49</td>
</tr>
</tbody>
</table>

W1-W7 are elements in each layer.

Note: Negative sign indicates that the stresses are more in the case of wall panel with conventionally adopted blocks (with equal web thickness) than the wall using the redesigned blocks.
the stress variation is smooth with the rationalised block.

It could therefore be seen that for almost the same amount of material used in a block, a small change in the configuration of the blocks improves its efficiency and results in increased capacity of the masonry.

REFERENCES
2. IS 2185 (Part I) - 1979. Specifications for concrete masonry units, Part-I, Hollow and solid concrete blocks (Second Revision), Indian Standards Institution, New Delhi, India.
12. Research work on analysis and testing of hollow block masonry walls, Building Technology Laboratory, I.I.T., Madras - To be published.