11.—Tensile Strength Tests on Two Types of Brick

by

K. THOMAS
Brick Development Association, London

and

D. C. O’LEARY
University of Salford

ABSTRACT

The failure of brickwork subject to axial compression is normally by vertical splitting due to horizontal tension. This paper describes tests on two types of brick principally using the indirect tensile splitting method, but comparison is also made with direct flexural and compressive testing, the latter being carried out by traditional means and with Hilsdorf brushes specifically designed for testing bricks.

1. THE INDIRECT TENSILE STRENGTH OF BRICKS

1.1 Introduction

Several authors have suggested the use of cubes and similar prisms as a more practical alternative to the cylinder for measuring indirect tensile strength. ROSENHAUPT, VAN RIEL and WYLER studied the plane strain problem involved when compressive forces are applied along the opposite faces of a concrete cube. Using mathematical and photoelastic techniques they showed that the tensile stress was fairly uniform along the middle plane, and given by

\[ \text{Tensile stress} = \frac{0.648P}{dl} \]

where \( P \) = force (lbf), \( d \) = equivalent diameter and \( l \) = length of specimen. This formula, which has been used to calculate the indirect tensile strength of bricks in this paper, is similar to that for cylinders \( \frac{2P}{\pi dl} \), the difference being about 1.5%.

1.2 Method

Two types of brick were used in this investigation: type-A, deaired imperforate wirecuts manufactured from London clay, and type-B, perforated (three 1-in.-dia. holes) deaired wirecuts manufactured from Boulder Clay.

Four class-A testing machines were used:

- H—200 tonf Amsler
- S1—300 tonf Denison
- S2—180 tonf Avery
- S3—50 tonf Denison

The compressive strength of the brick was determined on samples of ten in accordance with BS 3921:1965. Samples were also tested dry. When bricks are tested in compression, the ceramic adjacent to the loading platens is restrained laterally. In order to eliminate this external effect a pair of 'brush' platens were designed and built. The Hilsdorf brushes (Figure 1) prevent the exertion of any significant transverse shear stress at the ends of the specimen. Each bed face was skimmed with plaster and the bricks tested dry. All bricks were tested at a rate of loading of 2000 lbf/in²/min. The results are given in Table 1.

For indirect tensile splitting tests samples of ten were

Figure 1—Brick between Hilsdorf brushes after crushing.
again taken. Type-A bricks were tested on machine H and type-B on S1. The bricks were placed between the platens on their bed faces with a plywood packing strip top and bottom through which the load was applied. These strips were placed either on the exact centre of the length of the brick or its width in different tests. Some workers suggest that the width of loading strips should be between one-tenth and one-twelfth of the diameter of the cylinder. In the initial stages of this work 3-in.-wide packings were tried but found to be impractical. All results quoted are based on 3-mm plywood packings 1-in. wide. The results and the ratios of tensile to compressive strength are given in Table 2.

In a second series of tests brick cores, 1.7 in. dia., were cut from the bricks to compare the tensile splitting strength with that obtained on whole bricks. To prevent premature failure of cores during testing, cardboard packings were used, 0.067-in. thick and 1-in. wide. Half the cores were cut from the centres and half from the ends of the bricks. The results are given in Table 3.

1.3 Indirect Tensile Splitting of Bricks
In every case the indirect tensile strength calculated on the width of a brick produced a higher stress than on the length. The difference is not significant for brick A but for brick B it is significant at the 0.1% level dry and 0.5% level wet. Any real difference can be attributed to a greater number of flaws likely to occur in larger volumes of material as postulated by Griffiths, and the poorer packing of the unfired clay at the ends of the brick during the extrusion process (Figure 2). The latter phenomenon is also most likely responsible for the lower core strength obtained when specimens are cut.

---

**Tensile Strength Tests on Two Types of Brick**

**Table 1—Mean Compressive Strength of Bricks Used**

<table>
<thead>
<tr>
<th>Brick type</th>
<th>Method of test</th>
<th>Machine</th>
<th>Calculated stress (lb/in²)</th>
<th>Coefficient of variation (%)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Wet</td>
<td>H</td>
<td>6 100</td>
<td>26.9</td>
<td>N.S.*</td>
</tr>
<tr>
<td>A</td>
<td>Dry</td>
<td>H</td>
<td>5 950</td>
<td>15.9</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Hilsdorf</td>
<td>S1</td>
<td>2 721</td>
<td>23.2</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Wet</td>
<td>S1</td>
<td>9 428</td>
<td>11.3</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Dry</td>
<td>S1</td>
<td>10 465</td>
<td>10.7</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Hilsdorf</td>
<td>S1</td>
<td>3 543</td>
<td>8.4</td>
<td></td>
</tr>
</tbody>
</table>

*Not significant.

**Table 2—Mean Indirect Tensile Strength of Bricks Tested Along the Length (L) and Across the Width (W) and Ratio of Tensile to Compressive Strength**

<table>
<thead>
<tr>
<th>Brick type</th>
<th>Direction</th>
<th>Condition</th>
<th>Rate of loading (lbf/in²/min)</th>
<th>Calculated stress (lbf/in²)</th>
<th>Coefficient of variation (%)</th>
<th>Tensile Compressive (%)</th>
<th>Significance (wet/dry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>W</td>
<td>Dry</td>
<td>200</td>
<td>555</td>
<td>14.4</td>
<td>9.3</td>
<td>N.S.*</td>
</tr>
<tr>
<td>A</td>
<td>W</td>
<td>Wet</td>
<td>200</td>
<td>603</td>
<td>20.9</td>
<td>9.9</td>
<td>5%</td>
</tr>
<tr>
<td>A</td>
<td>L</td>
<td>Dry</td>
<td>200</td>
<td>527</td>
<td>15.6</td>
<td>8.9</td>
<td>9.8</td>
</tr>
<tr>
<td>A</td>
<td>L</td>
<td>Wet</td>
<td>200</td>
<td>598</td>
<td>9.4</td>
<td>10.9</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>W</td>
<td>Dry</td>
<td>200/2630*</td>
<td>649</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>W</td>
<td>Dry</td>
<td>1250</td>
<td>886</td>
<td>10.7</td>
<td>7.9</td>
<td>N.S.*</td>
</tr>
<tr>
<td>B</td>
<td>W</td>
<td>Wet</td>
<td>1250</td>
<td>835</td>
<td>12.6</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>L</td>
<td>Dry</td>
<td>2250</td>
<td>1056</td>
<td>8.2</td>
<td>9.4</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>L</td>
<td>Wet</td>
<td>2250</td>
<td>1035</td>
<td>14.3</td>
<td>10.3</td>
<td></td>
</tr>
</tbody>
</table>

*Not significant.

†Average stress used based on this range of loading.

**Table 3—Mean Indirect Tensile Strength of Brick Cores**

<table>
<thead>
<tr>
<th>Brick type</th>
<th>Total no. of specimens</th>
<th>Average length (in.)</th>
<th>Condition</th>
<th>Machine</th>
<th>Rate of loading (lbf/in²/min)</th>
<th>Mean stress (lbf/in²)</th>
<th>Overall mean stress (lbf/in²)</th>
<th>Overall coeff. of variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>12</td>
<td>2.41</td>
<td>Dry</td>
<td>H</td>
<td>300</td>
<td>507</td>
<td>354</td>
<td>430</td>
</tr>
<tr>
<td>A</td>
<td>20</td>
<td>1.475</td>
<td>Wet</td>
<td>H</td>
<td>800</td>
<td>629</td>
<td>467</td>
<td>505</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>1.29</td>
<td>Dry</td>
<td>S2</td>
<td>385(av.)</td>
<td>1200</td>
<td>917</td>
<td>1059</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>1.25</td>
<td>Wet</td>
<td>S2</td>
<td>393(av.)</td>
<td>1028</td>
<td>868*</td>
<td>957</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>1.32</td>
<td>Dry</td>
<td>H</td>
<td>800</td>
<td>1112</td>
<td>929</td>
<td>1020</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>1.28</td>
<td>Wet</td>
<td>H</td>
<td>800</td>
<td>1083</td>
<td>967</td>
<td>1025</td>
</tr>
</tbody>
</table>

*Four specimens.

[FIGURE 2—Spiral lamination pattern in extruded bricks.]
from the end of an extruded brick. It could be argued that the packing of the unfired clay is equally poor along the length of the units but this was not so for the bricks tested.

For type-A bricks in every test other than flexure the wet test gave the highest results but in only one case was the difference significant (Table 2). For type-B bricks in every test other than one series of core tests, where the results of wet and dry test were virtually the same, dry tests gave the highest results but only the compressive strengths were significantly different (5%).

The general mode of failure was by tensile splitting for type-A bricks, a wedge usually forming under the plywood packing at ultimate load. Of 150 bricks tested in this manner, half displayed a single fracture, slightly less showed a double fracture (removing a central wedge from the specimen), and the remaining 4% had a wedge with a central fracture on the centre-line.

For type-B bricks, because of the three-hole perforation pattern, the general mode of failure in the length was by tensile splitting, four wedges being formed at ultimate load (Figure 3). In addition to the formation

of wedges 17.5% of the specimens split exactly on the centre-line, and in several instances the split was indistinguishable from the pencil guideline for the loading strips. Failure generally occurred at two loads, i.e. of forty specimens tested 72.5% failed in this manner, 22.5% at a single load and 5% with a third split. When failure occurred the first load was usually reasonably simple to detect and the final load unmistakably clear due to a rapid falling away of the needle and a well-defined report. It will be noted from Table 2 that the ratio of tensile splitting strength to compressive strength expressed as a percentage ranged from 8.9 to 10.9 for type-A bricks while for type-B the perforation pattern undoubtedly has a significant effect in the length, but in the width the ratios compare favourably with type-A.

1.4 Indirect Tensile Splitting of Brick Cores

Brick cores were cut from both types of brick to compare the tensile splitting strength with that obtained using whole units. Cores cut from type-B bricks were first tested in machine S2, but due to the specimens being small (1.7 in. diam. X 1.25-1.29 in. long) it was not possible to fix a precise rate of loading on this machine.

The average rates of loading and stresses are shown in Table 3. In no case for either brick was the average wet strength significantly different from the dry strength. The indirect tensile strength was 9.47% and 9.49% of the dry and wet compressive strengths respectively. Considering the 'within batch' variation, this is a rather remarkable result. It is also worthy of note that the indirect tensile strength of the dry brick cores is remarkably close to the wet and dry indirect tensile strength of the bricks when tested on the width. From Table 3 it will be seen that cores cut from the end of the bricks produce lower indirect tensile strengths than cores cut from the centre of the brick, but in several instances they have a lower coefficient of variation than the centre cores. A suggested reason has already been given for this phenomenon, and it is interesting to note that comparable results were obtained on both machines, a different operator being responsible for each machine.

A further check was made on cores cut from type-B bricks by testing them in machine H using a different operator and approximately twice the average rate of loading used on machine S2. The results are in relatively close agreement for such a variable material. In this second series of tests there is again no significant difference in indirect tensile strength between wet and dry specimens. The ratio of indirect tensile strength to compressive strength expressed as a percentage was 9.12 and 10.16 for dry and wet specimens respectively. Once again the second series of core tests provided close agreement with the indirect tensile strength of the bricks when tested on the width.

For type-A brick the mean strength of centre cores, both wet and dry, compares reasonably well with the splitting strength across the width of the brick. From the limited numbers of results available it would appear that for a rate of loading of 200 lb/in²/min a slightly lower stress can be expected and hence the comparisons with cores tested at a higher rate of loading should be treated with some reservation.

It is thought that apart from the more laminated material at the edge of an extruded brick (particularly at the end) the reason for the low core strength obtained for this brick is associated with the extremely irregular surface of the specimen due to a most complex and pumice-like structure, exposed when the cores are cut, the smoother external surface of the bricks due to extrusion and the accompanying manufacturing processes providing a skin effect.

1.5 Rate of Loading

A total of 120 type-A bricks were tested using the indirect tensile splitting method to determine the effect of rate of loading. All bricks were tested on machine H, dry and split across the width, ten bricks being tested for each rate of loading in the first instance. The packings used for the tests were 3-mm plywood, mahogany plywood being used in the first instance for all tests other than 1800 and 2000 lb/in²/min when supplies ran out and birch plywood was used. The stresses calculated at these rates of loading are low (Table 4) so additional tests were carried out at the same rates of loading but using samples of only five when further supplies of mahogany plywood were available. In fact the difference between the two types of packing is only barely significant (10%).
Tensile Strength Tests on Two Types of Brick

### TABLE 4—EFFECT OF RATE OF LOADING ON INDIRECT TENSILE STRENGTH

<table>
<thead>
<tr>
<th>Rate of loading (lbf/in²/min)</th>
<th>Calculated stress (lbf/in²)</th>
<th>Coefficient of variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>555</td>
<td>14.4</td>
</tr>
<tr>
<td>400</td>
<td>658</td>
<td>18.9</td>
</tr>
<tr>
<td>600</td>
<td>610</td>
<td>12.1</td>
</tr>
<tr>
<td>800</td>
<td>696</td>
<td>25.9</td>
</tr>
<tr>
<td>1000</td>
<td>640</td>
<td>13.5</td>
</tr>
<tr>
<td>1200</td>
<td>672</td>
<td>16.1</td>
</tr>
<tr>
<td>1400</td>
<td>660</td>
<td>26.9</td>
</tr>
<tr>
<td>1600</td>
<td>692</td>
<td>6.9</td>
</tr>
<tr>
<td>1800</td>
<td>552</td>
<td>23.7</td>
</tr>
<tr>
<td>2000</td>
<td>582</td>
<td>22.4</td>
</tr>
<tr>
<td>2630</td>
<td>670</td>
<td>17.5</td>
</tr>
<tr>
<td>1800†</td>
<td>622</td>
<td>24.5</td>
</tr>
<tr>
<td>2000†</td>
<td>668</td>
<td>9.1</td>
</tr>
</tbody>
</table>

*Birch. †Mahogany.

The results (Figure 4) clearly show that the rate of loading has little effect on the calculated stress. None of the results are significantly different except the 200 lbf/in²/min and 400 lbf/in²/min rate of loading at the 5% level. The two results indicate that a change in packing material could considerably affect the ultimate load and further work is required to determine the preferred material.

No satisfactory explanation can be given for the low result recorded at a rate of loading of 200 lbf/in²/min, but it is thought to be correct as it is not significantly different from the ten units tested wet at the same rate of loading (Table 2). This slow rate of loading is at the bottom end of the machine range which may account in part for the low readings obtained.

The machine used for indirect tensile testing was simple to control and capable of considerable refinement in setting; nevertheless, at rates of loading in excess of 1600 lbf/in²/min, it became more difficult to control with accuracy and for this reason it is suggested that a rate of loading in excess of 1000 lbf/in²/min should not be adopted for this method of testing.

It is well known that the rate of loading is fairly critical when bricks are tested in compression, which is no doubt due to the method by which the units are progressively crushed. The technique adopted for the indirect tensile splitting test does not permit crushing of the units if correctly controlled (i.e. the rate of loading is not increased after failure has occurred) and for this reason it is suggested that the rate of loading appears to be relatively unimportant.

### 2. DIRECT TENSILE STRENGTH TESTS

#### 2.1 Axially Applied Load

Direct tensile tests were carried out by bonding 4½ x 3 x 1-in. grooved mild-steel plates (Figure 5) to the ends of bricks using an epoxy resin compound with a PFA filler. The ½-in.-dia. standard Denison grips were screwed into the end plates and specimens tested dry in machine 53 at a rate of loading of 1875 lbf/in²/min (Figure 6). Early experiments indicated that this method of test would not give the true tensile strength of an extruded clay brick, but merely give some indication of its tensile strength at the end of the unit, where as discussed earlier in the paper a very much poorer value can be expected. In an attempt to overcome this difficulty, tests were carried out on further specimens after...
K. Thomas

Table 5—Direct Tensile Strength

<table>
<thead>
<tr>
<th>Brick Type</th>
<th>Number of Specimens</th>
<th>Brick Length (in.)</th>
<th>Calculated Stress (lbf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>14</td>
<td>8½</td>
<td>163</td>
</tr>
<tr>
<td>A</td>
<td>10</td>
<td>5</td>
<td>351</td>
</tr>
<tr>
<td>B</td>
<td>9</td>
<td>8½</td>
<td>293</td>
</tr>
<tr>
<td>B</td>
<td>9</td>
<td>5</td>
<td>337</td>
</tr>
</tbody>
</table>

*Not significant.

Table 6—Direct Tensile Strength of Bricks

<table>
<thead>
<tr>
<th>Brick Type</th>
<th>Number of Specimens</th>
<th>Condition</th>
<th>Calculated Stress (lbf/lin²)</th>
<th>Variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
<td>Dry</td>
<td>539</td>
<td>2</td>
</tr>
<tr>
<td>A</td>
<td>9</td>
<td>Wet</td>
<td>623</td>
<td>37</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>Dry</td>
<td>635</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>Wet</td>
<td>415</td>
<td>29</td>
</tr>
</tbody>
</table>

*Not significant.  †Significant.

over 1 in. had been cut from each end, taking care to leave a length of brick at least 5 in. long to eliminate the difficulties of end restraint due to the platens as described by SPELTA and KADLECOK. The results are given in Table 5.

Although only the results for brick A are significant it seems that this test procedure measured two properties of these particular bricks: (a) the direct tensile strength at the ends; and (b) the direct tensile strength at the weakest point after the ends have been removed. On this basis it is not considered reasonable to compare these results with the indirect tensile strength which measures the tensile strength at a specific position across or along the brick.

2.2 Expanding Plug System

As numerous difficulties were encountered with the axially applied test a simple 'expanding plug system' was developed in an attempt to measure tensile strength at a specific position in a brick. It consists of two plugs with tapered ends which fit into the two halves of a split cylinder having the same internal cone-shaped ends (Figure 7). To determine the tensile strength of the brick a ¼-in.-dia. hole is drilled through the centre of the brick and the split cylinder placed in the hole. The plugs are then placed in the cylinder ends and vertical load applied to the plugs in a compression testing machine (S1). From the ultimate load recorded the horizontal component is calculated.

Friction and other effects have not been taken into account in the results quoted as the proving ring arrangement shown in Figure 6 could not be calibrated in time for the appropriate coefficients to be determined. Table 6 gives the results. For type-A bricks the values compare well with the results for cores cut from the centre of the bricks. Type-B bricks do not exhibit so close a relationship. The results for the dry type-A brick are not significantly different from those for type-B, but wet the difference is significant at the 5% level.

2.3 Transverse Strength Test

This test was carried out using three ¾-in. dia. x 6-in. long rollers, placed one at each end beneath the brick with 7 in. between centres and one in the middle on top. Samples of ten bricks were tested, type-A in machine H and type-B in S1. As expected this test gave extremely variable results and no definite trends or relationships were noted (Table 7). Indeed, tested dry type-A brick was not significantly different from type-B, and wet only at the 5% level. For type-A bricks the wet flexural strength was 68.7% of the dry flexural strength. The dry flexural strength was 12.4% of the dry compressive strength, and for wet specimens was 8.3%. The average indirect dry tensile strength determined from Table 4 (ignoring specimens tested between birch plywood) was 88.3% of the dry flexural strength.

Table 7—Mean Transverse Strength

<table>
<thead>
<tr>
<th>Brick Type</th>
<th>Condition</th>
<th>Calculated Stress (lbf/in²)</th>
<th>Coefficient of Variation (%)</th>
<th>Significance (wet/dry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Dry</td>
<td>735</td>
<td>32.8</td>
<td>5%</td>
</tr>
<tr>
<td>A</td>
<td>Wet</td>
<td>505</td>
<td>33.7</td>
<td>N.S.*</td>
</tr>
<tr>
<td>B</td>
<td>Dry</td>
<td>855</td>
<td>44.5</td>
<td>43.3</td>
</tr>
<tr>
<td>B</td>
<td>Wet</td>
<td>780</td>
<td>43.3</td>
<td>N.S.*</td>
</tr>
</tbody>
</table>

*Not significant.
Tensile Strength Tests on Two Types of Brick

For type-B bricks the dry flexural strength was 7·6% of the dry compressive strength, and for the wet specimens was 7·7%. The indirect dry tensile strength for bricks tested across the width was 19% greater than the dry flexural strength.

3. DISCUSSION

The indirect tensile strength of bricks has not been previously measured as far as the authors are aware, although the indirect tensile strength of brickwork has been considered by several research workers. This method of testing has certain definite advantages over the more generally accepted compressive strength test, but the authors recognize that difficulties may arise when multi-perforation or frogged units are considered. The principal advantage of this method of testing is that it probably measures a property of brick bearing some relationship to incipient failure of brickwork, which is almost certainly not true of the currently accepted compressive strength test. The rate of loading tests carried out suggest that the rate of application of load is perhaps also less critical in this test than for the compressive test although it is recommended that one packing material be used as standard for all such tests. Other compressive strength tests carried out in the current programme, but not recorded in the paper, support the case for a standardized packing material. It is suggested that the maximum rate of loading of specimens should not exceed 1600 lb/in²/min, as operating difficulties can occur at rates in excess of this value. A standard rate of loading of 1000 lb/in²/min is recommended. Once the operator is accustomed to this test it is relatively simple to conduct, it takes less time to carry out and uses considerably less packing material thus reducing costs, but the method gives a high coefficient of variation and the significance of the results is difficult to establish.

Indirect tensile tests on brick cores were carried out to compare results with tests on whole bricks. Cores from type-A bricks gave low results for reasons already discussed, but cores from type-B were in close agreement with results when bricks are split across the width.

Experimental Hilsdorf brush platens were used for some compressive tests and facilitate measurement of the compressive load at which complete tensile breakdown of the unit occurs. For type-A bricks the ratio of Hilsdorf/compressive strength was 0·4573 and for type-B 0·3378. The ratio of indirect tensile strength of bricks across the width to strength between brushes is 0·2384 and 0·2796 respectively and is a difference of only 4·1%.

The direct tensile strength of bricks measured when the units are pulled apart by an axially applied load is thought to be of little value because (a) it is an extremely slow test, each unit requiring 24 h to cure before testing can take place; (b) accidental eccentricity of loading is extremely difficult to avoid; and (c) for extruded bricks, if tested on the full length, failure will almost certainly occur adjacent to the end plates, or if the length of the unit is reduced by cutting each end prior to fabricating the test-piece the least tensile strength of the remainder of the unit will be measured rather than the tensile strength at a randomly selected position.

For type-A bricks the expanding plug system of measuring the direct tensile strength gave comparable results with the core test, but for type-B bricks the results were disappointingly at variance.

Transverse strength tests gave erratic results as expected, although for type-A bricks the wet core strength was identical with the wet flexural strength.

Contrary to what is normally expected, type-A bricks in every case other than flexure gave higher results with wet specimens but in only one case was the difference significant. It may be that the PFA content in this particular brick had some bearing on this phenomena.

4. CONCLUSIONS

1. The indirect tensile strength of solid or suitably perforated bricks can be measured by splitting the unit across the width or along the length.

2. Splitting bricks across the width produced a higher indirect tensile strength than splitting along the length.

3. Brick cores cut from the ends of the extruded bricks produced lower strengths than cores cut from the centre of the bricks but the coefficient of variation of the centre cores was higher in some instances. The reason for the lower strength and cores is almost certainly due to the poorer packing of the unfired clay at the ends of the brick during the extrusion process.

4. Compressive testing with the Hilsdorf brushes indicated the apparent compressive strength when complete tensile breakdown of the units occurred. It may be possible to use this measurement or the indirect tensile strength of bricks to predict the wall strength.

5. The direct tensile test measured two properties of the bricks: (a) the direct tensile strength adjacent to the ends and (b) on 5-in. lengths of brick, the direct tensile strength at the weakest point. For type-A bricks the tensile strength at the end of the whole brick was 46·5% of the tensile strength on the 5-in. length for type-B bricks it was 87% and not significantly different.

6. The expanding plug system of direct tensile testing produced inconclusive results.

7. The rate of loading for indirect tensile testing appears to be unimportant but for practical reasons 1000 lb/in²/min is suggested.

8. A standard packing material is necessary for the indirect tensile test and it is desirable that the same material be standardized for the compressive strength test.

ACKNOWLEDGEMENTS

The authors are indebted to the B. Ceram. R.A. Computer Department for processing some of the results. Also to Woodside Brickworks (Croydon) Ltd. and J. & A. Jackson Ltd. for the supply of bricks. Thanks are also due to the University of Salford and Hatfield Polytechnic for providing laboratory facilities. Also to Mr F. J. Grimer of the Building Research Station for advice on the design of the Hilsdorf brushes.

REFERENCES

