BRICKBLOCK MADE FROM CRUSHED GLASS AND FLY ASH BOUND WITH BITUMEN

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Abstract

Brickblock is a masonry building block made from waste crushed glass and coal fly ash bound with bitumen (asphalt). The binder used was bitumen of 50 pen and hard H80/90. The properties of the blocks evaluated were compressive strength and creep. In order to minimize creep deformation, the samples were heat cured at 160 °C for 24, 48, and 72 hours. It was found that the Brickblock compressive strength was comparable to concrete block commonly used in the United Kingdom (UK). The samples using 50 pen bitumen requires, more than 48 hours curing and at least for 48 hours when using hard H80/90 bitumen to satisfy creep performance requirement.

Keywords: brickblock, waste crushed glass, fly ash, compressive strength, creep.

1. INTRODUCTION

Developed countries have a major problem that they are running out of space to store all of their rubbish. One type of their waste is glass. In the United Kingdom (UK) there is large amount of waste glass from glass jars or containers, food, liquor or wine industries. The glass industries in the UK have limited capacity to utilise excess of glasses. Every year around 2.5 million tonnes excess of waste glasses is available for further use [1].

Other by product material i.e. coal fly ash from power station is also available in the UK. The utilization of fly ash in the UK has remained stable for a number of years at around 50 % of production. The amount of fly ash available in stock, in addition to fresh production is estimated to have remained relatively constant at about 250,000,000 tonnes for a number of years. Fly ash has been used in many applications including concrete industry, concrete blocks, road pavements, grouting, fill materials etc. [2].

Currently, 160,000 new homes are built each year in the UK of which 90% are constructed from masonry. Each house on average requires approximately 200m² of building block work resulting in approximately 350 million blocks being manufactured each year [3].

In order to utilise excess of glasses and to supply demand on building blocks, this investigation was intended to develop Brickblock units utilizing all crushed glass bound with bitumen (asphalt). This effort can contribute to the UK Government’s aims for recycling waste glasses, hence reducing in demand for natural aggregate extraction and minimising waste sent to landfill. Bitumen can widely available in oil producing countries where other waste materials can also be incorporated [4].

In order to obtain optimum results, based on input from building block industries, some criteria were considered, such as: utilization of efficient bitumen content, the surfaces of the samples do not necessarily very smooth, and the range of compressive strength targeted 3.5 – 10 MPa (Sear, 2005; British Standard-BS 6073,1981)[5],[6], and the creep strain under 1 MPa stress is between 400- 500 microstrain [6].

For achieving the results expected, the following matters were tried, namely: the use of continuous grading with low filler content which has lower surface areas compared with gap grading with high fines content; the use of materials with low absorption properties as the main component (crushed glass). At this stage of the investigation the samples were compacted at 8 MPa static compaction pressure, and heat cured for hardening the bitumen to prevent creep deformation.
2. METHODS

2.1. Aggregate grading

In effort to obtain the results expected, aggregates with various particle sizes need to be properly graded. There are various ways of doing this. Within this investigation the aggregates were proportioned by utilizing Cooper’s formula [7], as follow

\[ P = \frac{(100 - F)(d^n - 0.075^n)}{D^n - 0.075^n} + F \]  

(1)

Where: \( P = \% \) material passing sieve size \( d \) (mm), \( D = \) maximum aggregate size (mm), \( F = \% \) filler, \( n = \) an exponential value that dictates the concavity of the gradation line.

The aggregates were separated into coarse fraction: (14-10)mm, (10-5)mm, and (5-2.36)mm. The fine fraction was of (2.36-0.075) mm, and the filler fraction was of passing 0.075 mm. D was 14 mm, and \( n = 0.45 \) is the exponential factor that widely had been used for best aggregate packing. The F meanwhile was taken = 4 %, based on the minimum filler content on the macadam dense grading with 14 mm max aggregate size (adopting BS 4987-1, 2003)[8].

The particle size of the coarse crushed glass (larger than 5mm) was found slightly flaky. This was not considered a significant problem, as the strength of the samples obtained not only from aggregate interlock, but also due to the application of heat curing to harden the bitumen binder. For a better appreciation of the Brickblock aggregate gradation curve and the gradation curve of a dense macadam (BS 4987-1, 2003)[8] are plotted in a graph as shown in Figure 1.

2.2. Materials used

The materials used and their specific gravity are shown in Tables 1. The Binder used was 50 pen bitumen and hard bitumen H80/90. Bitumen H80/90 is usually used for industrial purposes for providing impermeable protection, such as for coating pipes and roof layers. This bitumen has high softening point (80-90 °C) with penetration value from 6-12 at 25 °C (BS 3690-2, 1989)[9]. This bitumen was expected to have a good resistance to creep deformation.

3. INITIAL TRIAL

At this stage, the type of binder used was bitumen of 50 pen for bitumen content optimization.

3.1. Mixing, Compaction and Heat Curing

When using 50 pen bitumen, the materials (crushed glass, fly ash and bitumen) were first separately heated at 160 °C for 3 hours. The aggregates were dry mixed, added with bitumen, and mixing continued until the aggregates evenly coated. At this stage of the experiment the samples were compacted at 8 MPa static compaction pressure. The sizes of the sample were 100x100x65 mm as shown Figure 2, (including strain measuring equipment).

In using hard H80/90 bitumen, it required higher temperature, i.e. around 200 °C to heat the materials and to melt the bitumen in order to obtain sufficient viscosity for mixing workability.

![Figure 1. Aggregate Grading of Brickblock compared to Macadam.](image)

Table 1. The type of materials used

<table>
<thead>
<tr>
<th>Description</th>
<th>Material</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse fraction (58.5 %)</td>
<td>Crushed glass</td>
<td>2.51</td>
</tr>
<tr>
<td>&gt;2.36 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fine Fraction (37.5 %)</td>
<td>Crushed glass</td>
<td>2.51</td>
</tr>
<tr>
<td>(2.36 – 0.075) mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filler (4 %)</td>
<td>Fly ash</td>
<td></td>
</tr>
<tr>
<td>(&lt; 0.075 mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Binder</td>
<td>50 pen bitumen</td>
<td>1.02</td>
</tr>
<tr>
<td>Hard H80/90 bitumen</td>
<td></td>
<td>1.03</td>
</tr>
</tbody>
</table>

3.2. Bitumen content optimization

For optimization of bitumen content, 50 pen bitumen was used. The bitumen content was varied starting from 5.5 % (min recommended bitumen content - BS 4987-1, 2003) and reduced down up to 3 % with 0.5 % decrement by weight of total mix. For the determination of optimum bitumen content the samples were tested uncured. The optimum bitumen content was based on uncured samples and was found at 5 % as shown in Figure 3.

4. FURTHER TRIAL

After determining 5% optimum bitumen content from the uncured samples using 50 pen bitumen, then also at 5 % bitumen content other samples
were produced using hard H80/90 bitumen. The samples were then cured at 160 °C for 24, 48, and 72 hours. The application of heat curing was intended to harden the bitumen, hence reducing the sample’s susceptibility to undergo creep deformation. This further trial gave compressive strengths as shown in Figure 4, that conveniently meet the compressive strength targeted, i.e. 3.5 - 10 MPa.

The samples from both type of bitumen gave density between 2.056-2.068 g/cm³, with porosity of 12-13 %.

5. CREEP TEST

Creep tests were carried out by loading the samples using a simple equipment, i.e. an ‘arm load equipment’ as shown in Figure 5. The stress applied was 1 MPa which is the level of stress commonly applied on masonry material (Forth et al., 2006)[10]. The samples creep strains were measured by means of a 50 mm Demec gauge, which is completed with its supporting parts (Figure 6) which measure the strains occurred between a pair of Demec points (dp) that is attached vertically in the middle of each side of the samples (Figure 2). The testing temperature was room temperature 21 ± 0.5 °C.

5.1. Creep Test Results

During creep test, it was found that the samples using 50 pen bitumen cured at 160 °C for 24 hours failed in less than 24 hours, therefore its creep test result is not included in Figure 7.

Meanwhile, no sample failed when using H80/90 bitumen. The results are shown in Figure 8.
6. OVERALL ANALYSIS

Referring to Figure 4, it is shown that at shorter curing duration the samples using H80/90 bitumen gave higher compressive strength, but at 72 hours curing samples using 50 pen bitumen gave slightly higher results to H80/90. This appears to be sensible as softer bitumen is more susceptible to temperature, hence aged faster and then eventually becomes harder.

The creep test results indicate that the samples clearly need to be heat cured to reduce the magnitude of creep deformation, even when using hard H80/90 bitumen.

The typical creep strain of masonry units commonly used in the UK under 1 MPa stress, i.e. specific creep is around 400-500 microstrain (Tapsir 1985). Considering this matter, when heat cured at 160 °C the samples using 50 pen bitumen require more than 48 hours curing, and at least for 48 hours when using hard H80/90 bitumen. At 72 hours curing duration samples using 50 pen bitumen gave better resistant to deformation. This indicates that softer bitumen when heat cured more intensively can become at least equal or even possess better creep resistant to H80/90 bitumen. This is also supported by the compressive strength test results at 72 hours curing as shown in Figure 4.

7. CONCLUSION

Considering the results and the analysis above, it can be concluded that:
- Crushed glass and fly ash can be incorporated into Brickblock using bitumen as the binder.
- The Brickblock produced meet the targeted compressive strength: 3.5-10 MPa.
- In order to prevent excessive creep deformation (i.e. to obtain samples with creep strain equivalent to masonry units commonly used in the UK: 400-500 microstrain), when cured at 160 °C the samples using 50 pen bitumen require more than 48 hours curing and at least for 48 hours when using hard H80/90 bitumen.
- Samples with softer bitumen are more workable at lower temperature, and indicated effective creep performance at the more intensive (suitable) curing regime.

8. SUGGESTION

In order to shorten the time required for curing, higher but practicable and safe curing temperature is suggested.

9. ACKNOWLEDGMENT

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10. REFERENCES


