PERFORMANCE OF BITUMEN BOUND MASONRYBLOCK INCORPORATING WASTE MATERIALS

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Abstract: Continuous efforts are needed in utilizing waste materials in building industry. This investigation was intended to use waste materials, namely: steel slag, crushed glass and coal fly ash for producing Masonryblock, i.e. a masonry building block bound with bitumen (asphalt). The binder used was bitumen of 50 pen. The materials were pre-heated at 160 °C for 3 hours before mixing and compacted using static compactor at 8 MPa. 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. Creep test was carried out by loading the samples using a cantilever arm loading equipment with 1 MPa stress until the creep strain stable. The strain was measured by means of a 50 mm Demec gauge. It was found that the Masonryblock compressive strength comparable to the concrete block commonly used in the United Kingdom (UK). The sample requires at least 48 hours curing in order to satisfy creep performance requirement.

Keywords: masonry, waste materials, steel slag, crushed glass, fly ash.

KINERJA BLOK PASANGAN BATU YANG TERBUAT DARI BAHAN BEKAS YANG DIREKAT ASPAL

Abstrak: Diperlukan upaya yang berkelanjutan untuk mempergunakan bahan bekas pada industri bangunan. Penelitian ini dimaksudkan untuk mempergunakan bahan bekas yaitu *steel slag*, pecahan gelas bekas dan abu terbang batubara untuk membuat Blok Pasangan Batu, yaitu bahan pasangan batu dengan bahan perekat aspal. Aspal yang digunakan adalah aspal penetrasi 50. Sebelum dicampur, material dipanaskan terlebih dahulu pada temperatur 160 °C selama 3 jam dan dipadatkan dengan tekanan statis 8 MPa. Sifat Blok Pasangan Batu yang dievaluasi adalah kuat tekan dan rangkak. Tes rangkak dilaksanakan dengan membebani sampel mempergunakan suatu beban lengan kantilever dengan tekanan 1 MPa sampai regangan rangkak stabil. Regangan rangkak diukur dengan memakai *Demec gauge* 50 mm. Untuk mengurangi deformasi akibat rangkak, sampel dikondisikan pada suhu 160 °C selama 24, 48, dan 72 jam. Diperoleh hasil bahwa kuat tekan Blok Pasangan Batu sebanding dengan blok beton (batako) yang umum dipakai di Inggris. Diperlukan minimal 48 jam waktu pemanasan untuk memenuhi syarat kinerja rangkak.

Kata kunci: pasangan batu, bahan bekas, *steel slag*, pecahan kaca bekas, abu terbang.

INTRODUCTION

In line with the increasing pressure on environment conservation, virgin aggregate material exploration is being discouraged in many part of the globe. Effort to use waste or by product materials had been continuously carried out. One type of by product material available is steel slag. Metallurgical slags (basic oxygen steel slag (BOS)) are secondary products of the refining of metals from metal ores. In 1996, there were approximately 1.5 million tonnes of this industrial by-product produced each year and only 200,000 tonnes were recycled. In 2002, the volume of production had reduced to approximately 1 million tonnes (Dunster, 2002). This material is particularly suitable as a coarse aggregate and is commonly used in road construction materials. Steel slag is expansive by nature because of the presence of free calcium oxide and magnesium oxide. The detailed mechanism of this expansive nature is still not certain, however, it does make it unsuitable for use in cement concrete. The expansion of steel slag aggregates may cause premature deterioration (cracking) in bituminous mixtures. Hence in the UK it should be weathered before use (Shiratori, 2005).

One other 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 (Waste on Line, 2009).

Another 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. (Sear, 2001).

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 200m^2 of building block work resulting in approximately 350 million blocks being manufactured each year (Forth et al., 2008).

In order to utilise excess of glasses and to supply demand on building blocks, this investigation was intended to develop Masonryblock 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 (Thanaya, 2006).

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), and the creep strain under 1 MPa stress is between 400 - 500 microstrain (Tapsir, 1985).

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. 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.

METHODS

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 (Cooper et al., 1985), as follow

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

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). The aggregate grading is shown in Figure 1.

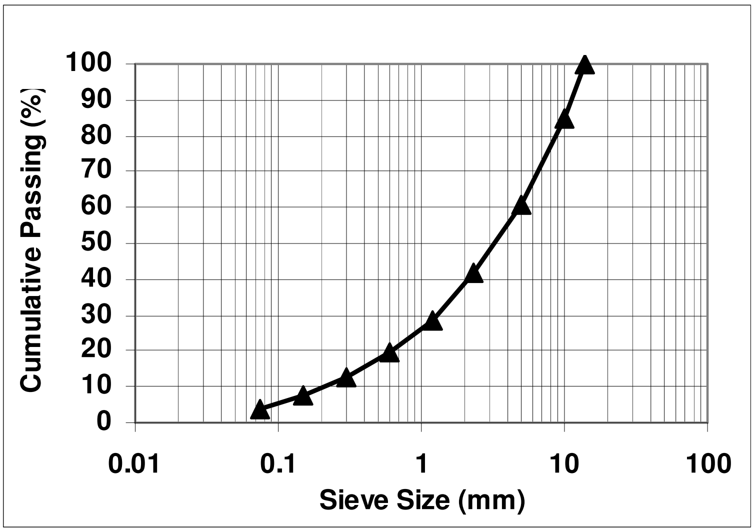

Figure 1. Aggregate Grading of Masonryblock based on Cooper's formula

Materials Used

The materials used and their specific gravity are shown in Tables 1. The binder used was 50 pen bitumen with a spe-cific gravity of 1.02.

Table 1. Type of materials and grading properties of the aggregate

Grading	Material	Specific Gravity	Water Abs. (%)
Coarse aggregates (58.5 %): (14-10), (10-5), (5-2.36) mm	Steel slag	3.39	1.9
Fine Aggregates (37.5 %): (2.36 – 0.075) mm	Crushed glass	2.51	<0.5
Filler (4 %): (< 0.075 mm)	Fly ash	2.16	-

Bitumen Content

The determination of bitumen content was based on the minimum effec-tive/efficient content, where the sample was compact and stable during handling. The aggregate grading used (which was based on Cooper's formula), was found to be very similar to Asphalt Macadam Gra-ding with max aggregate size of 14 mm (BS 4987-1, 2003), where the min recom-mended bitumen content is 5.5%.

Aggregate coating test was then car-ried out with bitumen content less than 5.5%, i.e. 5%, and 4.5%. It was found that coating test using 5% bitumen content was satisfactory, and gave compact and stable sample during handling. Therefore 5% bi-tumen content was adopted for this experi-ment.

Mixing, Compaction and Heat Curing

The materials were first separately heated at 160 °C for 3 hours. The aggre-gates were then dry mixed, added with bitumen, and mixing continued until the aggregates evenly coated. At this stage of the experiment the samples were com-pacted at 8 MPa static compaction pres-sure. The sizes of the sample were 100x100x65 mm as shown in Figure 2, (including strain measuring equipment).

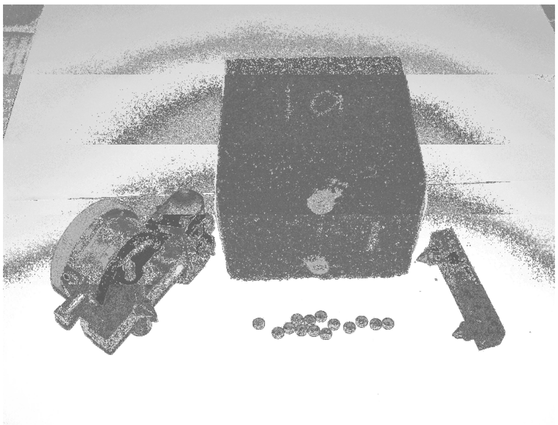

Figure 2. The Masonryblock sample and strain measuring equipment

After compaction, the samples were cooled down and de-moulded. After that the samples were then cured at 160 ºC 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. The compressive strengths are shown in Table 2. It is shown that the cured samples had met the compressive strength targeted, i.e. 3.5 - 10 MPa. The densities of the samples were in a range of 2.432-2.452 g/cm^3, with porosity of 13%-14%.

Table 2. The compressive strength of the Masonryblok samples

Curing (°C/hours)	Comp Strength. (MPa)
Uncured	3.3
160 °C /24 H	6.8
160 °C /48 H	8.6
160 °C /72 H	17.2

Creep Test

Creep tests were carried out by loading the samples with an 'arm load machine' as shown in Figure 3. The samples creep strains were measured by means of a 50 mm Demec gauge (Figure 4), which is completed with its supporting equipment that measure the strains occurred between a pair of Demec points attached vertically in the middle of each side of the samples as shown in Figure 2. There were four pairs of Demec points attached on the sides of each sample.

The Demec points were attached using a 'plastic padding chemical metal (paste and hardener)', which is a type of super glue, manufactured by Loctile Sweden AB Company.

Initial creep strain reading/measurement was carried out before loading. After loading, creep strains were read/measured soon after loading (within 2-5 minutes after loading), then consecutively every 4 x 15 minutes, (2-4) x 30 minutes, (2-4) x 60 minutes, then 3 times a day. After achieving a relatively constant strain reading, strains measurements were carried out once a day. The average room temperature during testing was 21±1 °C. The stress applied for the creep tests was 1 MPa, which is commonly used in masonry/building block creep tests (Forth et al., 2006).

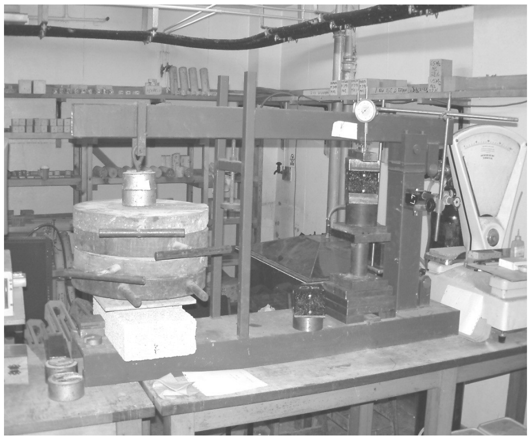

Figure 3. Arm load equipment

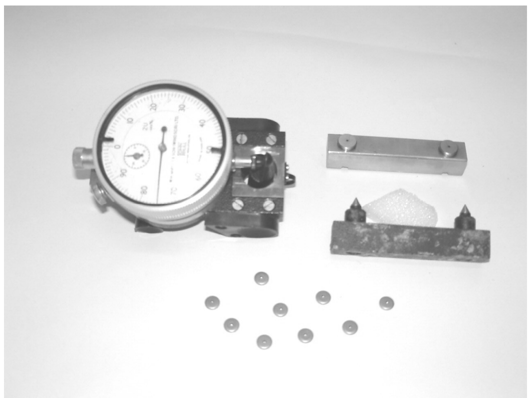

Figure 4. Demec gauge, with its supporting parts

CREEP TEST RESULTS

The strains data and explanation are given in Table 3. The average total strains results are presented in Figure 5. For further detail the creep strains are shown in Figures 6a and 6b.

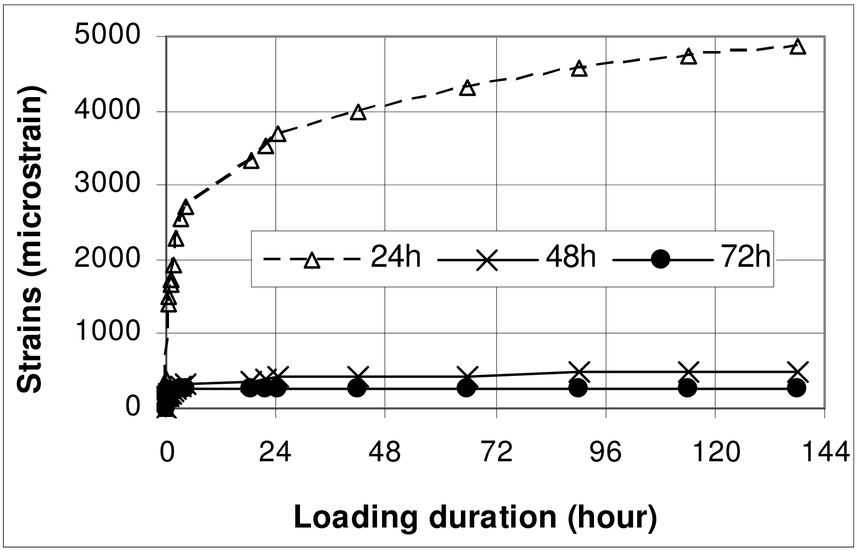

Figure 5. The total strains of the samples, cured at 160 ºC.

Table 3. Strains data of the samples

Curing	Total Strains (microstrain)	Elastic Strains (from first reading) (microstrain)	Creep Strains at the end of test (microstrain)
a	b	C	d = b-c
24 hrs	4865.85	381.15	4484.7
48 hrs	495	148.5	346.5
72 hrs	277.2	198	79.2

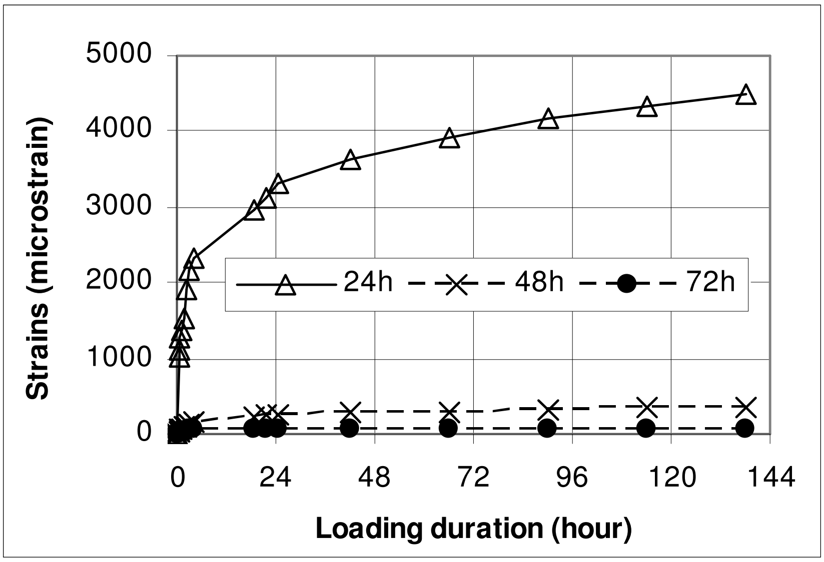

Figure 6a. The creep strains of the samples, cured at 160 ºC (in three curing regimes).

For a better reading, creep strains at 24 hours curing duration as shown in Figure 6a is deleted and is shown in Figure 6b.

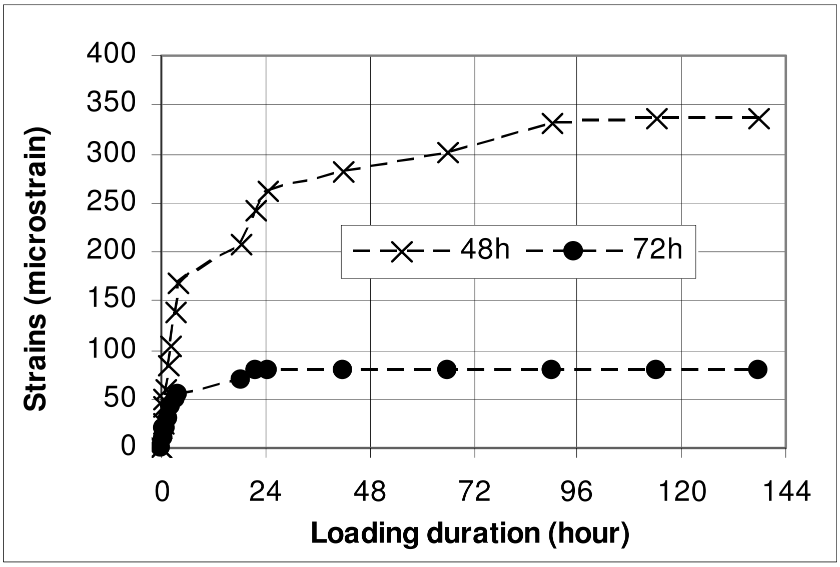

Figure 6b. Creep strains of the samples, cured at 160 ºC (in 2 curing regimes).

DISCUSSION

Referring to Table 2 the compressive strength of the samples well met the target of 3.5-10 MPa. As the samples have to be heat cured for reducing susceptibility to creep deformation, it was found that samples incorporating steel slag, crushed glass and fly ash, when cured at 160 ºC requires at least 48 hours, meet targeted creep strain between 400 - 500 microstrain (Table 3, Figures 6a and 6b). At curing duration of 72 hours, the samples creep performance was very satisfactory, i.e. far lower than the creep strain target. In addition due to sufficient density and curing regime, the angular shape and rough surface texture of the steel slag had positively contributed to the performance of the samples.

CONCLUSIONS

Referring to the results and discussion, it can be concluded that:

- The Masonryblock produced met both the compressive strength and creep performance requirement.
- The materials incorporated: steel slag, crushed glass, and fly ash bound with 50 pen bitumen are suitable for use as Masonryblock materials.
- When incorporating the materials mentioned above, with Masonryblock porosity between 12%-13 %, and cured at 160 ºC, the minimum curing duration required was 48 hours.

SUGGESTION

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

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