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FLEXURAL BEHAVIOR OF BASALT FIBRE REINFORCED FERROCEMENT COMPOSITE

S. Chen
School of Environment, Chemical and Environmental Engineering, China University of Mining and Tecnology (Beijing), Beijing, 100083, China. sherrychen1130@gmail.com

Y. Zhuge*
Faculty of Health, Engineering and Sciences, University of Southern Queensland, Springfield Central, Qld, 4300, Australia. Yan.Zhuge@usq.edu.au
(Corresponding Author)

G.X. Lu
Division of Engineering Mechanics, School of Mechanical & Aerospace Engineering, Nanyang Technological University, 639798, Singapore. mailto:GXLu@ntu.edu.sg

D.R. Eising
Faculty of Health, Engineering and Sciences, University of Southern Queensland, West St. Toowoomba, Qld, 4300, Australia. eisingd@usq.edu.au

ABSTRACT

Basalt fibre is produced from melted basalt rock. This paper presents the experimental investigation carried out on the flexural characteristics of basalt fibre reinforced ferrocement composite using various kinds of basalt meshes. The results indicate that the use of basalt fibre meshes as reinforcement system in the ferrocement composite contributes significantly to the improvement of bending characteristics of ferrocement composite in terms of first cracking load, ultimate flexural strength, and well-distributed fine cracks.

KEYWORDS

ferrocement ,basalt fibre, basalt meshes, flexural behaviour, cracking, four point bending test.

INTRODUCTION

Basalt is a natural, hard, dense, dark brown to black volcanic igneous rock. Basalt fibre is extruded from melted basalt rock at about 1450°C, followed by a rapid extrusion. It has equivalent tensile strength and better alkaline resistance relative to glass fibre, excellent interfacial shear strength, and is cheaper than stainless steel fibre (Sim et al. 2005). While basalt fibre is cheap, it is also strong and durable. Some recent efforts to diversify and encourage the further use of basalt fibre have come, like using basalt fibre as concrete confinement, or producing fibre-reinforced mortars for building repairmen (Ludovico et al. 2010; Harajli et al.2010; Francisco et al.2012; Ciniņa et al.2013).

Ferrocement is a type of reinforced concrete, which is commonly constructed by cement mortar and reinforced by layers of continuous and relatively small sized wire mesh (ACI Committee 549, 1988). Micro-reinforced concrete (MRC) marketed by Ducon, which contains 3D mats of wire mesh as reinforcement, is a kind of famous ferrocement used in the world. Compared with other meshes, stainless steel meshes have advantages in that they are corrosion resistant and exhibit high-energy absorption capacity (Gray et al. 2003; Noor et al. 2007). Fiberglass mesh, which is made of C-glass or E-glass fibres, can also be used in ferrocement because of the high ability of alkali resistant and high strength (Tassew et al. 2014; Yan et al. 2012). However, the research on ferrocement using basalt fibre meshes has been rare.

This study aimed at developing a new method to use basalt fibre as building and construction materials. In this paper, experimental investigations on flexural strength of 20 cases of ferrocement composite elements using various kinds of basalt reinforcement meshes, various mix designs and different curing period are discussed.

MATERIALS AND METHODS

Raw Materials

In the framework of this research specimens of ferrocement composites with dimensions 50×100×500 mm^3 were designed as shown in Figure 1. Mortars were prepared using commercial GP cement which was supplied by CEMIX Australia. The silica sand is used to reduce the cost of materials, which had a maximum 250μm grain size and 110μm average grain size. Aggregates were eliminated to increase the homogeneity of the mortar. For achieving adequate workability, high-range water-reducing admixture (HRWRA) was used, which was supplied by Chemical House Pty. Ltd (Australia). Typical properties of four different kinds of basalt fibre meshes, which were imported from China, are given in Table 1. BS10/25/50 are knitted by coated basalt fibre string (diameter=3.00-3.20mm), and BS05 is knitted by uncoated basalt fibre.

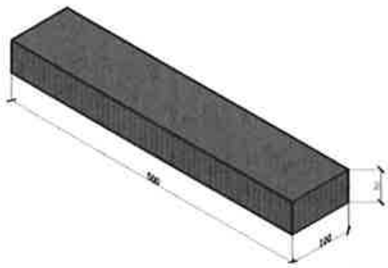
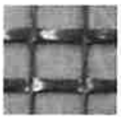
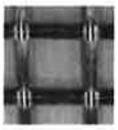


Figure 1. Specimens and distribution of meshes in specimens

Table 1. Properties of various kinds of basalt reinforcement meshes

Mesh name	Mesh geometry	Grid spacing (mm)	Net grid spacing (mm)	Tensile strength (MPa)	Elastic modulus (GPa)
BS05		5	4	3400-3500	66-70
BS10		10	7	3450-3600	68-72
BS25		25	19	3800-4000	75-80
BS50		50	38	3800-4000	75-80

Sample Preparation

The 20 cases of ferrocement composite elements, with three identical specimens of each case, were prepared for testing (Table 2). Meshes were cut to fit the steel molds prior to the mixing process. Mortar was prepared using a barrel mixer. The cement and sand were dry mixed in the mixer for a period of 3 min. Then water and HRWRA was added and mixed for a total of 5-7 min. Fresh mix was casted after the mesh was put into the steal molds layer by layer. All test specimens were vibrated on a vibration table for 3–5min until dense air bubbles stopped coming to the surface, and then covered with plastic. Specimens were de-molded after 24 h, and cured in the laboratory at ambient temperature and humidity.

Table 2. Designation of Ferrocement Thin Composite

Group &Number	Mix proportion Cement: water: sand	Weight fraction of HRWAR (%)	Type of mesh	No. of Layers	Volume fraction of reinforcement (%)
G1-0.30-control			-		-
G1-0.30-BS05			BS05		2.17
G1-0.30-BS10	1.00:0.30:0.36	1.00	BS10	10	3.25
G1-0.30-BS25			BS25		3.49
G1-0.30-BS50			BS50		3.27
G2-0.28-control			-		-
G2-0.28-BS05			BS05		2.19
G2-0.28-BS10	1.00:0.28:0.36	1.00	BS10	10	3.37
G2-0.28-BS25			BS25		3.40
G2-0.28-BS50			BS50		3.24
G3-0.26-control			-		-
G3-0.26-BS05			BS05		2.26
G3-0.26-BS10	1.00:0.26:0.36	1.00	BS10	10	3.32
G3-0.26-BS25			BS25		3.35
G3-0.26-BS50			BS50		3.34
G4-0.24-control			-		-
G4-0.24-BS05			BS05		2.16
G4-0.24-BS10	1.00:0.24:0.36	1.00	BS10	10	3.14
G4-0.24-BS25			BS25		3.22
G4-0.24-BS50			BS50		3.25

Testing Methods

Samples were tested under four point bending conditions using Impact loading machine (Figure 2) at 28 days. Load was applied in 2.40 kN steps for a period of 60s. A laser distance measure sensor was placed at the central point of the ferrocement composite for measuring the flexural load–deformation behavior. All data were collected using a data acquisition system. Crack characteristics and ultimate flexural load were observed and recorded at failure. General structural behavior of the ferrocement thin composite elements was carefully observed during the load application. The failure load is identified when the applied load drops.

RESULTS AND DISCUSSIONS

It was observed that the position of the basalt mesh layers in the specimens varied slightly during the casting. However, such variations did not lead to large differences in the experimental results of three identical specimens in each case. The test results are presented in the form of load vs. deflection curves. The test results are discussed as follows.

Effect of Basalt Reinforcement Meshes

Typical results of load vs. deflection curves of the specimens using different kinds of basalt reinforcement meshes (BS05/10/25/50) and control specimens are shown in Figure 3. It can be observed that the cracking load of the specimens using BS25 and BS50 as reinforcement system are similar and significantly higher than others. The reason could be the reinforcement of BS25 and BS50 mesh leads to a higher tensile strength than other two meshes. Higher tensile strength makes it more efficient in improving the flexural performance of the specimens.

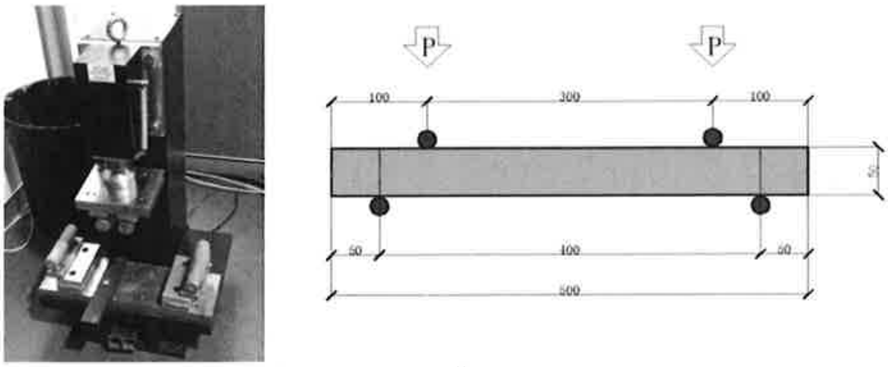


Figure 2. Four point bending test

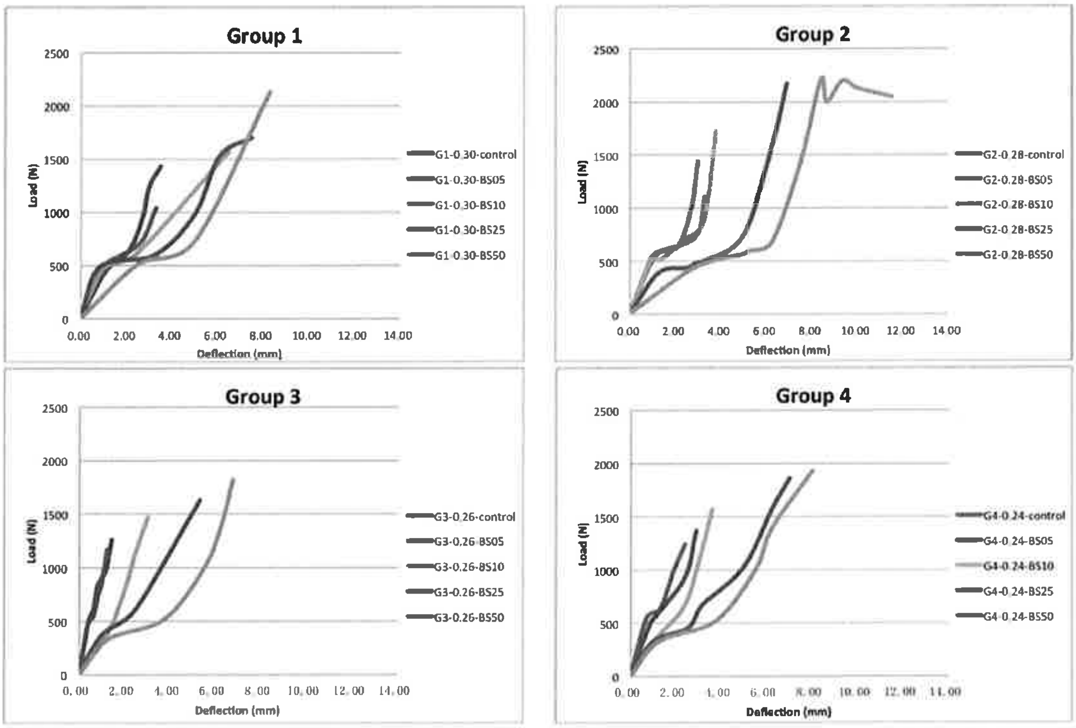


Figure 3. Load - deflection curves of specimens

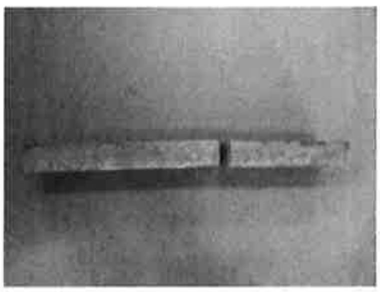


Figure 4a. Cracking pattern of specimens with BS05

Figure 4b. Cracking pattern of specimens with BS50

The failure pattern of the specimens using BS05 is shown in Figure 4a. As it can be seen that the specimen was broken into two separate pieces in a brittle manner which indicated that the ten layers of BS-05 meshes cannot improve the brittle nature of the concrete. However, the bending stiffness and the crack load were higher than the control sample without any mesh. The improved ductility was observed for specimens with ten layers BS50 as reinforcement (Figure 4b). The specimens using BS50 and water/cement ratio of 0.28 continued to sustain a significant load even after the maximum bending stress were reached. They have behaved in a ductile manner with numerous fine cracks.

Effect of Water/Cement Ratio

Figure 5 shows the cracking stress of specimens with different water/cement ratios. The hardened properties of mortar used in the casting have a relatively small different value; their bending performance should become similar. However, the cracking stress improvement strongly depends on the increase of fluidity of mortar. As shown in the figure, the cracking stress of the mix design with w/c=0.28/0.30 is better than other mix designs. Furthermore, the cracking stress of specimens with w/c=0.28 is higher than those with w/c= 0.30 at the same time; hence, it can be observed that the bending performance of the specimens made of w/c=0.28 as matrix is better.

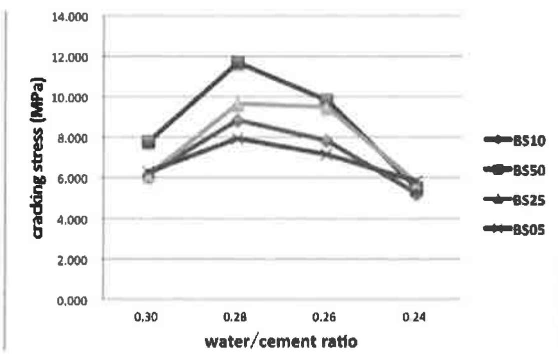


Figure 5. Effect of water/cement ratio

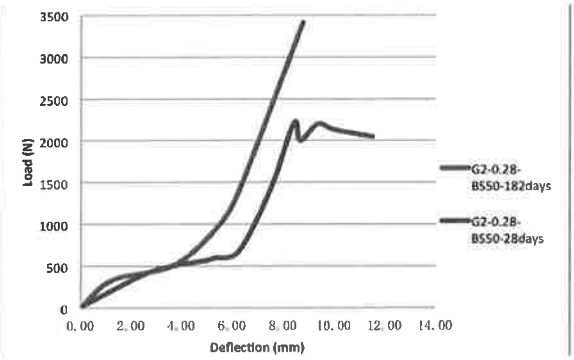


Figure 6. Effect of curing time

Effect of Curing Time

Three identical specimens made of w/c=0.28 and BS50 were prepared and kept in curing room for 182 days. The load vs. deflection curves are shown in Figure 6. As it can be seen, there was an increase in strength of specimens with longer curing time. This was attributed to a parallel increase in matrix strength and mesh/matrix bond strength. The results also indicated that there was a correlation between crack width and curing time. For example, specimens cured for 28 days developed cracks at width of approximately 1-3 mm after four points bending test (Figure 7a). Conversely, specimens tested at approximately 182 days developed relatively wider cracks between 5 and 8 mm (Figure 7b).


Figure 7a. Specimens cured for 28 days


Figure 7b. Specimens cured for 182 days

CONCLUSIONS

The following conclusions can be drawn from the results presented and discussed in this paper:

The use of basalt meshes as reinforcement system in the ferrocement composite elements contributes significantly to the improvement of bending characteristics compared to the control samples without basalt mesh, especially when using BS50 mesh. Maintaining 10 mesh layers and using different water/cement ratios have a relatively small effect on either the load capacity or the failure pattern, however, a water/cement ratio of 0.28 is the best choice. Increasing the curing time has an appreciable effect in increasing the first crack load and bending capacity. The variation in crack widths was mainly accredited to ageing.

Further studies need to be undertaken to investigate the bonding between basalt mesh and mortar by SEM technology, and predict the ultimate moment capacity of the ferrocement composite reinforced with basalt meshes by an approach similar to the ACI Building Code18 procedure for strength analysis recommendation on mesh efficiency factors, elastic modulus, yielding, and tensile strengths.

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