FATIGUE BEHAVIOUR OF MORTAR WITH BLAST FURNACE SLAG AS FINE AGGREGATES

Hokkaido University Student Member ○Muhammad Aboubakar Farooq
Hokkaido University Regular Member Yasuhiko Sato
Okayama University Regular Member Toshiki Ayano
Okayama University Regular Member Takashi Fuiji

1. INTRODUCTION

Blast furnace slag is a by-product generated during production of iron. This slag is obtained by quenching molten iron slag from blast furnace in water or steam to produce glassy, granular product that is then dried and ground into fine powder or sand particulate. It has been classified as an amorphous material when used as binder material and called granulated blast furnace slag. In Japan, volume of granulated blast furnace slag produced is over 20 million tons per year and 90% of it is used as a material for cement and concrete production (Nippon Slag Association, 2011).

Jariyathitipong et al. (2014) has found that when blast furnace slag is used as total amount of fine aggregates in mortar and concrete production, the resistance to sulfuric acid of such mortar and concrete are improved significantly. Fuiji et al. (2014) reported that concrete containing blast furnace slag is well known for improving durability properties of concrete against different environmental actions like frost damage, corrosion etc. The properties of blast furnace slag (BFS) mortar and concrete against mechanical actions are not clarified yet. Now it has become necessary to determine the mechanical properties of such mortar and concrete so that this material can be applied in new construction and for repair works. In this paper, the basic mechanical properties i.e. fatigue of mortar with blast furnace slag sand as full replacement of fine aggregates are investigated both in air as well as in water.

2. EXPERIMENTAL OUTLINE

2.1 Materials and Mix Proportions

Ordinary portland cement (Density: 3.15g/cm^3, Blaine fineness: 3,300cm^2/g) is used as binder. As fine aggregate, granulated blast furnace slag sand (Density in saturated surface dry condition: 2.72g/cm^3, Water Absorption: 1.12%, fineness modulus: 2.23) is used. Mixed proportion of blast furnace slag mortar is shown in Table 1.

Table 1: Mix proportion of blast furnace slag mortar

W/C (%)	Unit Content (kg/m^3)			HRWRA (kg/m^3)	AFA (kg/m^3)
	W	OPC	BFS		
35	268.45	767	1533	3.835	2.301

BFS: Blast furnace slag sand, HRWRA: High range water reducing admixture, AFA: Antifoaming Agent.

2.2 Specimens and Test Method

Cylinder specimens of 50mm in diameter and 100mm height were casted with mix proportion by weight as 1:2 (binder : blast furnace sand). Cylinders were cured in water for 7 days after demoulding. Six cylinders of blast furnace slag sand were tested for determination of compressive strength i.e. three cylinders in air and three cylinders were soaked in water for 48hours before testing in water. Loading was applied at rate of 0.01mm/sec for compressive strength test. Strain gauges and LVDTs were used for recording strain and displacement data of BFS mortar. The line diagram of loading arrangement is shown in Fig. 1.

The fatigue tests were carried out by using servo hydraulic machine. Four cylinder specimens of 50mm in diameter and 100mm were tested for determination of fatigue properties of blast furnace slag mortar out of which two cylinders were tested in air and two cylinders in water. The specimens tested in water; were soaked in water for 48hours so that the saturation can be properly distributed throughout specimen. The load was applied in form of sine signal with a constant amplitude. The frequency of cyclic loading is 5Hz. The maximum stress applied on cylinders was 70% of the average compressive strength (f_c') of blast furnace slag cylinders with constant load ratio of 0.14 between maximum and minimum load during the tests.

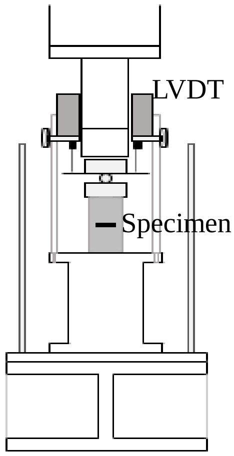

Fig. 1 Loading Arrangement

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Contact address: A-509, Graduate School of Engineering, Hokkaido University, Sapporo, Japan, Tel: +81-11-706-6219.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Since the BFS mortar cylinders were cured for 7-days in water, the average compressive strength (f_c'), Elastic modulus (E), and poison's ratio (v) both in air as well as in water are presented in Table 2. Typical stress-strain curves observed in the fatigue test are shown in Fig. 2.

Table 2: Mechanical Properties of BFS Mortar

Environmental Condition	f_c' (MPa)	E (GPa)	v
In Air	107	42.6	0.30
In Water	101	39.6	0.30

$$Log\ N = X\frac{(1-S_{max})}{(1-S_{min})} \quad (1)$$

Eq. (1) can be used for comparison between the experimental results of BFS mortar and fatigue life of ordinary concrete as shown in Fig. 3. Here value of X is 17 for air and 10 for water (JSCE Standard Specifications for Concrete Structutres-2012 Design). Table 3 represents the comparison of fatigue life of blast furnace slag mortar determined by experiments with ordinary concrete in air as well as in water at nominal stress level of 70% of ultimate compressive stress and frequency of 5Hz. Fig. 3 shows the relationship of S-N_f of BFS mortar based on experiments and that of ordinary concrete as per JSCE code.

Table 3: Fatigue Life (N) of BFS Mortar and Ordinary Concrete

Environmental Condition	Stress Level	BFS Mortar as per Experiments			Ordinary Concrete as per JSCE
		Specimens		Average Fatigue Life	
In Air	0.7	BFS1-air	69,986	60,553	4,64,159
		BFS2-air	51,120		
In Water		BFS1-water	452	2046	2,155
		BFS2-water	3,640		

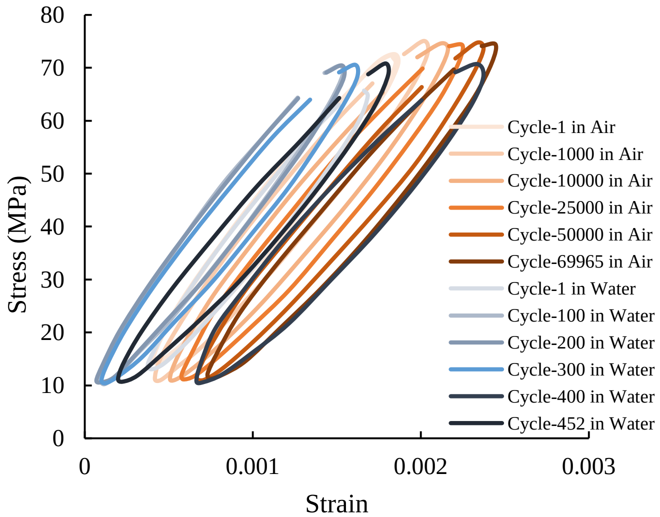

Fig. 2: Stress-Strain Curve for Fatigue Test

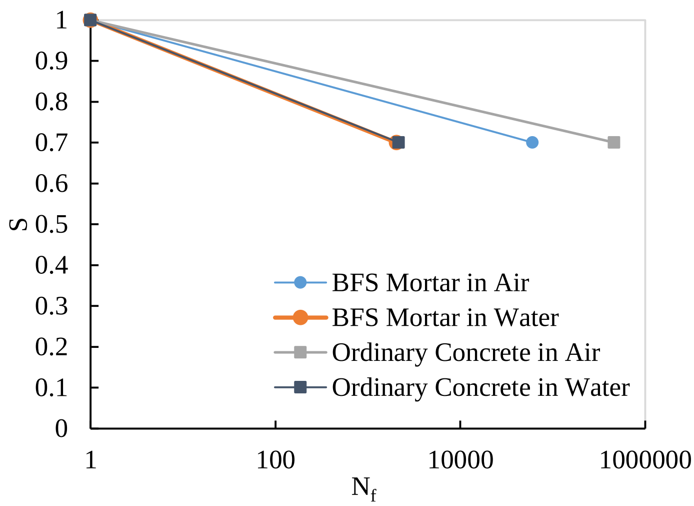

Fig. 3: Relationship between S and N_f

4. CONCLUSIONS

It may be said that with the incorporation of blast furnace slag sand as fine aggregates in mortar production, the fatigue life of mortar in air is small as compared to ordinary concrete, but the fatigue life of mortar with BFS sand as fine aggregates in water is almost same as that of ordinary concrete at 70% of the average compressive strength (f_c').

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