Thermal and Mechanical Properties of Basalt Fibre Reinforced Concrete

Tumadhir M., Borhan

Abstract**—**In this study, the thermal and mechanical properties of basalt fibre reinforced concrete were investigated. The volume fractions of basalt fibre of (0.1, 0.2, 0.3, and 0.5% by total mix volume) were used. Properties such as heat transfer, compressive and splitting tensile strengths were examined. Results indicated that the strength increases with increase the fibre content till 0.3% then there is a slight reduction when 0.5% fibre used. Lower amount of heat conducted through the thickness of concrete specimens than the conventional concrete was also recorded.

Keywords**—**Chopped basalt fibre, Compressive strength, Splitting tensile strength, Heat transfer.

I. Introduction

BASALT rock is a volcanic rock and can be divided into small particles then formed into continues or chopped fibres. Basalt fibre has a higher working temperature and has a good resistance to chemical attack, impact load, and fire with less poisonous fumes [1]. It was observed that the use of continuous basalt fibres improved the tensile strength of concrete more than E-glass fibres and gave a greater failure strain than the carbon fibres [2]. The use of continuous basalt fibre in concrete was investigated [3]. The results obtained in the research have shown an improvement in the thermal and mechanical properties of concrete. Little researches has studied the effect of using short basalt fibre on the mechanical properties of concrete [4], [5]. Dias and Thaumaturgo [4] have introduced basalt fibre into concrete composites. They investigated experimentally the influence of the volumetric fraction of chopped basalt fibre on the fracture toughness of geopolymetric cement concrete (PSS) (inorganic cement) reinforced with this type of fibre. They compared it with ordinary Portland cement concrete (PC) also reinforced with basalt fibre. The results showed that there was a gain in splitting tensile strength and flexural strength for all specimens in relation to PSS. On the other hand, there was a decrease in strength for PC specimens. A superior load capacity and fracture toughness of PSS over that of PC were observed. According to these results, they concluded that basalt fibres were more efficient in PSS than PC. However, the volume fractions of basalt fibre studied in their research were limited (0.5% and 1% only). Li and Xu [5] investigated the effect of using chopped basalt fibre with volume fractions range from 0 – 0.3% on the deformation and energy absorption capacities as well as the dynamic compressive strength of geopolymetric concrete under impact loading. Studying the effect of using wide range volume fractions of short basalt fibre on the mechanical properties of Portland cement concrete is required. In addition, the effect of using this type of fibre on the thermal properties of concrete has not been paid attention in the previous researches.

II. Experimental

A. Materials and Sample Preparation

Ordinary Portland cement and metakaolin (China clay) (10% by weight of cement) were used as a binder in this research. Limestone coarse aggregate with maximum size of 10mm was used in all mixtures. The Sperplasticizeru (SP) used was a sulphonated formaldehyde condensate (Daracem SP6). The optimum dosage was chosen after conducting a trial mixes for concrete with highest percentage of fibre (0.5%). The chopped Basalt fibre was provided by BASALTEX Ltd in Belgium (25.4mm length and 13µm in diameter) (Fig. 1). The volume fractions of (0%, 0.1%, 0.2, 0.3%, and 0.5% by volume) were suggested in this study. The control mix was designed to achieve design strength of 35MPa. The cement, coarse aggregate, water/ binder ratio, the total weight of the fine aggregate and the dosage of the superplasticizer were kept constant for all mixtures to show the effect of the fibre only on the properties of concrete. The mix proportion was 1:1.75:3.5 (cement: sand: coarse aggregate) by weight and the water/binder ratio was 0.55. The desired volume of fibre were gradually added into the mix while the mixing continued, after adding all the materials into the mixer, in order to achieve good fibre distribution. All the specimens were placed in water tank until the time of the test. Table I shows the physical and chemical properties of the materials used in this study.

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TABLE I
CHEMICAL AND PHYSICAL PROPERTIES OF CEMENT, METAKAOLIN, SUPERPLASTIZER AND BASALT FIBRE

Portland cement		Metakaolin		Superplasticizer		Basalt fibre	
Property	%	Property		Property		Property	
SiO_2	31.135	Colour	White	Appearance	Dark brown liquid	Density of unsized filament matl	2.67kg/dm^3
Al_2O_3	10.29	ISO brightness	>82.5	Air Entrainment	1% - 2%	Moisture content of basaltic rock	0.1%
Fe_2O_3	4.295	-2μ (mass%)	>60	Chloride Content	Nil	Melting point	1350°C
CaO	48.5	+325 mesh (mass%)	<0.03	Freezing Point	0°C	Filament breaking load	> 85 - 67cN/tex
MgO	2.27	Moisture (mass%)	<1			Elongation at break	2.8%
SO_3	2.49	Aerated powder density (kg/m^3)	320			E-Modulus	84 GPa
K_2O	0.835	Tapped powder density (kg/m^3)	620			Continuous max temperature	-250°C to 550°C 1200°C fire barrier
TiO_2	-	Surface area (m^2/g)	14				
Na_2O	0.22	Pozzolanic reactivity (mg $Ca(OH)_2$/g)	>950				
Eq Na_2O	0.765						
L.O.I	1.98						
Other	-						

Fig. 1 Basalt fibre used in this study

B. Testing

1. Slump Test

BS EN 12350-2:2009 [6] slump test was followed to evaluate the workability of fresh concrete.

2. Unit Weight and Compressive Strength Tests

The compressive strength test was conducted according to BS EN 12390-3:2002 [7]. Cubic samples (100×100×100)mm were used for both tests; the specimens were tested at three ages; 7 days, 28 days, and 90 days. The average of three specimens was recorded as a test result.

3. Splitting Tensile Strength Test

BS EN 12390-6:2000 [8] was followed to conduct the splitting tensile strength. Three cylinder samples (100mm in diameter and 200mm high) were tested for this purpose at 28 days and the average was recorded.

4. Modulus of Elasticity Test

This test was conducted according to BS EN 1881-121:1983. Three cylinders (100mm in diameter and 200mm in the height) were tested for each mix ate age of 28 days. The average of these three cylinders was recorded.

5. Heat Transfer

For testing the heat transfer through the specimen, a simple test was developed. The test procedure utilizes a kiln with automatic temperature control. Small specimens (100x100x25)mm were placed on the top of the kiln and insulated from the other direction (Fig. 2). The inside and the outside surfaces of the specimen's centre temperatures were measured using thermocouples (type k) adhered to the surfaces using a special type of glue (thermo–glue). The readings of the thermocouple on the outside surface were checked using a thermal imaging camera and surface probe. The temperature was raised to 600^{o}C at a rate of 5^{o}C/min. The differential temperature between the outside and the inside faces of the specimen was determined. The comparison between the mixtures was carried out by plotting the temperature difference- time histories.

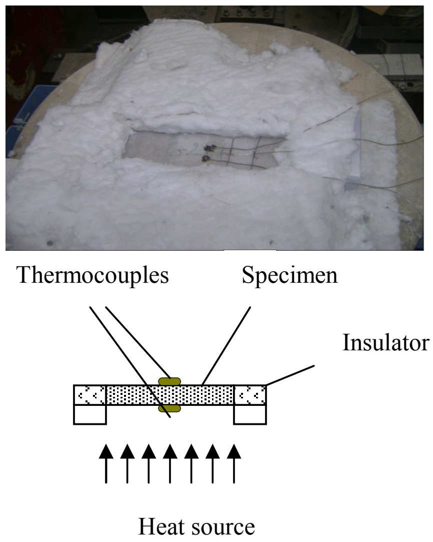

Fig. 2 Heat Transfer Test

III. Results and Discussion

Slump and Unit Weight results are shown in Table II. It can be seen that increasing the percentage volume of fibers leads to decrease the slump. This is mainly due to the fact that fibers hinder the flowability of fresh concrete and this results in a decrease in workability. The unit weight is not sensitive to the increasing the volume percentage of basalt fibre as its content was low in all mixes.

TABLE II
Slump and Unit Weight Results

Specimen Mark.	Basalt Fibre%	Slump (mm)	Unit Weight (kg/m3)
G0F0	0	C*	2418
G0F1	0.1	C	2415
G0F2	0.2	35	2406
G0F3	0.3	12	2412
G0F5	0.5	5	2410

C: Collapse

A. Splitting Tensile Strength

The results of splitting tensile strength are presented in Fig. 3. There is a slight increase in it with increase the volume fraction of fibre till 0.3% and then it decreases with 0.5% basalt fibre. Jianxun et al [9] experimental results show the same trend using a range of fibre from 0 to 7%. However, a statistical analysis carried out by the author using the null hypothesis testing at 95% confidence level indicates no significant change in the splitting tensile strength compared with the control mix (Table III).

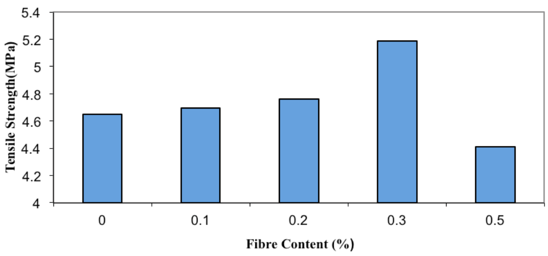

Fig. 3 Splitting tensile strength results

B. Compressive Strength

Fig. 4 shows that there is a slight decrease in the compressive strength when basalt fibre increases above 0.3%. The reduction was 12% when 0.5% fibre was used. Dias and Thaumaturgo [4] studied the effect of using 0.5% and 1% of basalt fibre on concrete strength. They found there was a 25% and 3.8% decrease in compressive strength when 1% and 0.5% of basalt fibre were used respectively. They concluded that using basalt fibre leads to a decrease in compressive strength of concrete. Jainxn et al. [9] confirmed these results and they attributed this behavior to the fact that adding basalt fibre results in increasing the poor areas of interface in the system of cement matrix which intern decrease the compressive strength of concrete.

The statistical analysis results confirm that there is a significant effect of using basalt fibre on the compressive strength. The null hypothesis assumes that there is no difference between the test data (not significant), whereas the alternative hypothesis assumes that there is a difference between them. The compressive strength results show that the basalt fibre variations lead to reject the null hypothesis with different curing time (Table III).

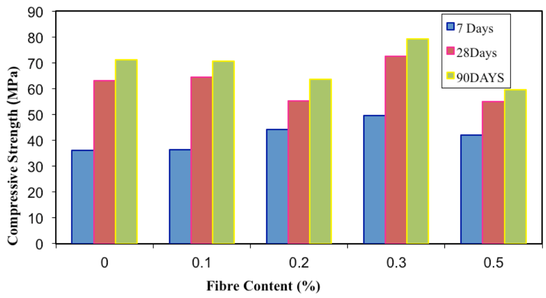

Fig. 4 Compressive strength results

TABLE III
Summary of the Statistical Analysis

Group	Sum of Square (SS)	Degree of freedom (df)	*F*	*P-value*	*F critical*
Compressive strength (7days)	261.2384	3	25.3452	0.000194	4.066181
Compressive strength (28days)	474.2676	3	774.4023	3.41E-10	4.066181
Compressive strength (90days)	549.054	3	213.1073	5.71E-08	4.066181
Splitting tensile strength	0.958534	3	3.445803	0.071825	4.066181

C. Modulus of Elasticity

The modulus of elasticity results show the same trend of that of the compressive and splitting tensile strengths (Fig. 5). It can be seen that increasing the volume fraction on the fibre from 0.1% to 0.3%, the Modulus of elasticity increase then there is a decrease in it when 0.5% of basalt fibre was used.

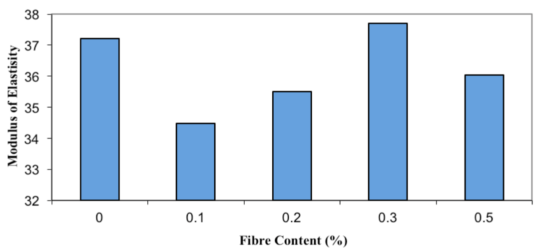

Fig. 5 Modulus of elasticity results

D. Heat Transfer

Increasing the volume fraction of basalt fibre leads to a decrease in the amount of heat conducted through the thickness of concrete specimens (i.e. a decrease the thermal conductivity) at all temperature levels (Fig. 6). Sim et al. [3] attributed this to the volumetric stability of basalt fibres against high temperature exposure. This due to the nature of the basalt rocks, which nucleates at high temperature. Li [5] confirm this confirmed Sim et al. conclusion and he found that the fracture of basalt filament occurred and almost all basalt filament were broken when temperature rised to 800^{o}C.

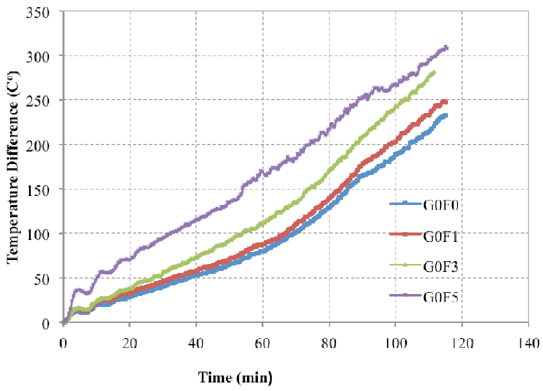

Fig. 6 Temperature profile of concrete with different fibre content

IV. Conclusions

From the results obtained it can be concluded the follows:

1) The slump of concrete decreases with increasing the volume fraction of basalt fibre and the unit weight is not sensitive to it as the fibre content was low in all mixes.
2) A slight increase in the splitting tensile strength with increase the volume fraction of fibre till 0.3% and then it decreases with 0.5% basalt fibre.
3) The compressive strength increases with increase the fibre content till 0.3% then there is a slight reduction of 12% when 0.5% fibre was used.
4) The modulus of elasticity shows the trend of the strengths results.
5) Adding basalt fibre to concrete decrease the amount of heat conducted through the thickness.

References

[1] Mingchao, W., et al., Chemical Durability and Mechanical Properties of Alkali-proof Basalt Fiber and its Reinforced Epoxy Composites. Journal of Reinforced Plastics and Composites, 2008.

[2] Berozashvili, M., continuous reinforcing fibers are being offered for construction, civil engineering and other composites applications. advanced material composite news, composite worldwide, 2001. 21(6): p. 5-6.

[3] Sim, J., C. Park, and D. Moon, Characteristics of basalt fiber as a strengthening material for concrete structures. Composites Part B: Engineering, 2005. 36(6-7): p. 504-512.

[4] Dias, D. and C. Thaumaturgo, Fracture toughness of geopolymeric concretes reinforced with basalt fibers. Cement and Concrete Composites, 2005. 27(1): p. 49-54.

[5] Li, X., Study on Thermal Resistance of Basalt Filament Yarn. Advanced Materials Research, 2011. 146: p. 666-669.

[6] BS EN 12350-2:2009 , Testing Fresh Concrete: Slump Test, British Standards.

[7] BS EN 12390-3:2002 ,Testing Hardened Concrete Part 3: Compressive Strength of Test Specimens, British Standard. .

[8] BS EN 12390-6:2000 ,Testing Hardened Concrete Part 6: Tensile Spliting Strength of Test Specimens, British Standard.

[9] Jianrun, M., Xuemei Q., Litao Cheng, Youlong Wang. Experimental research on fundamental mechanical properties of presoaked basalt fibre concrete. in Proceeding of the 5th International conference on FRP composites in civil engineering 2010. Beijing, Chaina.