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Evaluation the Effectiveness of Chopped Basalt Fiber on the Properties of High Strength Concrete

A.E.A. Elshekh, N. Shafiq, M.F. Nuruddin and A. Fathi
Department of Civil Engneering, Universiti Tekenoli PETRONAS Bandar, Seri Iskandar, 31750, Tronoh, Perak Darul Ridzun, Malaysia

Abstract: High amount of steel reinforcement content, durability and ductility issues has led the development of alternative types for reinforcement of high strength concrete HSC. Fiber Reinforcement (FR) of concrete has been investigated as strengthening materials with different techniques such as external and bar reinforcement. This is due to high contributions of the FR on the mechanical properties of HSC such as high compressive strength, toughness and ductility. Among the many types of FR have been used for this purpose, there are very few studies were conducted on developing new continuous basalt fiber in HSC. The main objective of this study is to investigate the effect of chopped basalt stands CBFS on the fresh and harden properties of HSC as a new internal strengthening material. This was done by changing of CBFS content in the mixture and comparing with 100% OPC of HSC. Experimental results showed that the workability of HSC affected negatively with increase of CBFS content. It is also shown that the early and long terms of compressive strength was not supported using the CBFS. Whereas, split and flexural tensile strengths were significantly improve. It was also observed that the brittleness was significantly decreased and its toughness and ductility were steadily improved. Therefore, it can be conducted that the CBFS is a suitable strengthening material to produce ductile HSC.

Key words: Basalt, HSC, CBFS

INTRODUCTION

Concrete reinforced with steel reinforcement have shortcomes on the durability properties such as salty water penetrating into concrete. When this water reaches the steel, it causes corrosion and crack in the concrete. Non-corrosive, non-magnetic and non-electric properties are necessary for a good serviceability. Therefore, the replacement of the traditional steel reinforcement has been required recently, reported by Singha (2012), Novitskii and Sudakov (2004), Li and Xua (2009) and Chin *et al*. (2012). Defects properties of traditional concrete have significantly improved using fibers as reinforcement materials as reported by Singha (2012).

So far, fibers are one of the basic reinforcing elements of composite materials which consist Carbon, Glass and Steel fiber. These types of fibers have been used for making composite. It's applications on the real construction are very limited due to its flaws such as unfriendly environmental of steel and high cost of glass fiber (Singha, 2012; Deshmukh, 2007).

Investigation of basalt fiber on concrete as an external strengthens materials as a Reinforced Polymer (FRP) has been done by Singha (2012), Caldarone (2008), Lee *et al*. (2002) and Mahmoud *et al*. (2009) recently. They reported that the properties of HSC have been improved using FRP such as strength and durability. External fibers strengthening materials have significantly good effect on the mechanical and durable properties but the bonding between the fiber and concrete become a problem for these systems by Leung *et al*. (2008).

Dias and Thaumaturgo (2005) pointed out that basalt fiber reinforcement geopolymeric concrete BFRGC has better fracture properties than basalt fiber reinforced OPC concrete. Dynamic compressive strength and energy absorption capacity of OPC concrete significantly improved by up to 26 and 14% respectively, using 0.1% (volume fraction) of basalt fiber. Its effect on the strengthening and toughening of OPC concrete was higher than those of carbon fiber for OPC concrete reported by Hong and Shin (2003).

A few studies were conducted on developing new continuous basalt fiber. Basalt fiber is a common term

Corresponding Author: A.E.A. Elshekh, Department of Civil Engneering, Universiti Tekenoli PETRONAS Bandar, Seri Iskandar, 31750, Tronoh, Perak Darul Ridzun, Malaysia Tel: +60104692973

used for a variety of volcanic rocks, which are gray and dark in color, formed from the molten. There are large deposits of this type in the world published by Rahim *et al*. (2011).

The continuous fiber classified as an inert and natural, friendly to environment and nonhazardous material. The advantages of basalt fiber are not only able to improve the mechanical properties of concrete, but it are cheaper and chemically more stability than the E-glass fibers composites. Moreover, it can work in a wide range of temperatures (-269-650°C) (Singha, 2012; Caldarone, 2008; Arivalagan, 2012). There is very little available literature on concrete strengthening by the basalt fiber as an internal strengthening or addition inside materials especially on the high strength concrete.

The purpose of this study was to investigate the fresh and harden properties of high strength concrete using chopped basalt fiber stands CBFS as internal strengthening materials.

EXPERIMENTAL WORK

Materials used and mix proportions: Type I Ordinary Portland Cement (OPC) with specific gravity 3.16 and specific surface area of 3200 cm^2 g^{-1} and Sika Viscocrete 34-30 as a good superplasticizer with low content of 0.8 % were used throughout this experimental investigation. River sand with well gradation and finesse module F.M = 2.2 was used as a fine aggregate. Coarse aggregate was crushed granite with 2.68 specific gravity and size ranged of 9 to 20 mm and drinkable water were used. The percentage of water to total binder materials was 0.275%. Finally, 1, 2 and 3% of CBFS by weight of cement was added as internal strengthening materials. This kind of CBFS was manufactured in china from malting, natural rock with 25 mm length and 18 μ mm diameter. Table 1 shows its chemical components.

In available literature there is no guide line of HSC mix design, but there was a basic concept from the experts. This concept involved quality of materials, improvement of paste cement as well as the aggregate, enhancing the bond between aggregate surface and cement paste and lastly denser backing between the both components pointed out by Caldarone (2008). Mix proportion of the materials was made by trail using these basic criteria to produce the HSC mix design. The mix which labeled No. 1 in Table 2 later it will be used with various dosages of CBFS to complete this work as a control mix.

Mixing and preparing of specimens: For all mixes, fresh and hardened concrete properties were tested according to American Standard Testing Materials (ASTM). All the specimens were casted and tested at the Universiti Tecknologi PETRONAS lab. Each concrete specimen was

Table 1: Chemical components of CBFS

Components	Percentage
Combustible matter content	0.5200
Water content	0.0025
SiO2	51.6500
AL2O3	15.5800
Fe2O3	3.9700
FeO	6.1500
CaO	9.3500
MgO	6.1000
K2O	1.4300
Na2O	2.0500
TIO2	1.3300
Other oxides	2.3900

Table 2: Proportion of mixes

Mix No.	Cement ($kg\ m^{-3}$)	C.B.F (%)	C.A ($kg\ m^{-3}$)	F.A ($kg\ m^{-3}$)	W/C ratio	S.P (%)
1	550	0	975	740	0.275	0.8
2	550	1	975	740	0.275	0.8
3	550	2	975	740	0.275	0.8
4	550	3	975	740	0.275	0.8

prepared in a tilting drum mixer with a tilt angle of X0, total mixing time of 5 min. The workability of fresh concrete was tested using slump test in according to ASTM C 172. 100 mm cubes were casted for compressive strength, 100 mm diameter ×200 mm cylinders for split tensile strength and 100×100×500 mm beams for flexural tensile strength were casted. All specimens compacted by electrical vibrating hammer in three layers, after compaction at the 26±2°C room temperature it were maintaining in the molds of 24 hours. Lastly after demolded all of them were cured in the water tank till the test date, the temperature curing period was 20±2°C till to date of test.

RESULTS AND DISCUSSION

This study focuses on the effectiveness of CBFS on the fresh and mechanical properties of 100% OPC HSC as an internal strengthening material. Workability of fresh concrete, compressive strength, splitting and flexural tensile strengths, modulus of elasticity and stress-strain relationship all these properties were investigated. The experiments have been conducted using 1, 2 and 3% CBFS by weight of cement.

Effect of CBFS on workability of fresh concrete: Workability is one of major property of fresh concrete due to its effect on the productivity of HSC. Therefore, a high effective super plasticizer Sika Viscocrete 34-30 with lower content 0.8% with lower ratio of w/c of 2.75% was used. To prevent the balling and make a homogenous fiber concrete total time of mix increases an increasing of CBFS content. After the mixing the CBFS may absorbed same of hydration water this may be led to decrease the workability of the fresh concrete. However, this reduction in the slump is proportional increase as an increasing of CBFS content as shown in Fig. 1. There was full homogeneousness and no aggregate segregation occurred. To recover this issue, can be increase the superplasticizer content. From the tests result observed the concrete after addition of fibers still is a workable concrete.

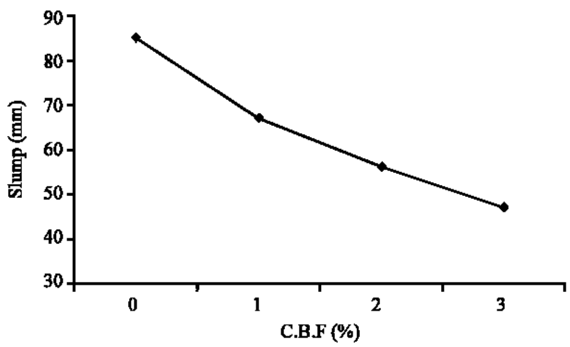

Fig. 1: Effect of CBFS on the workability of HSC

Effect of CBFS on the compressive strength of HSC: Figure 2(a-e) shows the effect of CBFS on the compressive strength of HSC obtained from the conducted tests. Compressive strength results calculated here are the averages of three specimens. It was obtained from the tests results that the early and long term strength of HSC was not provided by CBFS as addition internal materials even it decreased. The compressive strength decreases with increasing of CBF content as shown in Fig. 2. There are many reasons can be observe from the results led to show the trend of the experimental. As an increases of percentage of CBFS the probability of CBFS balling together and make poor areas in the harden sample of HSC was increasing. Therefore, first collapse on the concrete may be happen through those voids regions. Furthermore, fibers after mixing had absorbed too much of the mixing designed water, cement around them may be does not get sufficient water for hydration.

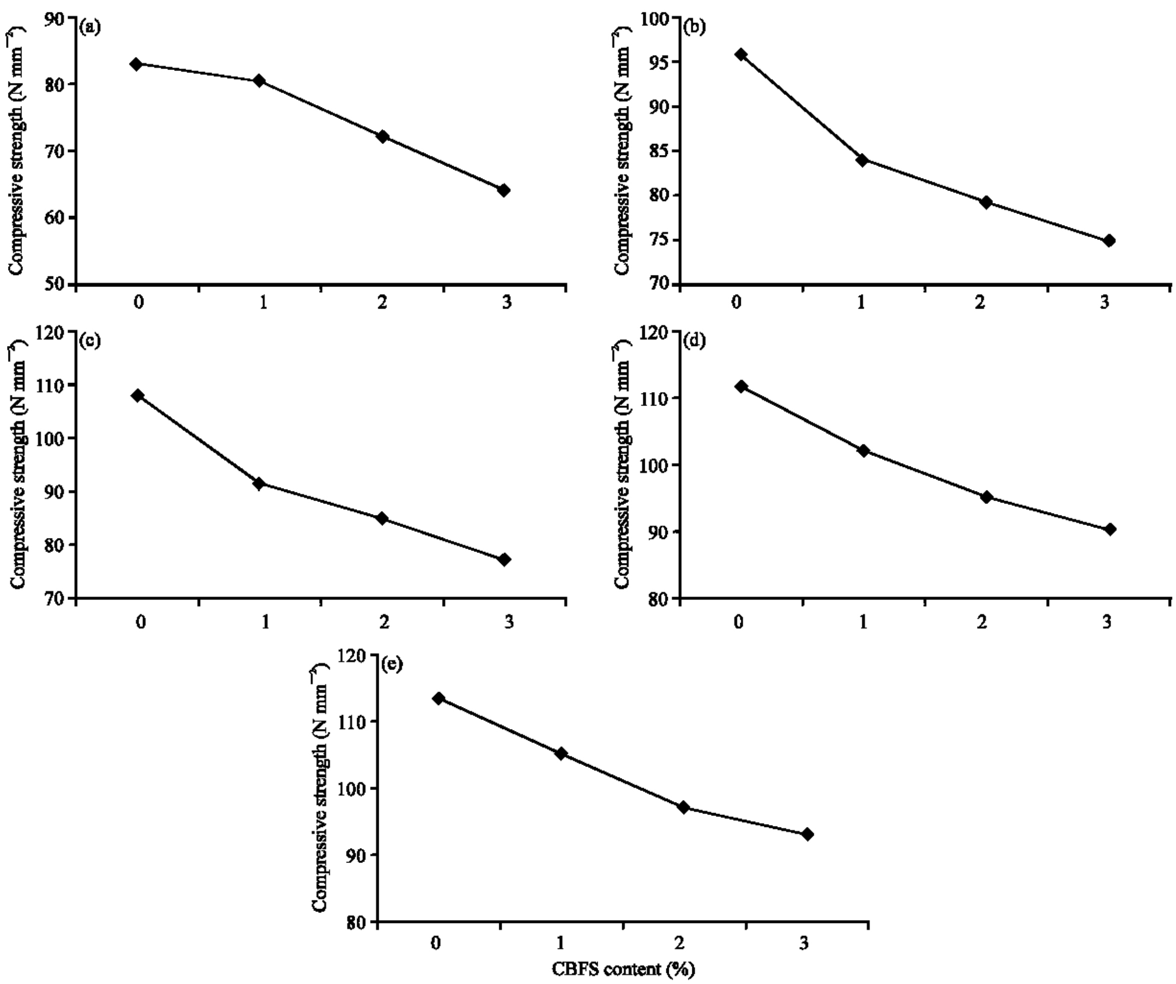

Fig. 2(a-e): Effect of CBFS on the early age (a) and (b) and long term (c), (d) and (e) of HSC strength

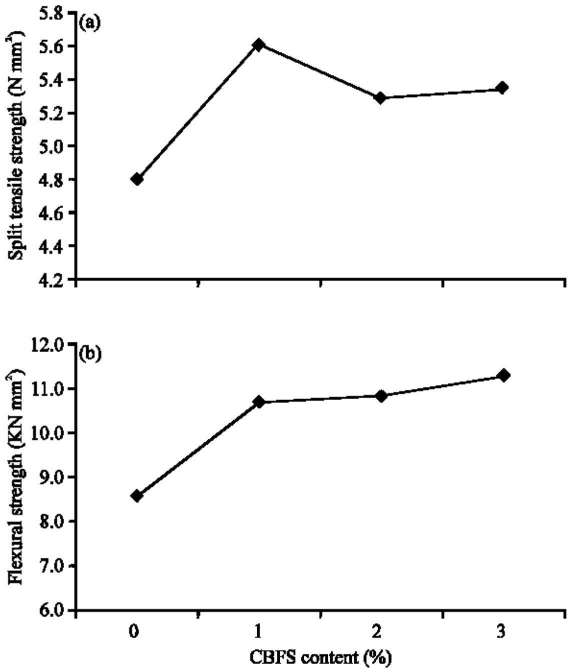

Fig. 3(a-b): Effect of CBFS on the split (a) and flexural (b) tensile strengths of HSC

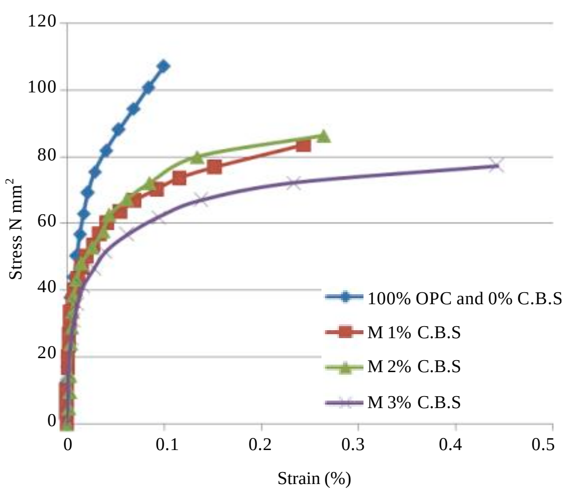

Fig. 4: Effect of CBFS on the stress-strain relationship of HSC

Effect of CBFS on the tensile strength of HSC: Splitting and flexural tensile strengths of HSC were measured through indirect tests. Each sample was loaded by four points load up to failure. It is observed that CBFS which have randomly distributed inside the beams, were prevented the cracks growth which appeared while the specimens were loaded. Furthermore, fibers are bridged deformation cracks thus transferring the loads to the concrete. Splitting and flexural tensile strength of HSC are

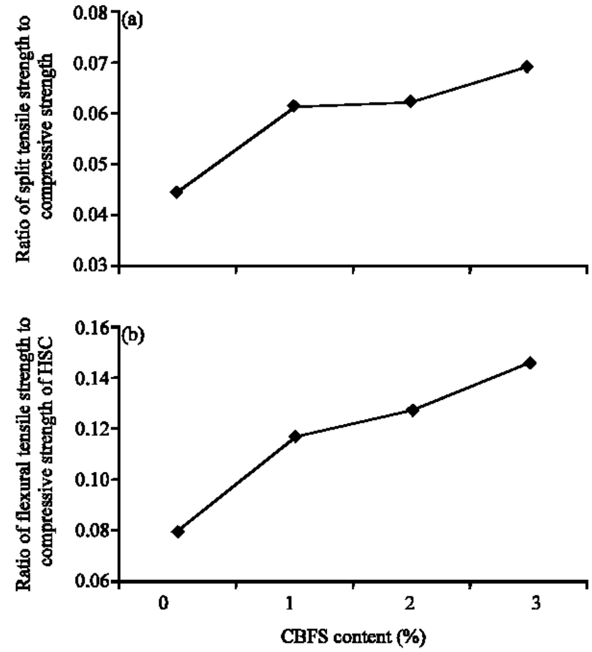

Fig. 5(a-b): Effect of CBFS on the Ratio of splitting (a) and flexural (b) tensile to compressive strength of HSC

steadily increased by using CBFS as internal strengthening materials as shown in Fig. 3a, b.

Effect of CBFS on the toughness and ductility of SHC: The toughness and ductility of the CBFS concrete cubes are observed trough the test in stress-strain relationship curves for all specimens. These relationships were plotted using the electrical resistance strain control gauge to measure the strain of plain concrete cube under compressive strength test. From test results, the ascending parts of the curves were linear. The consecutive parts have non-linear shape up to the failure point. All the curves shapes changed with increase in their strain by adding the CBFS as shown in Fig. 4. The reason here is CBFS enhance the interaction zone strength between the aggregate and cement paste. Depending on this result, can be said that the pattern of HSC is moving from a brittleness collapse towards the ductile collapse.

The percentage between tensile strength to compressive strength is another indicator of the toughness and ductility of concrete. High value of it at the same mixes is reflecting of less brittleness and high toughness of HSC. Ratio of tension and compressive of HSC are obviously increased when the dosage of CBFS increased as shown in Fig. 5a, b. From these results the HSC brittleness was decreased. Furthermore, due to improvement of tensile and flexural strength, the toughness and ductility of HSC was enhanced.

CONCLUSION

The effect of CBFS as internal strengthening materials of HSC was experimentally investigated in this study. A mix which considered as a control mix was a 550 kg m^{-3} of cement 975 kg m^{-3} of coarse aggregate, 1.32 coarse to fine aggregate ratio, 0.275% w/c and 0.8% Sika Viscorete 34-30. 1, 2 and 3% of CBFS, which has 25 mm length and 18 μ mm diameter, was added as additional materials.

The results showed that, slump of HSC was reduced. This negative effect increases as an increase of CBFS. Despite this decrease on the slump the concrete was workable concrete. To control for this issue we should increase the superplasticizer content. The mixes were observed to be fully homogeneous and no aggregate segregation occurred.

Compressive strength concrete was not provided by CBFS as internal additional materials even though it's decreased with an increase of CBFS content.

Splitting and flexural tensile strengths of HSC was increased with increasing the content of CBFS. Energy absorption of HSC was enhanced by adding CBFS. Control mix shows low strain less than 0.1%, results are obtained that this high brittleness was significantly reduced using CBFS. Depending on these results can be said that the pattern of HSC is moving from brittleness collapse towered the ductile collapse.

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