Proc. of the Intl. Conf. on Advances in Civil, Structural and Mechanical Engineering --CSM 2013

ISBN: 978-981-07-7227-7 doi:10.3850/ 978-981-07-7227-7_17

Compressive behavior of Basalt Fiber Reinforced Composite

Smriti Raj
Academy of Scientific and Innovative Research;
CSIR-Structural Engineering Research Centre,
CSIR Campus, CSIR Road, Taramani (P.O), Chennai,
INDIA 600 113,
Corresponding Author: smritiraj007@rediffmail.com,
smritirajdeo@serc.res.in

Smitha Gopinath, Nagesh R. Iyer
CSIR-Structural Engineering Research Centre,
CSIR Campus, CSIR Road, Taramani (P.O), Chennai,
INDIA 600 113,

Abstract- The development of basalt fiber reinforced composite is an important milestone in improving the mechanical performance and durability of concrete construction. Basalt fiber is environmentally safe, non toxic, non corrosive and it possess high resistance against low and high temperatures. Incorporation of basalt fiber as reinforcement in concrete is one of the recent developments and the detailed information regarding its characterization is scanty in literature. The present study aims towards mechanical characterization of basalt fiber reinforced composite under compressive loading. Experimental investigation has been carried out on basalt fiber reinforced composite cylinder and cubes having different amount of basalt fibers. The volume fractions of basalt fibers used for studies ranges from 0.3% to 2%. Based on experimental investigation, effect of different volume fraction of basalt fiber has been studied under compression and optimal volume fraction of basalt fiber has been arrived at. Different failure modes have been observed for each volume fraction of fiber under compressive loading. The effect of volume fraction of basalt fibers on compressive strength, and the compressive stress-strain curve has been examined for ultimate strength up to 0.02% strain . The stress strain curve has been determined experimentally for optimal 0.5% volume fraction of basalt fiber reinforced composite and compared with that of unreinforced mix. Further Modulus of elasticity has been determined from stress-strain curve obtained from the experimental investigation.

***Keywords*— Basalt fiber reinforced composite, Compression, volume fraction, stress-strain, composite**

I. INTRODUCTION

Basalt fiber has excellent properties like high modulus, high strength, corrosion resistance, and it retains its strength at high temperature also which made civil engineering community to develop it further for different application purposes. Mostly from 20th century onwards, different studies have been done on basalt towards determining compressive behavior, tensile behavior, flexural behavior, strengthening purposes.

The composite material generally signifies mixing of more than two material where each material has their unique physical and mechanical property but the material so called composite is formed after combining different materials and it posses better physical and mechanical property than individual components. The structural property of composite material mostly derived by high performance basalt fiber. The studies have shown that basalt fiber has little or no effect on compressive strength of concrete on basalt fiber reinforced concrete with different volume fractions 0.1,0.25,0.4,0.5% (Ramakrishnan,1998). Basalt fiber has been studied with different kind of concrete such as geopolymeric concrete under impact loading (Weimin Li et al ,2010). It was found that addition of basalt fiber can significantly improve deformation and energy absorption capacities while no notable improvement for dynamic compressive strength. Effect of basalt fiber on compressive strength was carried out for M20 & M30 grade concrete (Arivalagan,2012). In this study, basalt fiber was found to increase compressive strength of concrete. Scanty literatures are available for generalizing the effect of basalt fiber on compressive strength behavior.

In the present studies, basalt compressive behavior has been characterized for a composite for four different volume fraction Vf of 0.3%, 0.5%, 1% and 2%. The ingredient of composite mix contains cement, flyash, silica fume, quartz powder, Ennore sand, Carboxylate based superplasticizer and water. All the ingredients of composite mix has particle size in the range of µm to mm. The composite mix has been developed for design strength of 50MPa based on trial and error. Failure of composite mix is found to be completely brittle in nature whose behavior has been investigated after incorporating different volume fraction of basalt fiber into it and also maximum compressive strength has been found out for composite mix for different volume fraction of 0%, 0.3%, 0.5%, 1% and 2% by optimizing Vf of basalt fiber. Average compressive strength is determined for cube specimen of size 70mmx70mmx70mm under accelerated curing .

Further to examine the effect of basalt fiber for composite mix under compressive loading , stress-strain behavior for optimal Vf 0.5% of fiber has been compared with 0% Vf of fiber by testing with cylinderical specimen of size 75mmx150mm. . The stress-strain behavior is unique for every material and it helps in determining individual component effect in taking load for composite material.

II. EXPERIMENTAL PROGRAMME:

The experimental work aimed at towards (a) investigating effect of different volume fraction of basalt fiber in compressive strength enhancement of composite mix and optimizing volume fraction of basalt fiber. (b)The different failure mode of composite mix with and without fiber. (c)experimentally determine the stress-strain behaviour of

Proc. of the Intl. Conf. on Advances in Civil, Structural and Mechanical Engineering --CSM 2013

ISBN: 978-981-07-7227-7 doi:10.3850/ 978-981-07-7227-7_17

basalt reinforced composite and comparing with unreinforced mix.

A. *Mix design and preparation:*

The mix design for composite mix to get strength of 50 MPa was designed based on trial and error. The composite mix design for each % of volume fraction of basalt fiber is given in Table 1. Different batches of concrete mix were cast using Hobart mixer (capacity 15Kg) for different volume fraction of (0%, 0.3%, 0.5%, 1% and 2%) basalt fiber. For uniform mixing of finer particles, Pan mixer (Hobart) was used . Total mixing was done for 10 minutes, in which three minutes dry mixing (cement ,sand, flyash, silica fume, quartz powder) was done. Then water along with superplasticizer is added to composite and mixing continued for three more minutes. For Basalt Fiber Reinforced Composite, (BFRC) mix, after adding all the materials into the mixer, the desired volume of fiber were gradually added into the mix while mixing continued in order to achieve good fiber distribution. The cement, flyash, silica fume, quartz powder, ennore sand, water/binder ratio, super plasticizer percentage were kept constant for all mixes to show the effect of basalt fiber on composite mix strength. The basalt fiber was added as a percentage of the total volume of the mixture.

TABLE I. COMPOSITE MIX DESIGN

Material	*MF0*	*MF3*	*MF5*	*MF1*	*MF2*
Cement (Kg/m^3)	**520**	**520**	**520**	**520**	**520**
Fly Ash (Kg/m^3)	**175**	**175**	**175**	**175**	**175**
Silica Fume (Kg/m^3)	**70**	**70**	**70**	**70**	**70**
Ennore Sand (Kg/m^3)	**500**	**500**	**500**	**500**	**500**
Quartz Powder (Kg/m^3)	**300**	**300**	**300**	**300**	**300**
Super-plasticizer (%)	**0.4%**	**0.4%**	**0.4%**	**0.4%**	**0.4%**
Water (Kg/m^3)	**280**	**280**	**280**	**280**	**280**
Water/binder ratio	**0.36**	**0.36**	**0.36**	**0.36**	**0.36**
Fiber(%)	**0%**	**0.3%**	**0.5%**	**1%**	**2%**

B. *Acceleated Curing:*

For all the specimen, in order to get early strength accelerated curing was done, in which accelerated curing cycle consist of six days as shown in Fig1. After demoulding of specimen, initial three days it was kept for normal water curing followed by two days under temperature up to 90˚C in autoclave, and then in oven at 200 ˚C.

C. *Raw material for BFRC composite mix*

a)Cement(1µm-100µm): It is a fine mixture of lime, alumina, silica. Portland cement is a fine powder of chalk, clay and lime bearing minerals fired to 1500 ˚C (calcinated). The particles of cement lies in the range of 1µm-100µm . The advantage of cement is that, it forms a paste when dissolve in water and has sufficient strength but they are weak and brittle. For experimental work, Primo Zuari Cement 53 grade was used

b)Fly Ash(1µm-100µm): It is a artificial pozzolanic material, which is generated from industrial waste (by-product of coal power plant). The particles of flyash are spherical lies in the range of 1µm-100µm, which is advantageous from water requirement of view and have a very high fineness. Due to the high specific surface, they are readily available for reaction with calcium hydroxide. Flyash has been classified based on the reactive calcium oxide content as class-F(less than 10%), and class –C(more than 10%).For the experimental work, Class-F Flyash has been chosen.

c)Silica Fume(0.1 µm to 1 µm): It is also pozzolanic material, which is a by-product of the induction arc furnaces in the silicon metal and ferrosilicon alloy industries. The silica fume are generally used to get high early strength in concrete. The beneficial effect of silica fume are not only limited to its pozzolanic reaction but good packing is achieved by the particles which are typically 100 times smaller than cement particles. For experimental work, Corniche SF silica fume were used.

d)Sand(.09mm to .5mm): For experimental work, Ennore sand Grade III supplied from Tamilnadu minerals limited was used.

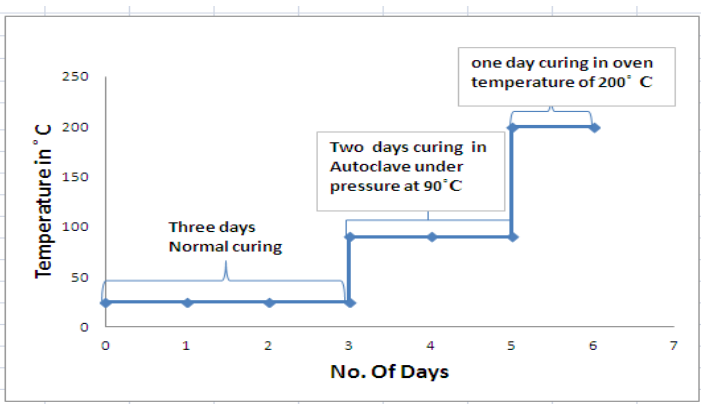

Fig 1 Accelerated Curing Cycle

Proc. of the Intl. Conf. on Advances in Civil, Structural and Mechanical Engineering --CSM 2013

ISBN: 978-981-07-7227-7 doi:10.3850/ 978-981-07-7227-7_17

e)Quartz Powder (5 µm to 25 µm): Quartz is the most abundant mineral of earth from where quartz powder are formed. The maximum reactivity of quartz powder occurs during heat treatment. So accelerated curing would have enhance the effect of quartz powder in the composite mix.

f)Superplasticizer: Polycarboxylate based superplasticizer supplied by Sure Chemical Co.,Ltd, Chennai was used for the experimental work..

g)Water: For experimental work, AML lab, CSIR –SERC Tap water was used throughout this study.

g)Basalt Fiber: Chopped basalt fibers with different volume fraction (0%,0.3%, 0.5%, 1% and 2%) were used to investigate its influence on mechanical properties of composite mix. The fibers were bundled, so they do not have uniform diameter as shown in Fig 2 . The length of Individual fiber was 23mm and 16 µm in diameter. Technical data for basalt fiber as supplied by supplier Flipps India Engineering, Mumbai, India is given in Table II.

Fig2 Chopped Basalt Fiber

TABLE II. PROPERTIES OF BASALT FIBER

Property	***Unit***	***Value***	***Tolerance***
Technical data for basalt chopped fiber			
Density of unsized filament material	***Kg/dm^3***	***2.63***	***+/-5%***
Moisture content of basaltic rock	***%***	***0.1***	***+/-0.05***
Melting point	***˚C***	***1350***	***+/-100***
Diameter	***µm***	***16***	
Sizing type		***silane***	
Moisture content	***%***	***0.0642***	***+/-5%***
Tensile strength	***MPa***	***>2000***	***+/-5%***
Elastic Modulus	***GPa***	***70-85***	***+/-5%***
Elongation at break	***%***	***3.1***	***+/-5%***

III. EXPERIMENTAL INVESTIGATION

A. Slump Value

Adding basalt fiber into composite mix resulted into decrease in workability. Workability has been measured through flow table test as shown in Fig3. Composite mix should be filled in two layers in a cone and each layer should be tamped 10 times with a special wooden bar. The cone is then raised, and composite is allowed to spread under 15 times stroke in 10 minutes. Then flow of composite is measured in terms of % increase in flow .The test was done in accordance with BS EN 12350-5.

Flow (%) = ((Change in diameter)*100) / (Original diameter)

Fig3 Flow Table Test

TABLE III. SLUMP VALUE TEST

Volume Fraction(%)	Slump Value(%)
0	130
0.3	100
0.5	85
1	82
2	80

B. Average Density Test:

Incorporating basalt fiber into composite resulted into increase in density as shown in Fig4. Average density has been taken as average of both cube specimen 70 mm x 70 mm x 70 mm and cylindrical specimen 75 mm x 150mm.The average density varied between 2147 Kg/m^3 to 2251Kg/m^3 for basalt fiber reinforced composite depending on the different basalt volume fraction.

Proc. of the Intl. Conf. on Advances in Civil, Structural and Mechanical Engineering --CSM 2013

ISBN: 978-981-07-7227-7 doi:10.3850/ 978-981-07-7227-7_17

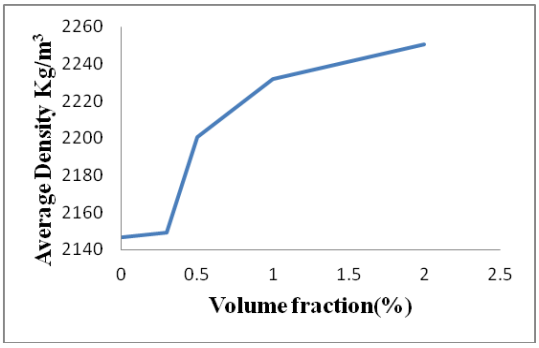

Fig4 Density Vs Volume Fraction of Basalt Fiber

C. Compressive strength test

Compression strength of composite with and without basalt fiber was conducted on cube specimen of 70mmx70mmx70mm. The compression test was conducted as per IS 516-1959.The specimens were kept for accelerated curing for 6 days as reported in earlier. The load was applied at a constant rate of approximately 140 Kg/cm^2/min. The maximum load applied to the specimen was recorded. Average of three values was taken as representatives of the compressive strength of the sample. All the experimental reading along with 15% and 10% variation in compressive strength is shown in Fig5. Neglecting 10% variation in compressive strength of individual sample, average compressive strength for each volume fraction of fiber was found. The individual variation in average compressive strength for each volume fraction is shown in Fig 6.The composite mix strength without fiber was 58 Mpa, after incorporating different fiber volume fraction Vf, increase in compressive strength behaviour is shown in Fig7. For .3%, .5%, & 2% Vf of basalt fiber, percentage increase in compressive strength varies between 11% to 12% but 0.5%Vf of basalt fiber is found to be optimal volume fraction for getting maximum compressive strength of 65.86 MPa.

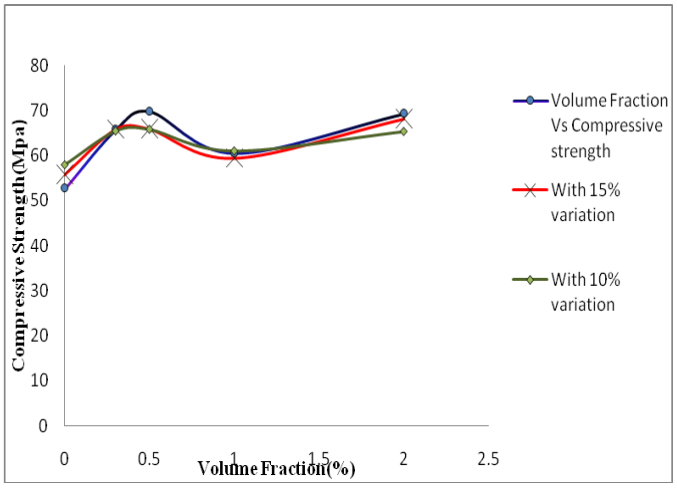

Fig 5 Experimental dispersion of compressive strength of each samples

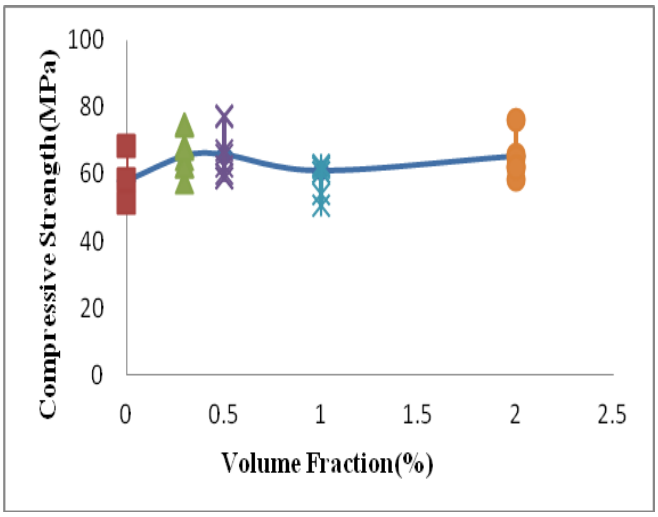

Fig 6 Compressive strength Vs Volume Fraction of Basalt fiber

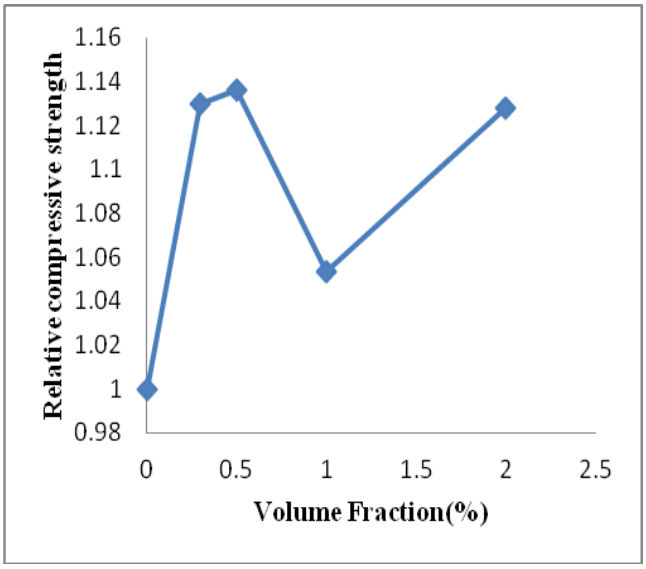

Fig7 Relative Compressive Strength Vs Volume Fraction Of Fiber

D. Stress-Strain Behaviour

Since 0.5% Vf of basalt fiber has been optimized, so stress-strain curve has been plotted, denoted by MF5 and has been compared with specimen containing no basalt fiber denoted by MF0 as shown in Fig 8 . In order to get stress strain curve, 10mm strain gauge has been instrumented with highly viscosity adhesive at middle of specimen of size 75mmx150mm to get strain data and 50 tonnes load cell has been used to get load data. Since, initial failure of the specimen was surface failure so it is very cumbersome to plot stress-strain curve up to peak strain and the failure was brittle failure, so it is difficult to get descending branch also. Stress-Strain curve has been plotted and data has been received by using Kyowa data logger. Data Plot has been made up to peak stress for cylindrical specimen of size 75mmx150mm.

Proc. of the Intl. Conf. on Advances in Civil, Structural and Mechanical Engineering --CSM 2013

ISBN: 978-981-07-7227-7 doi:10.3850/ 978-981-07-7227-7_17

From stress strain curve, Modulus of Elasticity 'E 'is computed for linear portion of the curve using initial tangent modulus of elasticity. For MF0 ,(specimen without basalt fiber), E value calculated was 20 GPa while for MF5 (specimen containing .5% Vf fiber, E value is 34 GPa. Stress- strain behaviour shows, specimen containg fiber has higher stiffness than specimen containing no fiber although mode of failure is same

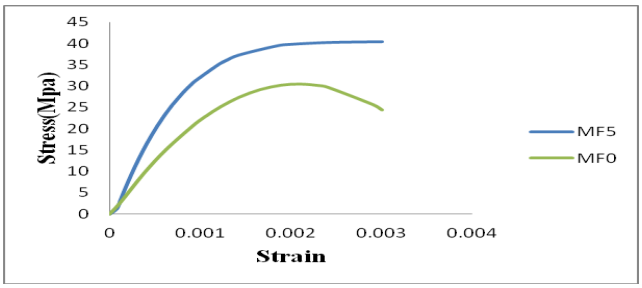

Fig8 Stress Strain Behaviour

E. Failure Mode:

Since the matrix is brittle in nature, so failing should be brittle failure .Even after adding different volume fraction of basalt fiber, failing was found to be brittle. Once the load is applied , initially corner spalling was observed, followed by longitudinal crack propagation. When the crack thickness increases such that it is clearly visible, the outer layer peeled off from surface and sudden specimen failure happened. The different modes of failure is shown in Fig 9

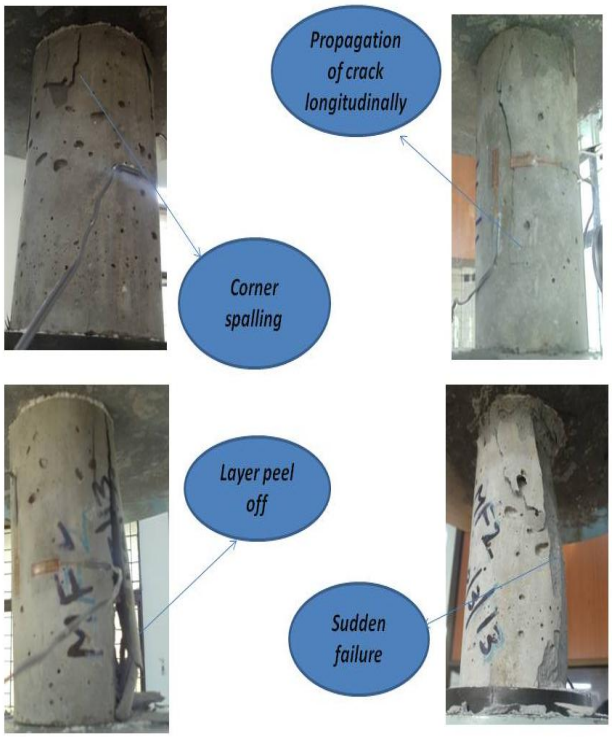

Fig 9 Different Modes Of failure

SUMMARY

For incorporating basalt fiber into composite mix. it was observed that there is decrease in workability and increase in density as volume fraction of fiber increases. Experimental results showed increase in compressive strength for basalt fiber reinforced composite. Among four different volume fraction of basalt fiber 0.3%,0.5%, 1% and 2%,optimal volume fraction has been found as 0.5% which showed 12% increase in compressive strength. Although mode of failure is nearly same for specimen with and without fiber, but modulus of Elasticity for basalt fiber reinforced composite is higher than composite mix alone. Yet many more experimental investigation needs to be done for showing the effect of basalt fiber on compressive strength enhancement and to get complete ascending and descending branch of stress-strain curve for basalt fiber reinforced composites.

ACKNOWLEDGMENT

The author's thank the support rendered by the staff of Computational Structural Mechanics Group. For experimental work, special thank are extended to staff of Advanced Material Lab Group and Heavy Testing Laboratory Group. This paper is being published with the kind permission of the Director,CSIR-SERC

.

.

REFERENCES

[1] A. M. Nevile, Properties of Concrete, 4th & Final ed., Addison Wesley Longman Limited,England pp.62-103.

[2] V.Ramakrishnan, and Neeraj S. Tolmare., Performance Evaluation of 3-D Basalt Fiber Reinforced Concrete & Basalt Rod Reinforced Concrete-Final Report for Highway IDEA Project 45, South Dakota School of Mines & Technology, Rapid City,1998.

[3] Weimin Li, Jinyu Xu, Mechanical properties of basalt fiber reinforced geopolymeric concrete under impact loading, Material Science and Engineering A 505,2010, pp 178-186.

[4] Arivalangan, S., Study On the Compressive and Split Tensile Strength Properties of Basalt Fiber Concrete Members, Global Journal of Researches in Engineering, Civil and Structural Engineering, Volume 12, Issue 4, Version 1.0, 2012.

[5] BS EN 12350-5:2009 Testing fresh concrete. Flow table test

[6] I.S 516-1959,Indian code for method of tests for concrete.