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Fresh and Hardened Characteristics of Basalt-Glass Hybrid Fibre Reinforced Self Compacting Concrete

Uzair Khan, Sandeep Kumar Tripathi, Anurag, Rizwan A Khan

Abstract: Proof that, just as results, self-compacting concrete is complete benchmark in the area of construction. Because of its highly profitable qualities, Self Compacting Concrete (SCC) extremely favoured and used drastically all over the construction world. SCC is that creative concrete which does not require any help of vibration for arrangements and compaction. It is shown that SCC have capability of complete filling formwork by property of flow under its self weight. Hence, it attain over all compaction, even in case of choke reinforcement. The main intent of this research paper is to find the fresh characteristics of basalt- glass hybrid fibre reinforced self-compacting concrete like T50 cm, spread flow, L-box, V funnel and hardened characteristics such as compressive strength, ultrasonic pulse velocity (UPV) and flexural strength at 7 and 28 days. Basalt-glass hybrid fibre reinforced self-compacting concrete has shown improved hardened characteristics with the addition of fibres.

Keywords: Glass Fibres (GF), Basalt Fibres (BF), Hybrid Fibre Reinforced Self Compacting Concrete (HFRSCC), Self Compacting Concrete (SCC).

I. INTRODUCTION

Durability of concrete structures was important area of interest in the early 1980's.The design engineers used proper mix design and quality control checks, yet the durability of concrete structures was not achieved. Later it was investigated that failure of concrete structures was due to improper compaction of concrete. It is required to do adequate compaction by skilled labours to produce durable concrete structures, but there was considerable deterioration in the availability of skilled labours in the construction industry of Japan *(Okamura and Ouchi 2003).* In the modern day construction heavy and congested reinforcement mesh is no longer unusual, and hence to produce heavily reinforced durable concrete structures is a major problem.

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***** Correspondence Author

Uzair Khan*, Department of Civil Engineering, ABES Engineering College, Ghaziabad, India.

Sandeep Kumar Tripathi, Department of Civil Engineering, ABES Engineering College, Ghaziabad, India.

Anurag, Department of Civil Engineering, ABES Engineering College, Ghaziabad, India.

Rizwan A Khan, Department of Civil Engineering, Z. H. College Engg. & Tech., Aligarh Muslim University, Aligarh, India.

This problem can be mitigated or completely eliminated by the introduction of self-compacting concrete (SCC), which compacts without the requirement of agitation or vibration. Okumura recommended the requirement of this type of concrete in 1986. Studies carried out by "Ozawa and Maekawa" at the university of Tokyo to develop SCC, which includes the fundamental investigation on the workability of concrete *(Okamura et al.1993).*

The concrete with high durability due to the water cement ratio being low in amount was termed as high performance concrete *(Gagne et al. 1989).* For the longevity of structure high durable concrete is used for gaining effective results. Therefore, Okamura and Ouchi, have changed the term for the proposed concrete, for their work, to "Self –consolidating high performance concrete".

Self-compacting concrete is highly flow able and rational which is easy to spread and compact under its self-weight without applying any external vibration. Small interstices of formwork and compounded shapes in structural members can easily be filled by self-consolidating concrete. Long distance pumping of concrete is also possible. Self-compatibility in self-compacting concrete can be achieved by limiting the maximum size of coarse aggregate and content. Chemical admixtures such as viscosity modifying admixtures (VMA) and high range water reducer (super-plasticizer), incorporating and adopting low water to binder ratios can also be commonly practiced to achieve self-compatibility in self-compacting concrete *(Okamura and Ozawa 1995).*

Self –compacting concrete is a concrete that is not separated nor bled owing to its self-weight *(Aggarwal et al. 2008).* No internal vibration for compaction is used by self-compacting concrete *(Murthy et al. 2012).* It completely includes the formwork and achieves thorough compaction even in the weighty crowded mesh of strengthening. Self-compacting concrete has various superiority over ordinary concrete in terms of productivity enhancement, general labour cost degradation, finished high-quality product with outstanding of hardened characteristics and durability.

The self-compacting concrete manufacturing technique is similar to the standard concrete, but its production requires a sufficient variety of aggregates and finely ground cemented materials along with an adequate water powder (w / p) ratio to preserve its desire workability so that the concrete does not bleed and segregate. Suitable choice of finely ground aggregates proliferates strong particle packing density and allows water content to be cut.

In order to produce SCC, extremely finely ground powder [fly ash (FA) and silica fume (SF)] is required to enhance the slump quality and cohesiveness. In addition, viscosity enhancing admixtures and super plasticizer (SP) and are extremely needed and used in SCC production.

Hybrid fibre reinforced self-compacting concrete (HFRSCC), it is an advanced form of composite material generated by using different fibres types, shapes and sizes in a SCC *(Kumar 2017).* Adding two or more fibres to the self compacting concrete blend enhances the hardened characteristics of SCC and it is called as hybrid fibre reinforced self-compacting concrete *(Khan and Singh 2019).* With the addition of fibres, the fracture values of self-compacting concrete are elevated *(Khan et al 2019).* Polypropylene fibres enhance cement matrix bending and acts as crack arrester *(Nandhini and Manju 2017).* When fibres are used, micro cracks can be minimized. The inclusion of hybrid fibres reduces the main crack generation and maximizes failure load *(Nandhini and Manju 2017).*The authors conducted experiments on fresh and hardened characteristics of HFRSCC in the current research. The testing of ultrasonic pulse velocity (UPV) were also carried out to verify the quality of the hybrid fibre reinforced self compacting concrete thus generated.

II. EXPERIMENTAL INVESTIGATION

The fresh properties of HFRSCC such as T50cm (sec), flow spread (mm), V- funnel time (sec), L-box (h2/h1), hardened characteristics of HFRSCC such as flexural strength, ultra-sonic pulse velocity (UPV) test and compressive strength were carried out at 7 and 28 days. The proportion of basalt fibres in the current experimental program is 0.25% by volume fraction of concrete quantity, whereas glass fibres are 0%, 0.1 %, 0.2% and 0.3%. Table 1 shows the percentage of fibres used in the corresponding blend. In each blend, 6 cubes of (150 x 150 x150) mm and 6 beams of (100 × 100 × 500) mm samples has been casted in order to evaluate the flexural strength, ultra-sonic pulse velocity (UPV) test and compressive strength of HFRSCC. Table 2 shows details of the SCC mix ratio.

Table 1 Experimental programme

S. No.	Blend	Fibre proportion (%)	
		Basalt fibres (BF)	Glass fibres (BF)
1	M-BF0-GF0	0	0
2	M-BF0.25-GF0	0.25	0
3	M-BF0.25-GF0.1	0.25	0.1
4	M-BF0.25-GF0.2	0.25	0.2
5	M-BF0.25-GF0.3	0.25	0.3

Table 2 Blend ratio of SCC

Cement (kg/m^3)	Fly ash (kg /m^3)	Fine aggregates (kg/m^3)	Coarse aggregates (kg/m^3)	Water (litres)	Super plasticizer (litres)
410	205	846	602	246	7.2

III. MATERIALS USED

The present research work was completed by using 43 grade Ordinary Portland Cement (OPC). Table 3 presents the physical characteristics of Ordinary Portland Cement. Potable tap water has been used for all mixtures. Fine aggregates were used as natural river sand (zone II). The most extreme size of the coarse aggregates was restricted to 12.5 mm. In present study Master Genelium SKY 8765 was utilized as super-plasticizer .In the current paper, the hybrid blend consisted of basalt fibres and glass fibres. Table 4 provides specialized information on basalt fibres and glass fibres.

Table 3 Physical characteristics of OPC (43 Grade)

S. No.	Property	Units	Result obtained
1	Fineness (specific surface)	cm^2/gm	2340
2	Normal consistency	%	32
3	Initial setting time	minutes	65
4	Final setting time	minutes	410
5	Soundness	mm	3
6	Compressive strength 7 days 28 days	MPa	 35.50 45.10
7	Specific gravity	-	3.14

Table 4 Specialized information of basalt fibres and glass fibres

S. No.	Parameters	Basalt Fibres (BF)	Glass Fibres (GF)
1	Length (mm)	12	12
2	Density (g/cm^3)	2.65	2.6
3	Elastic Modulus (GPa)	93-100	72-85
4	Tensile Strength (MPa)	4500	2050
5	Diameter (μ)	12 micron	14
6	Appearance	Golden Brown	White

Figure 1 Chopped basalt fibres (BF)

Figure 2 Glass fibres (GF)

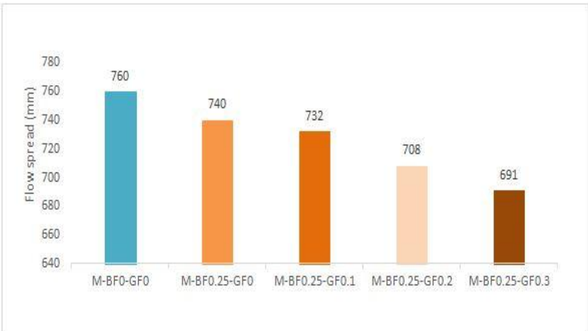
IV. RESULTS FOR FRESH CHARACTERISTICS OF HFRSCC

Table 5 Results of fresh characteristics of HFRSCC

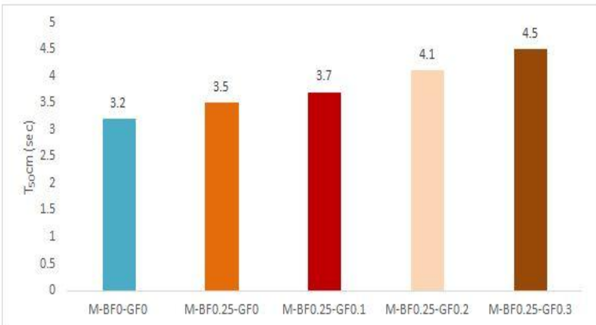
Blend	% Fibres	T_{50}cm (sec)	Flow spread (mm)	L-box (h_2/h_1)	V-funnel time (sec)
M-BF0-GF0	0	3.2	760	0.97	6.7
M-BF0.25-GF0	0.25	3.5	740	0.94	7.4
M-BF0.25-GF0.1	0.35	3.7	732	0.88	8.5
M-BF0.25-GF0.2	0.45	4.1	708	0.84	8.7
M-BF0.25-GF0.3	0.55	4.5	691	0.8	9

Table 5 and graph 1-4 demonstrate the flow spread value decrease due to fibres incorporation. The logic for this situation is that owing to the dispersed fibres in the concrete, a network structure may form, which limits mixing from segregation and flow.

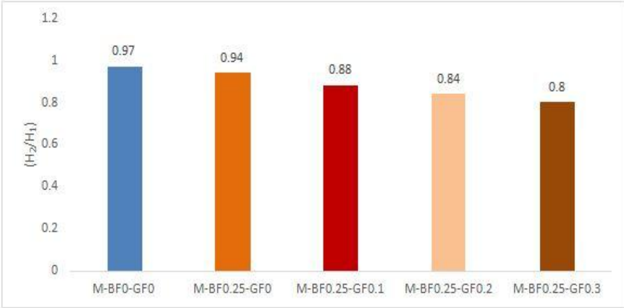
Compared to control blend (M-BF0-GF0), the maximum decline in flow value was observed 9.07 percent for M-BF0.25-GF0.3. The reason for this is due to the highest percentage of fibres compared to the other blends in this mix. As the flow spread value decreases, the T50 cm flow, measured in terms of time (sec) rises. The optimum flow time was found 4.3 sec for M-BF0.25-GF0.3.The L-box ((h2/h1) value reduces with the rise in fibre ratios. The decrease in the value of L-box (h2/h1) also results in a simultaneous reduction in the value of the slump flow. The optimum value for M-BF0-GF0 (SCC reinforced with basalt of 0 percent and glass fibres of 0 percent) was 0.97.The value of the V-funnel, measured as time (sec) rises as the value of the slump flow declines. Mix M-BF0.25-GF0.3 was observed to have the highest value of V-funnel, whereas M-BF0-GF0 had the minimum value.



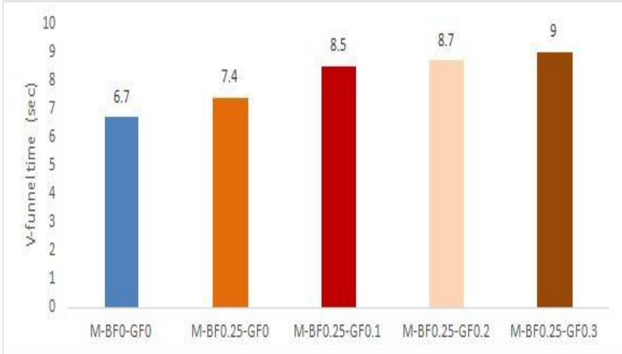
Graph 1. Results of flow spread for HFRSCC blends



Graph 2. Results of T_{50}cm for HFRSCC blends



Graph 3. Results of L-box for HFRSCC blends



Graph 4. Results of V-funnel for HFRSCC blends

V. RESULTS FOR HARDENED CHARACTERISTICS OF HFRSCC

Samples were tested on 7 days and 28 days of normal curing to contrast the different hardened characteristics of HFRSCC blends. Table 6-7 and Graph 5-6 outline the results.

Table 6: Results for Compressive Strength

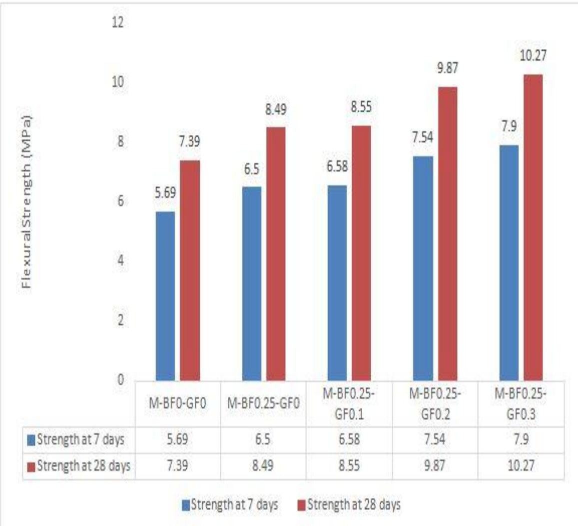
S. No.	Blend	Compressive Strength (MPa) at 7 days	Compressive Strength (MPa) at 28 days
1	M-BF0-GF0	22.01	28.61
2	M-BF0.25-GF0	24.1	31.45
3	M-BF0.25-GF0.1	24.5	31.70
4	M-BF0.25-GF0.2	24.6	32.10
5	M-BF0.25-GF0.3	24.9	32.37

Graph 5. Results of Compressive Strength for HFRSCC blends

In comparison to the control blend (M-BF0-GF0), compressive strength was enhanced for all the blends. However, for M-BF0.25-GF0.3 mix with the mixture of 0.25% basalt fibres and 0.3% glass fibres, the optimum compressive strength was acquired. Compared with the control blend (M-BF0-GF0), compressive strength improved by 9.92 percent at 28 days of self-compacting concrete strengthened with 0.25% basalt fibres. The compressive strength of self-compacting concrete strengthened with 0.25% basalt fibres and 0.1% glass fibres (M-BF0.25-GF0.1) improved by 10.80% compared to the control blend (M-BF0-GF0). The compressive strength of self-compacting concrete strengthened with basalt fibres 0.25% and glass fibres 0.2% (M-BF0.25-GF0.2) improved by 12.19% compared to the control blend (M-BF0-GF0). The compressive strength of self-compacting concrete strengthened with basalt fibres 0.25% and glass fibres 0.3% (M-B0.25-G0.3) improved by 13.14% compared to control blend (M-BF0-GF0). In addition, with the percentage increase in glass fibres remaining continuous as basalt fibres (M-BF0.25-GF0.3), compressive strength was discovered to be nearly the same as compared to M-BF0.25-GF0.2.

Table 7: Results for Flexural Strength

S. No.	Blend	Flexural Strength (MPa) at 7 days	Flexural Strength (MPa) at 28 days
1	M-BF0-GF0	5.69	7.39
2	M-BF0.25-GF0	6.5	8.49
3	M-BF0.25-GF0.1	6.58	8.55
4	M-BF0.25-GF0.2	7.54	9.87
5	M-BF0.25-GF0.3	7.9	10.27

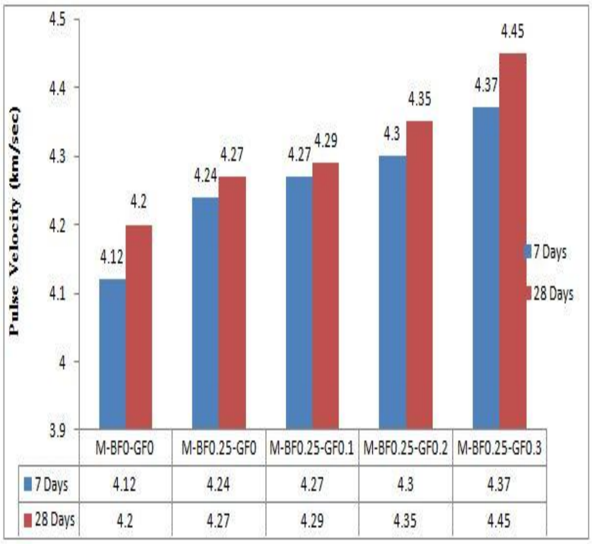


Graph 6: Results of Flexural Strength for HFRSCC blends

In comparison to the control blend (M-BF0-GF0), flexural strength was enhanced for all blends. However, for M-BF0.25-GF0.3 mix with the mixture of basalt fibres 0.25% and glass fibres 0.3%, the optimum flexural strength was acquired. Compared with the control blend (M-BF0-GF0), flexural strength improved by 14.88 percent at 28 days of self-compacting concrete strengthened with 0.25% basalt fibres. The flexural strength of self-compacting concrete strengthened with 0.25% basalt fibres and 0.1% glass fibres (M-BF0.25-GF0.1) improved by 15.69% compared to the control blend (M-BF0-GF0). The flexural strength of self-compacting concrete strengthened with basalt fibres 0.25% and glass fibres 0.2% (M-BF0.25-GF0.2) improved by 33.55% compared to the control blend (M-BF0-GF0). Further, with the percentage increase in glass fibres remaining continuous as basalt fibres (M-BF0.25-GF0.3), flexural strength was discovered increment when contrasted with the M-BF0-GF0 by 38.97%.

Table 8: Results for Ultrasonic Pulse Velocity (UPV)

S. No.	Blend	UPV (km/sec) at 7 days	UPV (km/sec) at 28 days
1	M-BF0-GF0	4.12	4.20 (Good)
2	M-BF0.25-GF0	4.24	4.27 (Good)
3	M-BF0.25-GF0.1	4.27	4.29 (Good)
4	M-BF0.25-GF0.2	4.3	4.35 (Good)
5	M-BF0.25-GF0.3	4.37	4.45 (Excellent)



Graph 7: Variation of Pulse Velocity for HFRSCC blends

In order to examine the concrete sub-surface without damaging the surface or the integrity of the structure UPV test is found helpful. It allows the hard concrete to be comprehensively understood and quality assured. The quality of SCC strengthened with basalt fibres of 0.25 percent and glass fibres of 0.3 percent is excellent and all the others are in good condition.

VI. CONCLUSIONS

- As the percentage of fibres added increases, fresh HFRSCC properties decrease.
- For the M-BF0.25-GF0.3 blend, the highest decrease in spread flow was evaluated to be 9.07%. This may be due to the highest fibre proportion.
- By including fibres in self-compacting concrete, hardened properties such as compressive strength, ultrasonic pulse velocity and flexural strength were enhanced.
- Compared to the control blend (M-BF0-GF0), compressive strength of self-compacting concrete at 28 days improved by 9.92% with 0.25% basalt fibres.

- Compared with the control blend (M-BF0-GF0), 28 days compressive strength of self-compacting concrete strengthened with basalt 0.25% and glass fibres 0.3% (M-BF0.25-GF0.3) increased by 13.14%.
- Glass fibres inclusion increases flexural strength.
- Optimum flexural and compressive strength was found for M-BF0.25-GF0.3.
- Improving the fibre proportion has enhanced the quality of SCC.
- Self-compacting concrete strengthened with 0.25% basalt and 0.3% glass fibres has shown excellent quality.

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AUTHORS PROFILE

Uzair Khan received his B. Tech in Civil Engineering in 2012 from Integral University, M. Tech in Structural & Construction Engineering in 2018 from Dr B R Ambedkar National Institute of Technology, Jalandhar and Ph.D (Pursuing) in Civil Engineering Delhi Technological University, New Delhi in the field of Concrete Technology. He is currently working as an Assistant Professor in the Department of Civil Engineering, ABES –Engineering College, Ghaziabad. He has more than 7 years of teaching, research and educational experience and published more than 13 research papers in peer reviewed journals and conferences. His interests are Self Compacting Concrete, Concrete Composites, Fibre Reinforced Concrete and Geopolymer Concrete.

Sandeep Kumar Tripathi received his B. Tech in Environmental Engineering in 2009 from Uttar Pradesh Technical University, Lucknow, M. Tech in Environmental Engineering in 2013 from Jaypee University of Engineering and Technology, Guna, Madhya Pradesh and Ph.D (Pursuing) in Civil Engineering Jamia Millia Islamia, New Delhi in the field of Remote Sensing and GIS. He is currently working as an Assistant Professor in the Department of Civil Engineering, ABES Engineering College, Ghaziabad. He has more than 7 years of industrial, teaching, research and educational experience and published eminent research papers in peer reviewed journals. His interests are wastewater treatment and technologies, Remote Sensing, Geographic Information System.

Anurag received his B. Tech in Civil Engineering in 2019 from ABES –Engineering College, Ghaziabad. He is currently studying for higher education. His area of interest includes Self Compacting Concrete and Fibre Reinforced Concrete.

Dr. Rizwan Ahmad Khan is currently an Associate Professor in the Department of Civil Engineering at AMU Aligarh. Dr Khan earned his Ph.D. from Indian Institute of Technology, Delhi (IITD). He has more than 10 years of teaching, research and educational experience. He has guided more 40 Master's thesis and published more than 70 research papers in peer reviewed journals and conferences. His interests are Self Compacting Concrete, Concrete Composites, Fibre Reinforced Concrete and Recycling of Materials in Concrete