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Effect of basalt fibre on the mechanical properties of M70 grade high performance concrete

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Abstract. The presented work reveals the strength properties of M70 grade high performance basalt fibre reinforced concrete (BFRCC) containing 0.2%, 0.3% and 0.4% basalt fibre content by volume of concrete. 10% Silica fume is admixed for attaining higher strengths as preferred. Compressive, split-tensile and flexural strengths are evaluated. The BFRCC microstructure is found to be improved due to enrichment of interfacial transition zone with chopped basalt fibres. It was found that different fibre lengths require different dosages to yield maximum effect on the properties of concrete. Stress- strain responses of M70 grade BFRSCC yields improved ultimate strain and strain at peak load indicating its energy dissipation capacity at fracture.

1 Introduction

Development of microstructure of concrete plays a key role it's mechanical characteristics particularly the porosity of the concrete. Fibres in concrete is a very popular way a enhancing few properties of concrete. As many types of fibres are available in market, the choice of fibres have become a topic of debate even though each fibre will have its own specific effect on the properties of concrete. Use of naturally obtained basalt fibres in imparting greater delamination resistance, fracture energy absorption capability, toughness against fracture and the improved ductility endorsed to be used extensively in concrete. The popular problems associated with fibres such as segregation, dispersion, loss of shape, stiffness and cost involved are reduced by the use of basalt fibres. Research showed that not more than 0.5% of fibre volume fraction is required to be used. This low volume fibre content reduces shrinkage cracks especially in concrete elements with more exposed surface area such as pavements, slabs etc. In case of use in structural applications its content can be in the range of 1- 2% to attain the strain hardening in concrete.

2 M70 grade mix proportion

In this study, mechanical properties of M70 grade high performance concrete is assessed based on strength tests, stress-strain under uniaxial loading of compression machine. Quantities needed for cubic metre of concrete are-

- Cement - 554.20 kg/m^3
- Fine Aggregate 659.15 kg/m^3
- Coarse Aggregate 1164.83 kg/m^3
- Silica Fume 55.42 kg/m^3
- Super plasticizer) 7.10 kg/m^3
- Water/binder ratio 0.28

3 Workability

The slump and inverted cone slump test are done of M70 grade BFRCC mixes are presented below.

Table 1. Slump in mm of M70 BFRCC mixes

Type	Designation	Fibre length	Fibre volume	Slump in mm	Inverted Slump in sec
Normal Concrete	0%	0	0	80	5.12
Basalt fibre Concrete	12 mm + 0.2%	12 mm	0.20%	156	4.98
	12 mm + 0.3%	12 mm	0.30%	122	4.44
	12 mm + 0.4%	12 mm	0.40%	138	3.65

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	36 mm + 0.2%	36 mm	0.20%	168	4.38
	36 mm + 0.3%	36 mm	0.30%	176	4.01
	36 mm + 0.4%	36 mm	0.40%	160	3.77
	50 mm + 0.2%	50 mm	0.20%	176	3.98
	50 mm + 0.3%	50 mm	0.30%	180	3.56
	50 mm + 0.4%	50 mm	0.40%	112	3.22

4 Strength investigations

The table 2 presents compressive strengths of M70 grade BFRSCC mixes. Table 3 shows split-tensile strengths of M70 grade BFRSCC mixes. Table 4 gives flexural strength values of M70 grade BFRSCC mixes.

Table 2. Compressive strengths of M70 BFRCC mixes

Type	Designation	Fibre length	Fibre volume	Compressive Strength in MPa
Normal Concrete	0%	0	0	78.24
Basalt fibre Concrete	12 mm + 0.2%	12 mm	0.20%	80.38
	12 mm + 0.3%	12 mm	0.30%	82.48
	12 mm + 0.4%	12 mm	0.40%	86.30
	36 mm + 0.2%	36 mm	0.20%	83.14
	36 mm + 0.3%	36 mm	0.30%	87.56
	36 mm + 0.4%	36 mm	0.40%	80.46
	50 mm + 0.2%	50 mm	0.20%	88.78
	50 mm + 0.3%	50 mm	0.30%	87.10
	50 mm + 0.4%	50 mm	0.40%	80.22

Table 3. Split tensile strength of M70 BFRCC mixes

Type	Designation	Fibre length	Fibre volume	Split-tensile Strength in MPa
Normal Concrete	0%	0	0	5.92
Basalt fibre Concrete	12 mm + 0.2%	12 mm	0.20%	6.22
	12 mm + 0.3%	12 mm	0.30%	6.58
	12 mm + 0.4%	12 mm	0.40%	7.56
	36 mm + 0.2%	36 mm	0.20%	7.76
	36 mm + 0.3%	36 mm	0.30%	8.68
	36 mm + 0.4%	36 mm	0.40%	9.04
	50 mm + 0.2%	50 mm	0.20%	7.98
	50 mm + 0.3%	50 mm	0.30%	8.42
	50 mm + 0.4%	50 mm	0.40%	7.96

Table 4. Modulus of rupture of M70 BFRCC mixes

Type	Designation	Fibre length	Fibre volume	Modulus of rupture MPa
Normal Concrete	0%	0	0	7.24
Basalt fibre Concrete	12 mm + 0.2%	12 mm	0.20%	7.78
	12 mm + 0.3%	12 mm	0.30%	9.12
	12 mm + 0.4%	12 mm	0.40%	9.98

	36 mm + 0.2%	36 mm	0.20%	8.26
	36 mm + 0.3%	36 mm	0.30%	10.68
	36 mm + 0.4%	36 mm	0.40%	10.9
	50 mm + 0.2%	50 mm	0.20%	10.44
	50 mm + 0.3%	50 mm	0.30%	11.34
	50 mm + 0.4%	50 mm	0.40%	10.54

5 Stress-strain investigation on BFRCC mixes

The investigations to assess stress strain values of various length and dose combinations of M30 BFRCC mixes. Cylinders are uniaxially compressed under strain controlled rate of loading.

Table 5. Stress strain values of various length and dose combinations of M70 grade BFRCC mixes

0% fibre		12 mm length + 0.4% fibre M70 BFRCC		36 mm length + 0.3% fibre M70 BFRCC		50 mm length + 0.2% fibre M70 BFRCC	
Strain	Stress(MPa)	Strain	Stress(MPa)	Strain	Stress(MPa)	Strain	Stress(MPa)
0	0	0	0	0	0	0	0
0.0002963	5.240175	0.0000373	1.167116	0.000043	0.393013	0.000044	2.155172
0.0004444	9.432314	0.0002422	7.39229	0.000302	5.502183	0.000177	9.051724
0.0006667	13.9738	0.0004286	12.45202	0.000732	14.14847	0.000486	15.94828
0.0008889	17.81659	0.0006894	18.68221	0.001076	21.22271	0.000817	22.84483
0.0011296	23.40611	0.0010062	24.52949	0.001528	30.65502	0.001126	33.62069
0.0012593	25.15284	0.0014534	34.26772	0.001742	39.30131	0.001435	40.94828
0.0016667	32.48908	0.0018447	42.44923	0.002043	46.37555	0.001811	49.13793
0.0020926	39.12664	0.0021988	50.6274	0.002474	53.05677	0.002142	56.89655
0.0022963	43.66812	0.0026273	59.20019	0.002819	57.37991	0.002407	60.34483
0.0025556	48.9083	0.0029627	65.04914	0.00312	64.84716	0.002672	67.24138
0.0027037	52.0524	0.0031304	67.39173	0.003616	71.9214	0.002959	75.86207
0.0029444	56.94323	0.0034472	71.2994	0.003941	74.27948	0.00329	78.44828
0.0031481	62.18341	0.0037453	74.04162	0.0042	77.42358	0.003621	80.60345
0.003537	64.27948	0.0040621	78.3372	0.00448	80.56769	0.003997	81.46552
0.0037407	64.97817	0.0042298	81.45564	0.004674	83.31878	0.004328	83.18966
0.0040741	70.21834	0.004528	81.4824	0.005021	84.49782	0.004438	83.62069
0.0043333	66.37555	0.0048261	80.7333	0.005454	84.89083	0.004858	87.06897
0.0044074	62.53275	0.0050497	77.64998	0.00576	77.81659	0.005233	87.06897
0.0046111	55.8952	0.0051429	72.61533	0.00587	71.52838	0.005521	87.06897
0.0047407	49.25764	0.0051988	67.18941	0.005981	64.06114	0.005763	81.89655
		0.0052547	63.70311			0.005918	75.43103
						0.006006	67.24138

If the patterns in which cracks are formed, for smaller fibre lengths vertical cracks are formed due to localized fracture whereas in higher aspect ratios the cracks are diagonally formed. In higher aspect ratio the distribution of stresses are evenly throughout the concrete matrix. Stresses undergone by 50 mm fibre length + 0.2% fibre dose BFRCC mix is found to be high when compared with the stress-strain responses of the other BFRCC mixes with fibre less than 50 mm.

Table 6. Strains at peak and ultimate stresses

M30 grade BFRCC Type	Stress strain characteristics			
	Stress at Ultimate load (MPa) σ	Corresponding strain at Ultimate load ε_1	Ultimate Strain ε_2	Strain ratio $\varepsilon_2/\varepsilon_1$

0% fibre	70.22	0.0040741	0.0047407	1.16
12 mm length + 0.4% fibre	81.48	0.004528	0.0052547	1.16
36 mm length + 0.3% fibre	84.89	0.005454	0.005981	1.10
50 mm length + 0.2% fibre	87.06	0.005521	0.006006	1.09

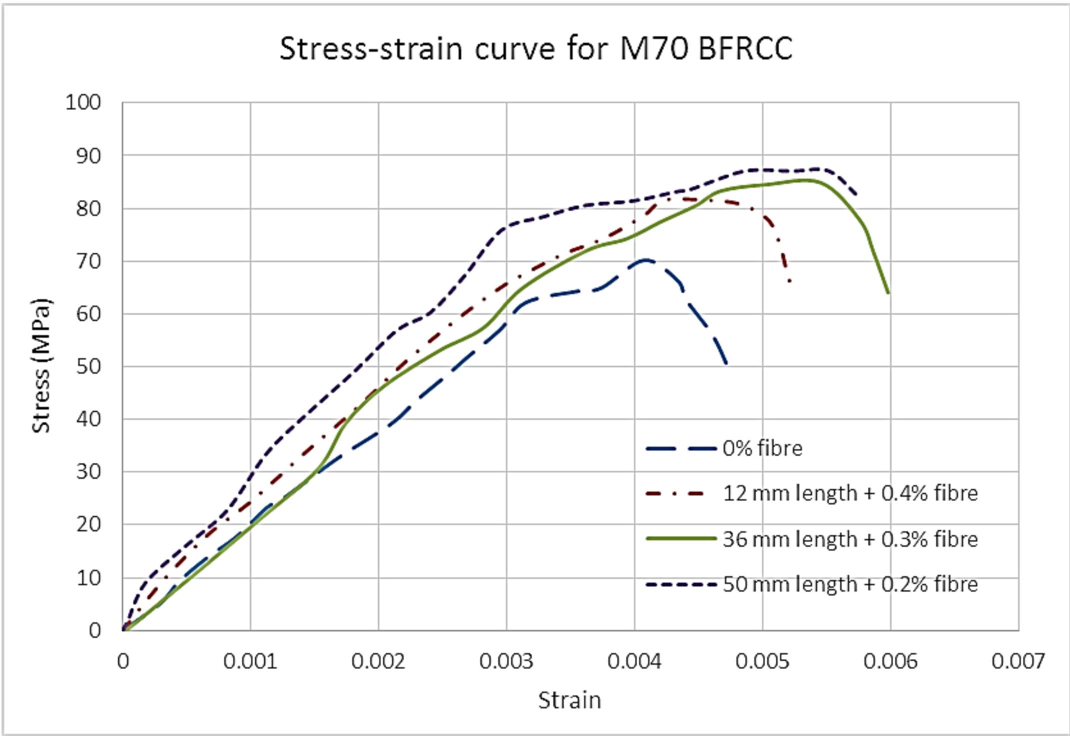

Fig. 1. Stress-strain curve for M70 grade BFRCC

In normal concrete the stress is found to be attaining peak value for a strain value of 0.002 and afterwards stress decreases which indicated by a dipping curve till ultimate crushing strain is reached. In BFRCC mixes the strain at peak value of stress is more than 0.002 showing its ability to endure more strain without normal failure. As the stresses increases, the pre-peak curve becomes nonlinear and the post-peak curve which indicates strain capability also decreases. The curve beyond post peak is directly related to the fibre length and fibre dose and it is virtually steep as arising curve for 12 and 36 mm fibre lengths and is further progressively inclined for the 50 mm fibre lengths. Dosage required decreases as fibre length increases. Table 7 conceals the Elastic Modulus (E) and Toughness Modulus of M70 grade BFRSCC mixes

Table 7. Elastic Modulus (E) and toughness

M30 grade BFRCC Type	Elastic Modulus (E) and Toughness Modulus	
	Elastic Modulus (E) GPa	Toughness Modulus MPa
0% fibre	42.19	0.086
12 mm length + 0.4% fibre	44.87	0.153
36 mm length + 0.3% fibre	47.81	0.166
50 mm length + 0.2% fibre	49.38	0.184

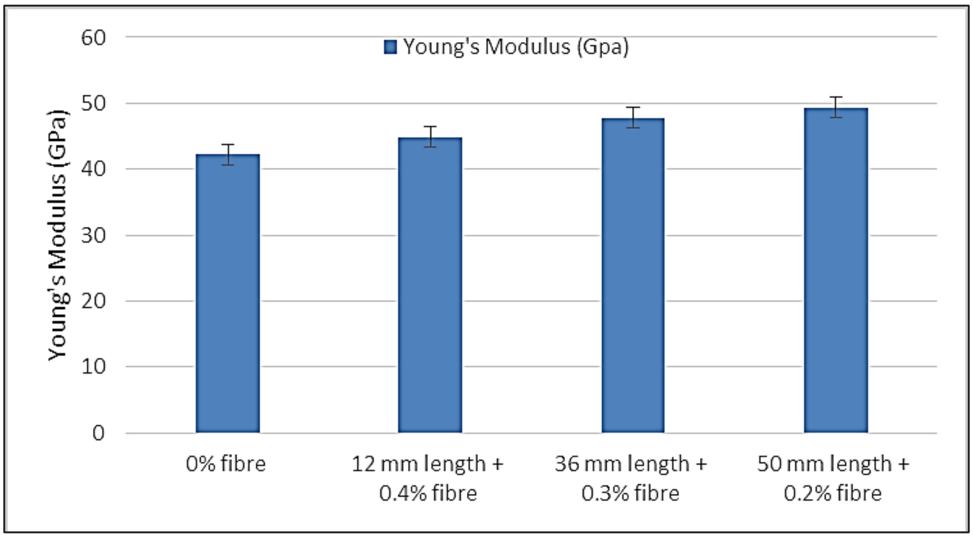

Fig. 2. Modulus of Elasticity for M70 grade BFRCC

5 Conclusions

From the interpretations from the stress-strain curves, the resulting conclusions are presented below:

1. For fibre length of 50 mm and measure of 0.2% fibre volume of the concrete, the compressive and flexural strengths achieved are maximum but the split tensile strength is found to be more for fibre length of 36 mm and dosage of 0.3% fibre volume of the concrete.
2. The increase in split-tensile and flexural strength of basalt fibred concrete is significant than the compressive strength.
3. The best length of fibre for basalt fibre concrete is 50 mm and dosage is 0.2% by volume fraction.
4. M70 grade BFRCC mixes has demonstrated greater stress values for the comparable strains as length of fibres and dose increases.
5. The strain at ultimate stress is slightly more, and the slope of the descending part is sharper due to the decrease in the extent of internal micro cracking in bacteria induced concrete
6. Ares underneath stress-strain plot gives the energy relieving ability of the concrete. BFRCC mixes has high energy dissipation ability due to fibres. As length of fibre increases impact resistance also increases similarly as dose increases the impact energy dissipation increases in BFRCC mixes due to fibres will control the cracks length and width formation by disintegrating distortion energy.
7. Improvement in moduli of toughness value in BFRCC mixes imply its developed resistance to impact. It is witnessed that Elastic modulus (E) is moderately increased for all BFRCC mixes as fibre lengths and added volume fraction increases indicating its better performance.

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