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Stress-Strain behaviour of basalt fibre reinforced concrete

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Abstract. This paper prophesies the stress strain behaviour of M30 grade concrete reinforced with basalt fibres of length 12 mm, 36 mm and 50 mm of amounts 0.4%, 0.4% and 0.3% by volume of concrete respectively. Modulus of elasticity and toughness of M30 grade basalt fibre reinforced concretes are also evaluated. It was found that BFRCC mixes show good resistance to impact and has superior dissipation capacity. The optimal basalt fibre volume fraction is 0.3% and length is 50 mm. For this case, toughness index and energy absorbed at fracture have considerably enhanced. With the volume fraction of basalt fiber exceeding the optimum volume fraction, the mechanical properties of basalt fiber are weakened.

1 Introduction

Basalt fibres improves the cracking behaviour of concrete and improves the failure pattern mode to non-brittle. Many researchers' debated on the mix quantities of basalt fibre in refining strength properties of concrete. J Wang et al. (2014) used fibres of length 30 mm and dosage of 0.1%, F Chen et al. (2013) adopted fibres of length 24 mm and dosage of 0.04%, N Kabay et al. (2014) preferred fibres of length 24 mm and dosage of 0.16%, C Jiang et al. (2014) examined fibres of length 12 mm and dosage of 0.3%, A B Kizilkanat et al. (2015) used fibres of length 12 mm and dosage of 0.25%, Z O Pehlivanh et al. (2015) used fibres of length 8 mm and dosage of 0.304%, S Jalasutram et al. (2017) used fibres of length 12.7 mm and dosage of 0.1%, M E Arslan et al. (2016) used fibres of length24 mm and dosage of 0.07%, J Branston et al. (2016) used fibres of length 36 mm and dosage of 0.46% and H Katkhuda et al. (2016) used fibres of length 18 mm and dosage of 0.3%,

2 Methodology

The objective of this work is to evaluate experimentally the stress-strain performance of M30 grade fibre reinforced concretes made with basalt fibres of length 12 mm, 36 mm and 50 mm of amounts 0.4%, 0.4% and 0.3% by volume of concrete respectively. Basalt fibre reinforced concretes cylinders of size 150 mm diameter x 300 mm height are casted and cured for 28 days and tested in Uniaxial compression under strain control as per IS: 516-1999 to comprehend the stress-strain performance of M30 grade basalt fibre reinforced concretes (BFRCC).

Fig. 1. Test arrangement for stress-strain analyses

3 Optimum dosage of fibre

The Fig. beneath displays the compressive strengths of BFRCC mixes made with various lengths and dosages of fibre volume. It can be see that for different lengths, the optimal amount of fibre required is varying. In this case for M30 grade BFRCC, the length considered for examination are 12 mm, 36 mm and 50 mm based on the availability in the market. Various quantities such as 0.2%, 0.3% and 0.4% are selected based on the past research studies. It was found that compressive strength of 12 mm length + 0.4% fibre, 36 mm length + 0.4% fibre and 50 mm length + 0.3% fibred BFRCC mixes gave maximum strengths so forwards now examinations are carried out on effect of these combinations in various elements and properties of BFRCC mixes. For comparative purpose, concrete mixes without basalt fibres are also prepared.

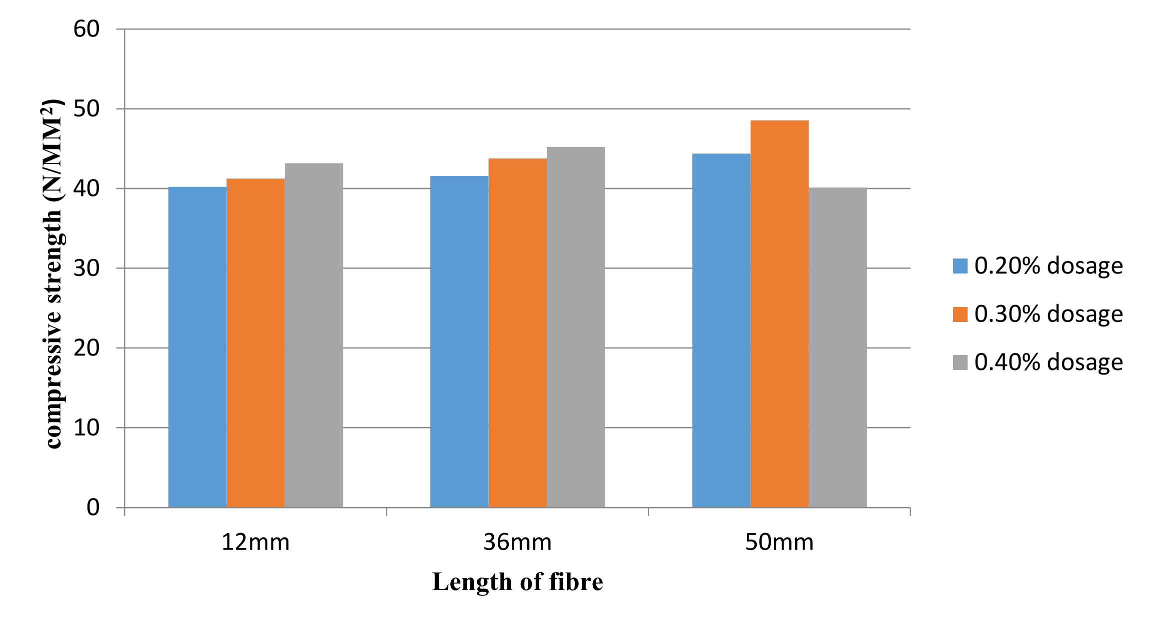

Fig. 2. Effect of fibre lengths and dose on the compressive strength

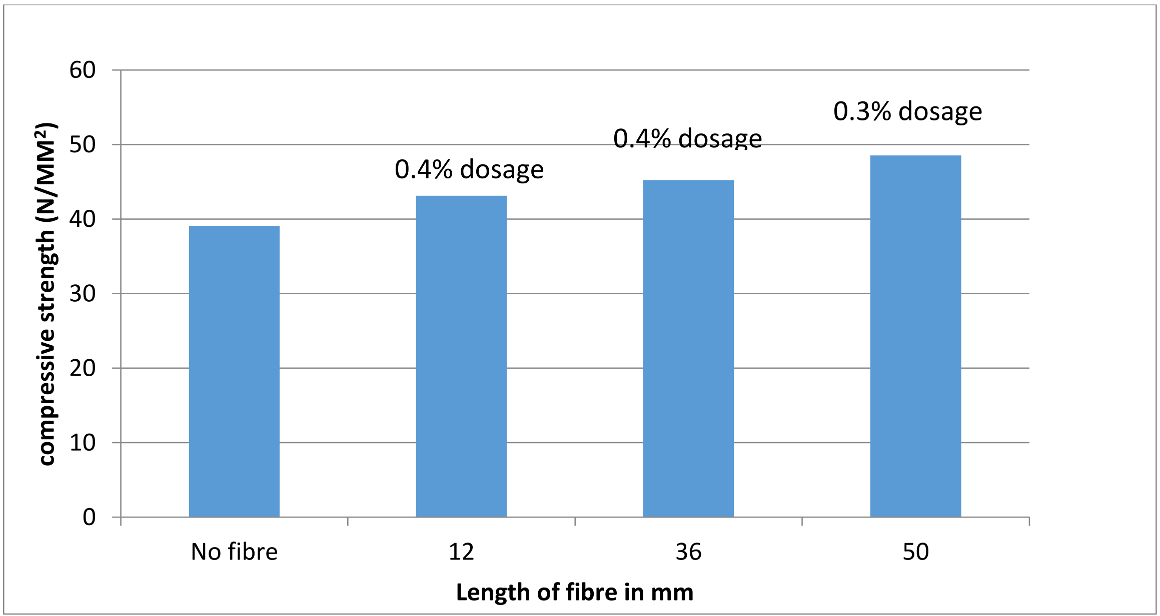

Fig. 3. Optimum dose for different fibre lengths and corresponding compressive strengths

4 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 1. Stress strain values of various length and dose combinations of BFRCC mixes

0% fibre		12 mm length + 0.4% fibre BFRCC		36 mm length + 0.4% fibre BFRCC		50 mm length + 0.3% fibre BFRCC	
Strain	Stress(MPa)	Strain	Stress(MPa)	Strain	Stress(MPa)	Strain	Stress(MPa)
0	0	0	0	0	0	0	0
0.000167	3.008281	0.00013	2.757046	0.006	0	0.000037	0.216442
0.000303	6.181143	0.000315	5.909672	0.000013	45.19565	0.00028	5.856222
0.00053	9.858162	0.000574	10.04824	0.000037	0.391304	0.000523	10.19168
0.000712	13.36644	0.000778	13.39823	0.00043	7.826087	0.000821	14.95907
0.000985	17.54553	0.001074	16.94901	0.000691	12.52174	0.000952	18.21327
0.001258	22.39128	0.001241	20.29728	0.000952	16.04348	0.001214	23.41733
0.00147	25.56761	0.0015	23.84635	0.001232	20.34783	0.001549	26.44374
0.001758	29.08075	0.001648	26.60425	0.001419	25.43478	0.001791	30.77919
0.001939	32.42235	0.001889	29.36644	0.001754	28.17391	0.002238	34.45209
0.002212	34.26816	0.002111	32.32428	0.002015	31.69565	0.002592	37.91233
0.002485	35.11397	0.002352	34.69347	0.002351	35.02174	0.002852	39.20342
0.002727	34.95842	0.002519	36.86273	0.002742	37.56522	0.003001	40.06541
0.003015	33.80497	0.002778	37.46425	0.003058	40.30435	0.003262	41.79127
0.003182	30.47933	0.002926	39.82915	0.003151	41.28261	0.003522	43.29975
0.00353	27.49536	0.003111	38.85521	0.003522	39.13044	0.003838	41.54458
0.003712	23.67042	0.00337	37.88471	0.00367	35.80435	0.004079	40.01059
0.003894	21.01214	0.003685	35.34476	0.003892	33.45652	0.00432	37.60704
0.004197	18.52607	0.003889	33.58568	0.004096	31.30435	0.004542	36.07399
0.004379	16.03444	0.004222	31.8326	0.004337	28.95652	0.004709	34.32638
0.004561	15.54279	0.004352	29.08756	0.004633	26.6087	0.004968	31.70451
		0.004537	26.73811				
		0.004741	24.97902				
		0.004944	23.41644				

If the crack patterns are observed the characteristic failure is by vertically developed cracks for 12 mm and 36 mm fibre lengths and dosage of 0.4% because of failure at localized areas whereas for 50 mm fibre length of 0.3% fibre volume the cracks are developed diagonally due multiple cracks leading to failure at high strain and also stress redistribution is expected to happen at 50 mm fibre length of 0.3% fibre volume. The mode of failure of BFRCC is transformed to non-brittle failure due to integration of basalt fiber. So, by witnessing the failure mechanics of basalt fibers at the section of failure, it can be adjudicated that there exists a good bond between basalt fiber and concrete matrix.

Stresses endured by 50 mm fibre length + 0.3% fibre dosage BFRCC mix is found to be ultimate when compared with the stress-strain responses of the other BFRCC mixes with fibre less than 50 mm.

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Fig. 4. Failure patterns of (a) 12 mm length + 0.4% fibre (b) 36 mm length + 0.4% fibre (c) 50 mm length + 0.3% fibre

Table 2. 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	35.11	0.002485	0.004561	1.84
12 mm length + 0.4% fibre	39.83	0.002926	0.004944	1.69
36 mm length + 0.4% fibre	41.28	0.003151	0.004633	1.47
50 mm length + 0.3% fibre	43.30	0.003522	0.004968	1.41

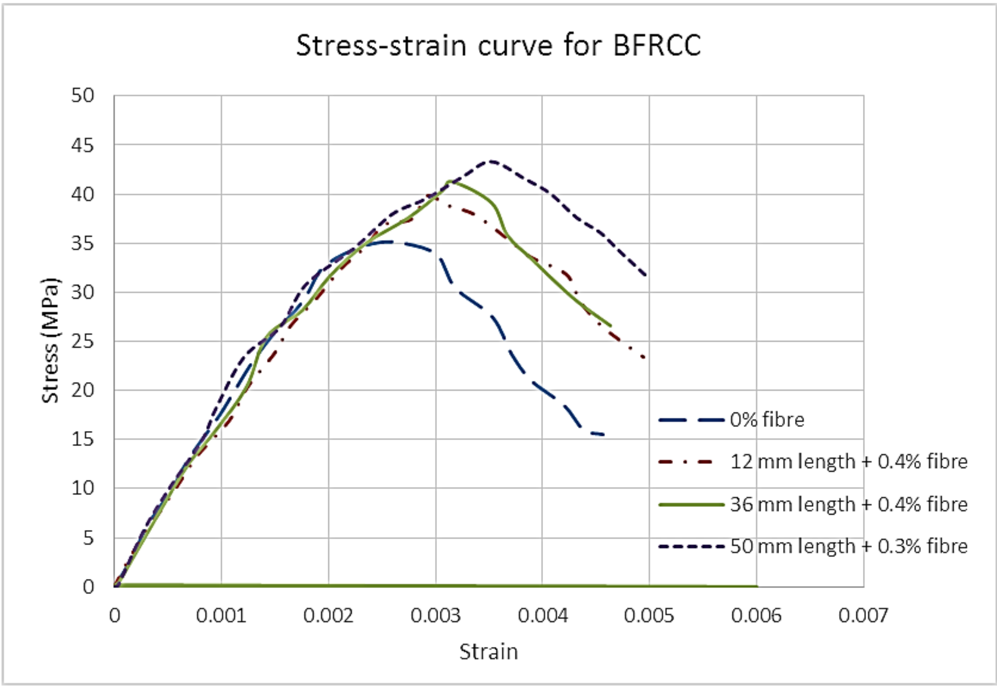

Fig. 4. Stress-strain curve for BFRCC

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 3. Elastic Modulus (E) and toughness

M30 grade BFRCC Type	Elastic Modulus (E) and Toughness Modulus	
	Elastic Modulus (E) GPa	Toughness Modulus MPa
0% fibre	32.29	0.066
12 mm length + 0.4% fibre	34.67	0.070
36 mm length + 0.4% fibre	37.88	0.080
50 mm length + 0.3% fibre	39.08	0.084

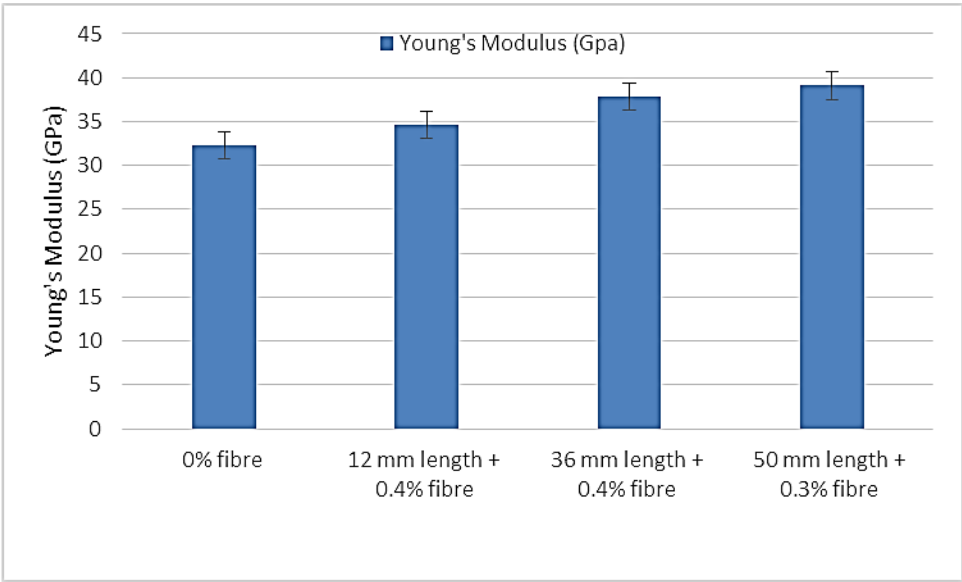

Fig. 5. Variation of 'E' based on fibre length and fibre dose

5 Conclusions

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

1. BFRCC has displayed enhanced stress values for the similar strains as length of fibres and dose increases.
2. The strain at ultimate stress is marginally more, and the slope of the descending part is steeper due to the decrease in the extent of internal micro cracking in bacteria induced concrete
3. 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.

4. 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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