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Experimental Study on Mechanical Properties of Basalt Fibre Reinforced Concrete

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Abstract: ***Concrete is very strong in compression but very weak in tension. However it is reported that tensile and bending strength of concrete is 10 to 15% of the compressive strength respectively. The addition of different types of fibres in concrete have significantly improves its compressive as well as tensile strength. Among the new advancement in field of FRC is the basalt fibre reinforced concrete. In the present study basalt chopped fibres were used in the concrete mixes and compressive and flexural strength of the specimens were tested. A total of 5 mixes were prepared by varying the percentages of basalt fibres on M 25 grade of concrete mix. Based on the laboratory results the compressive and flexural strength was reported to increase up to 46% and 74%. However the workability of fresh concrete mixes is not much affected by the addition of fibre content. The flexural strength of concrete is improved which shows the wide application of basalt fibres in concrete mixes for construction in various fields i.erailway, bridges, runway and tunnels.***

Keywords: *Compressive Strength, Flexural Strength, Basalt Fibers, M 25 Grade of concrete.*

1. Introduction

Concrete is the most widely used building material in the construction industry. It consists of a rationally chosen mixture of binding material such as cement, well graded fine and coarse aggregates, water and admixtures. Conventional concrete is modified by random dispersion of short discrete fine fibres to improve its mechanical properties. The improvement in structural performance depends on the strength characteristics, volume, spacing, dispersion and orientation, shape and the aspect ratio of the fibres. For fibres to be more effective, each fibre needs to be fully embedded in the matrix, thus cement paste requirement is more**[5].**Several fibres have been used so far to improve the properties of conventional concrete viz: asbestos, steel, glass, carbon, polypropylene, nylon etc. A new advancement in the fibre reinforced concrete is the use of basalt fibre which has shown better results in improving the compressive & flexural strength of concrete composites. Basalt fibre is a relatively new material aramid for strengthening. It has a similar chemical composition as glass fibre but has better strength characteristics, and is highly resistant to alkaline, acidic and salt attack making it good for concrete, bridge and shoreline structures. It is easy to disperse when mixed with cement concrete and mortar. Therefore basalt fibre reinforced concrete serves the functions of reinforcement, crack resistance and can extend the life of construction in the fields of housing, Highways, railways, urban elevated roads, runways, ports, subway tunnels etc. Basalt fibre is produced in a continuous process by melting crushed basalt rock at 1500°c temperature and is stretched into the fibres. The fibre has high strength of extension and has excellent ductility and its corrosion resistance is far better than other types of fibres**[1-2]**.

2. Literature Review

Several experimental investigations have been done in the past to study the behaviour &mechanical properties of basalt fibre reinforced concrete. The inclusions of basalt fibres in the concrete have shown better results in relation to tensile, compressive and flexural strength. The results also indicate improved ductility and better resistance to cracking. The performance of basalt fibre concrete was reported by varying the percentages of fibres in the concrete. It shows that the performance of concrete is higher at 0.25% then it gets decreased slowly **[3].**The addition of basalt fibres in high strength concrete decreases the 7 and 14 days strength but the strength increases more than the design mix after 28 days **[1]**. About 83 to 92% increase in compressive strength was observed when basalt fibres are introduced in the concrete. Similarly 40 to 50% increase in flexural strength was observed **[4]**. The split tensile strength of concrete is supposed to increase with increase in the volume fraction of fibre till 0.3% and then it decreases with 0.5% basalt fibre. The slump of concrete decreases with increasing the volume fraction of basalt fibre and the unit weight is not sensitive to it as the fibre content was low in all mixes. The modulus of elasticity shows the trend of the strengths results [5]. In the present study basalt fibres were used throughout the experiments to obtain the concrete specimens. The study comprises of a comparative study of some of the properties of concrete at the age of 7 and 28 days by varying the percentages of fibres.

3. Experimental Programme

An extensive experimental Programme involving the various processes of material testing, mix proportioning, mixing, casting and curing of test specimens were done. The forthcoming sections elaborate the various physical and chemical properties of each material separately.

A. Materials Used

The material used in the preparation of concrete mixes includes cement, fine aggregates, coarse aggregates, basalt chopped fibres and admixtures. Each material was tested &its physical properties are described below.

Cement
Ordinary Portland cement of 43 grade were used, conforming to recommendations stated in IS 4031(1999). OPC manufactured from ultratech cement plant was used throughout the experimental work. The physical properties of OPC are tabulated in Table 1.

Fine Aggregate
Locally available Jhansi sand was used as fine aggregate. The test procedures as mentioned in IS-383(1970) were followed to determine the physical properties of fine aggregate as shown in Table 2.

Coarse Aggregate
Two single sized stone grit ranging from 20 mm to 4.75 mm and 40 mm to 4.75 mm (12.5mm and 20mm sizes) were used in respective proportions in concrete mixes. The aggregates were tested in accordance to IS-2386 (Part I, III & IV). The results obtained are tabulated in Table 3.

Basalt Fibre
Basalt chopped fibre golden brown color was used in the concrete mixes. The density of the fibre is 2.75 kg/m^3 and is available in the length of 6 mm to 10 mm. The specifications of these fibres are presented in Table 4.

Admixtures
In order to make the concrete mixes workable Conplast SP 430 G admixture was used. The addition of fibres reduces the workability; therefore in order to make it use for practical purposes admixtures in appropriate quantity was added to the mix.

Water
As per recommendation of IS: 456 (2000), the water to be used for mixing and curing of concrete should be free from deleterious materials. Therefore potable water was used in the present study in all operations demanding control over water quality.

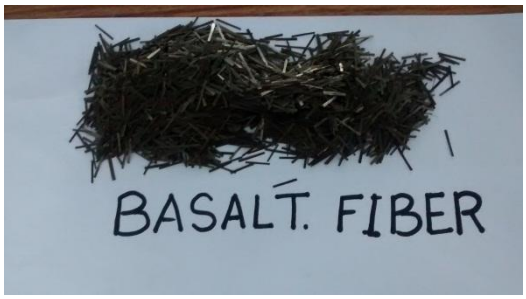

Figure 1: Basalt Fibres used

Table 1: Physical properties of ordinary Portland cement

Physical properties	Experimental values	Recommended values
Normal consistency (% by weight of cement)	31	30-35
Setting time (minutes) (i)initial (ii)final	 124 235	 30(min) 600(max)
Compressive strength (MPa) (i) 7-days (ii) 28-days	 35.3 43.5	 33 43

Table 2: Physical Properties of Fine aggregate

Physical Properties	*Observed values*	*Recommended values*
Grading Zone	II	-
Fineness modulus	4.216	2.9-3.2
Specific Gravity	2.61	2.6-2.67
Water absorption (%)	0.81	< 0.5%

Table 3: Physical Properties of coarse aggregate

Physical Properties	Observed values		Recommended values
	12.5mm aggregate	20mm aggregate	
Fineness Modulus	7.96	6.96	6.5-8.0
Aggregate crushing value (%)	19.25	24.48	Not more than 45%
Aggregate impact value (%)	27.36	23.10	Not more than 45%
Water absorption (%)	0.49	0.45	< 0.5%

Table 4: Physical Properties of Basalt Fibre [9]

Physical Properties	Recommended values by the supplier
Density (g/cc)	1.9-2.1
Tensile Strength (Mpa)	> 1000
Yield Strength (Mpa)	> 600
Tensile Elastic Modulus (GPa)	> 50
Length (mm)	6-10

B. Methodology
The mix proportioning procedure for the concrete was done according to IS 10262: 2009. The proportioning is carried out to achieve specified characteristics at specified age, workability of fresh concrete and durability requirements. M 25 concrete grade were proportioned according to the procedure as mentioned in the code.

C. Mix Proportioning
The basic mix proportion for M 25 grade of concrete is cement, fine aggregate, coarse aggregate and water: 1.0:1.709:2.780 respectively. Mix 1 contains 0% basalt fiber. Mix 2, 3,4& 5 contains 0.25%, 0.50%, 0.75%& 1.0%basalt fibre by weight of cement. A total of 5 mixes were studied. Water/cement ratio of 0.42 for M 25grade were maintained for all the concrete mixes. Superplasticizer was mixed 0.5% by weight of cement in the mix to obtain a workable mix. Details of these mixes are presented in Tables 5.

D. Mixing of Concrete, Casting and Curing of test Specimens
Mixing was done using machine mixer. Initially the dry mix constituents of the mix namely cement, fine aggregate and coarse aggregate was mixed for two minutes and then the water with chemical admixtures were added and mixing continued for another 2 minutes. The total mixing time was kept at 4 minutes for all the trials until a homogeneous mixture was obtained. Compaction was achieved initially by hand using the standard tamping rod ensuring the filling of the moulds in layers with appropriate blows and then finally compacting by vibrator. All specimens were de molded after 24 hours and stored in water until the age of testing.

E. Test Methods

Test methods include the tests of fresh concrete mix for workability and hardened concrete specimens for compressive and flexural strength test.

Workability Test

Slump test was done conforming IS 1199-1959in order to measure the workability of concrete mixes.

Compressive Strength Test

Compressive strength test was performed according to IS 516: 1959.6 Cubes of specimen size 150 mm x 150 mm x 150 mm were prepared for each mix. After 24 hours the specimens were de moulded and cured in water until the age of testing. The specimens were tested at the age of 7 days and 28 days. The compressive strength reported is the average of three results obtained from three identical cubes.

Table 5: Mix details of Basalt Fiber Concrete Mixes

MIX NO.	Grade of concrete	W/C	% of Basalt Fibres	Cement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Water content(Litre)	Coarse Aggregate (Kg/m^3)
M-1	M-25	0.42	0	410.53	701.68	172.42	1141.56
M-2			0.25				
M-3			0.50				
M-4			0.75				
M-5			1.0				

Figure 2: Compressive Strength Test

Flexural Strength Test

Flexural strength was obtained from four point bending setup according to IS:516-1959.The test was carried out after 7 &28 days of curing on the beam sample of size 100mm x 100 mm x 500mm.The flexural strength reported is the average of three results obtained from three identical beam specimens. Flexural strength is calculated by the following formula:

$$fckt = \frac{FL}{bd^2} \quad (i)$$

Where, fckt=Flexural Strength in Mpa.
F = Load at the fracture point.
L = Length of support span.
b& d = Width & depth of beam

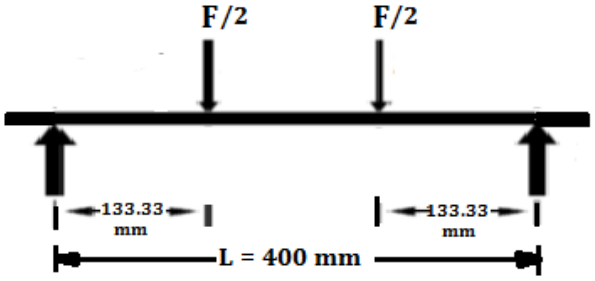

Figure 3: Flexural strength test setup

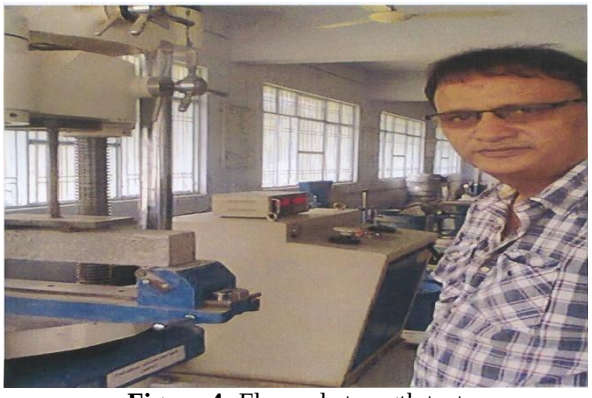

Figure 4: Flexural strength test

4. Results and Discussion

The test results obtained are presented in Table 6. Result indicates that as the percentage of basalt fibers increases in the mix there is corresponding increase in the strength. Apart from this workability of the mixes is also affected by the addition of fibres.

Table 6: Compressive &Flexural strength of Basalt Fibre Reinforced concrete

MIX NO.	% of Basalt Fibres	7 Days Mean Compressive strength (Mpa)	28 Days Mean Compressive strength (Mpa)	7 Days Mean Flexural strength (Mpa)	28 Days Mean Flexural Strength (Mpa)
M-1	0	22.47	34.58	1.94	3.69
M-2	0.25	23.60	37.46	2.74	5.83
M-3	0.50	33.73	42.65	4.64	7.43
M-4	0.75	38.13	50.35	7.11	9.45
M-5	1.0	41.86	64.09	7.70	10.22

A. Effect of percentage of fibers on workability of concrete

The workability of fresh concrete is not much affected by the inclusion of basalt fibres in the mix. However a decreasing trend was obtained in the slump value as the percentage of fibres increases in the mix. The slump value ranges between 95 to 110 mm indicating a workable mix for use in all practical purpose construction work. Fig. 5 illustrates the variation in slump value on addition of glass fibers.

B. Effect of percentage of fibers on compressive strength of concrete

The result shows that the compressive strength of concrete mixes increases with the addition of fibers. Inclusion of 0.25% of basalt fibres to concrete mix increases the strength to 4.78% & 7.69% for 7 & 28 days. Similarly a higher increase in strength was observed for 1%addition of fibers by weight of cement i.e 46% increase in strength was obtained for 7 & 28 days respectively. This shows that as we go for higher increases in percentage of fibers the strength increases rapidly. Fig. 6 clearly shows the increase in strength for different percentage of basalt fibres in concrete.

C. Effect of percentage of fibers on flexural strength of concrete

A remarkable increase in flexural strength was obtained on addition of basalt fibres to the concrete mixes. Addition of 0.25% basalt fiber increases the flexural strength to 29.2% for 7 days and 36.70% for 28 days. Further addition of 1.0% of fibers, the average increase in strength is reported as 74.8% for 7 days & 63.9% for 28 days respectively. Fig. 7 shows the effect of percentage of fibers on flexural strength of concrete.

D. Compressive Strength and Percentage of Fibres Relationship for Basalt Fibre Reinforced Concrete

Fig. 8 shows the correlation between compressive strength and percentage of fibres at the age of 7 and 28 days. In these plots it is clear that the compressive strength is very much dependent upon the percentage of fibres for a particular grade of concrete. Empirical equations for 7 & 28 days compressive strength are obtained for M 25 grade of concrete mix. The correlation coefficient for these two equations was 0.92 & 0.95, indicating a high degree of correlation between compressive strength and percentage of fibres.

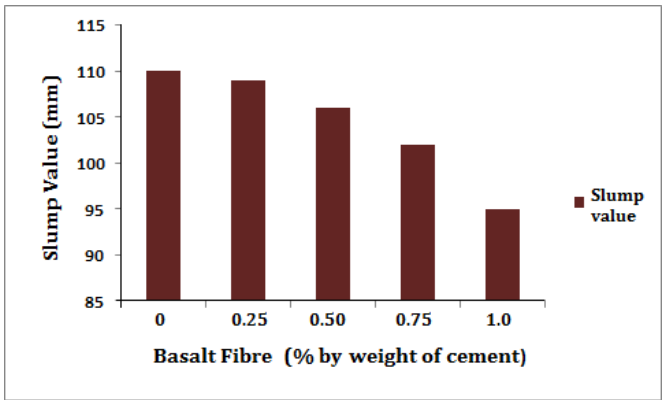

Figure 5: Effect of % age of fibers on slump value of concrete mixes

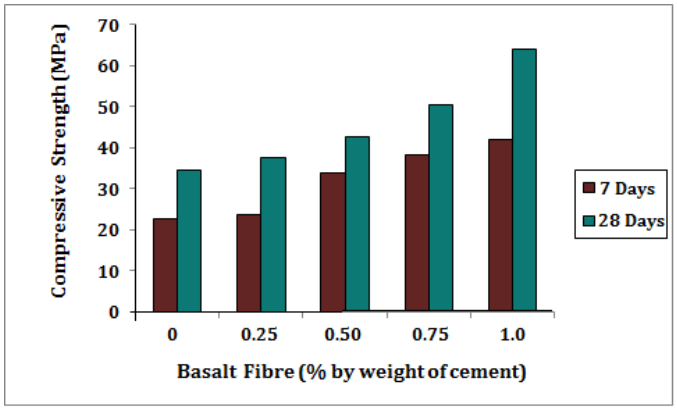

Figure 6: Effect of % age of fibers on compressive strength of concrete

E. Flexural Strength and Percentage of Fibres Relationship for Basalt Fibre Reinforced Concrete

Similar to compressive strength flexural strength also depends on percentage of fibres as shown in fig. 9. The empirical equations are also shown in the figure. The correlation coefficients are almost approaching to 1, indicating a very high degree of correlation between flexural strength and percentage of fibres.

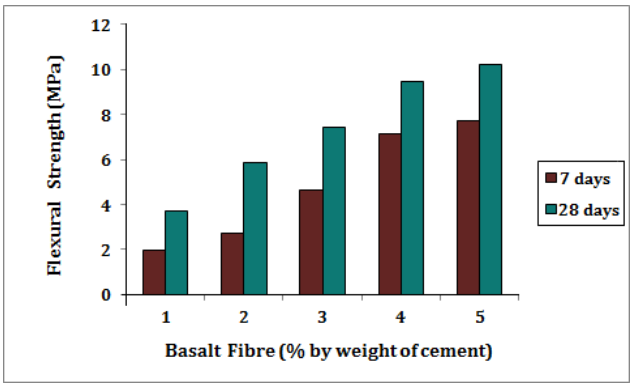

Figure 7: Effect of %age of fibers on tensile strength of concrete

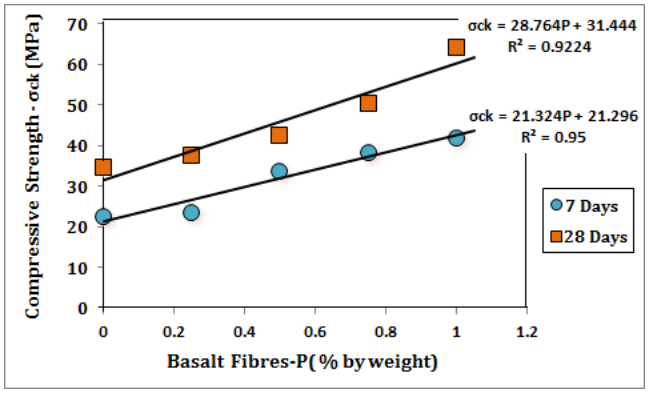

Figure 8: Relation between Compressive Strength and %age of fibres

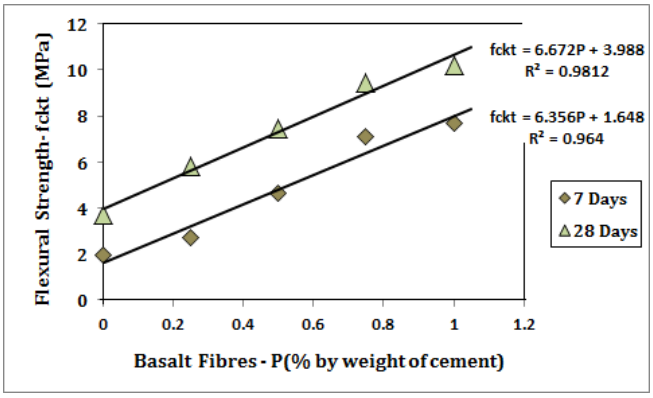

Figure 9: Relation between Flexural Strength and %age of fibres

5. Conclusions

1) The use of basalt chopped fibers advantageously improves the compressive as well as flexural strength irrespective of affecting the workability of concrete mixes.
2) The inclusion of basalt fibres does not affect the slump value significantly. The slump value ranges between 95 to 110 mm respectively.
3) The increase in the content of percentage of fibres increases the compressive strength marginally. Addition of 1% basalt fibres increases the strength to 46% for 7 & 28 days. Similarly for every increase in fibre content the strength shows an increasing trend.
4) The flexural strength also shows similar variation compared to compressive strength of concrete. The graph shows an increasing trend in strength as the content of basalt fibres increases in the concrete mix. Maximum increase in flexural strength is also reported at 1%. 64 % increase is obtained at the age of 28 days.
5) An empirical equation has been formulated for calculating 28 days compressive and flexural strength which is as follows:

$$\sigma ck = 28.764P + 31.44 \quad (ii)$$
$$fckt = 6.672P + 3.988 \quad (iii)$$

where σck=28 Days compressive strength in Mpa.
fckt= 28 Days flexural strength in Mpa.
P = Percentage of basalt fibres

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