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Experimental Investigation on Mechanical Properties of Basalt Fiber Reinforced Concrete with Partially Replacement of Cement with Fly Ash

M. Naga Suresh, K. Prafulla Devi

Abstract— **The objective is to investigate and compare the compressive, split tensile and flexural strength of basalt fiber reinforced concrete with plane M 25 grade of concrete. Fiber reinforced concrete is a most widely used solution for improving tensile and flexural strength of concrete. Various types of fibers such as steel, Polypropylene, glass and polyester are generally used in concrete. For the preparation of M 25 grade of concrete the cement replacement level by Class F Fly Ash was 5%, 10%, 15%, 20%, 25% and 30% for that optimum value basalt fibers of length 6mm are added as 0.5%, 1%, 1.5%, 2%, 2.5% and 3% to volume of cement. In this research, the effect of inclusion of fly ash and basalt fibers on the compressive, flexural and splitting tensile strength of fiber reinforced concrete was studied. Based on the laboratory experiment cube, beam and cylindrical specimens have been designed. The optimum percentage of replacing fly ash and adding basalt fibers was determined to be 20% and 2% which showed the maximum improvement in tensile and flexural strength.**

Key Words— **Basalt Fibers, Class F Fly Ash, Compressive Strength, Flexural Strength, Split Tensile Strength.**

6) 1) INTRODUCTION

Construction industry has undergone a fast change in the last century particularly with the advancement of different types of concrete. Concrete with the increase of technology has undergone several changes not in its composition, but also in its performance and applications. Concrete is the most widely used construction material. Apart from its excellent properties concrete is very poor in tensile strength.

To improve its tensile strength, fibers are added to concrete which is known as fiber reinforced concrete. Cement industry is one of the major contributors to pollution by releasing carbon dioxide. One ton of OPC production produces around one ton of Carbon dioxide. So by partially replacing cement with pozzolanic material such as fly ash, the cement industry can serve both the purposes of meeting the demands of construction industry and at the same time providing a green and clean environment.

1.1) Fly Ash

Fly ash is a fine powder which is a byproduct from burning pulverized coal in electric generation power plants. Fly ash is a pozzolan, a substance containing aluminous and siliceous material that forms cement in the presence of water. When mixed with lime and water it forms a compound similar to Portland cement. The fly ash produced by coal-fired power plants supply an excellent prime material used in blended cement, mosaic tiles, and hollow blocks among others. Fly ash can be an cheap replacement for Portland cement in concrete although using it improves strength, segregation, and ease of pumping concrete. Fly ash is difficult to decay so using fly ash is a major step towards sustainable growth.

1.2) Basalt Fiber

The name Basalt is originated from a Latin “BASALTES” [Very hard stone].Basalt fibers are originated from the Basalt rock. This Basalt rock is generated with rapid cooling of molten lava on the earth crust. Fundamentally this rock is normally available on the earth surface, beneath of the oceans. Basalt rock is also one type of igneous rock containing 45-60% of Sio_2 content to its volume.

2) EXPERIMENTAL PROGRAM

2.1) Cement

In concrete, cement act as a binder. It will bind the aggregate together to become one fine solid concrete.

For this project, the cement used is the ordinary Portland cement (OPC) with grade 53 is used and is available in local market. Portland cements are commonly characterized by their physical properties for quality control purposes. The physical properties of cement are categorized in table 1 as per IS 456-2000.

I. Physical Properties of Cement

S.NO	Properties	Value
1	Specific Gravity	3.15
2	Initial setting time	43 min
3	Final setting time	450 min
4	Normal Consistency	32%
5	Fineness test	6% retained

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M. Naga Suresh*, Post Graduate Student, Depatment of Civil Engineering, Gudlavalleru Engineering College, Gudlavalleru, India.*
K. Prafulla Devi, *Assistant Professor, Depatment of Civil Engineering, Gudlavalleru Engineering College, Gudlavalleru, India.*

2.2) Fine aggregate

Locally available river sand was preferred as fine aggregate for entire experimental work. The physical properties of sand was carried out in table 2 by taking the help of IS 383-1970 and IS 2386-1963 code books.

II. Properties of Fine Aggregate

S.No	Properties	Value
1	Specific Gravity	2.63
2	Fineness Modulus	2.16
3	Water absorption	1.8%
4	Grading Zone	Zone II

2.3) Coarse aggregate

Crushed Granite stone of sizes 20mm and 10mm were selected for this work. Taking the reference of IS codes in table 3 the properties of coarse aggregate have been tested.

III. Properties of Coarse Aggregate

S.No	Properties	Value
1	Specific Gravity	2.61
2	Fineness Modulus	7.16
3	Water absorption	0.6%
4	Crushing Value	14.21%

2.4) Water

Water is essential in concrete as it allow hydration process to occur. Without water, there will be no reaction between cement and other concrete materials. Water will react with cement to produce C-S-H gel.

In any mix, water use should not be contaminated it should be in neutral state with PH level not less or more than 7.

In this research, the water use is tap water which is supply nearby concrete lab.

2.5) Fly ash

Fly ash is finely divided residue resulting from the combustion of pulverized coal and transported by the flue gases of boilers by pulverized coal. It was obtained from thermal power station, dried and used. Specific Gravity is 2.11.Chemical composition of fly ash in table 4.

IV. Chemical composition of fly ash

S.NO	Chemical Compositions	Percentage	As per Requirements of IS 3812-2003
1.	Silicon dioxide (SiO_2)	66.80	>35%
2.	Aluminum oxide (Al_2O_3)	24.50	>70%
3.	Iron oxide (Fe_2O_3)	4	-
4.	Calcium oxide (CaO)	1.50	-
5.	Magnesium oxide (MgO)	0.45	<5%
6.	Sodium oxide (Na_2O)	0.40	<1.5%
7.	Potassium oxide (K_2O)	0.22	<1.5%

2.7) Basalt Fiber

Basalt has a fine-grained mineral texture due to the molten rock cooling too rapidly for large mineral crystals to grow, although it is often porphyritic, containing the larger crystals formed prior to the extrusion that brought the lava to the surface, entrenched in a finer-grained matrix. The basalt rock is heated up to 1000^{o}c to prepare this fiber.

Colour:- It is available in golden brown in color.

Diameter: 13 µm

Length: Available in 6mm, 8mm, 12mm etc.

Tensile strength: 3200 – 3850 Mpa

Elastic Modulus: 93 Gpa

Density: Density of basalt fiber is 2.75 g/cm^3

Fig -1: Basalt Fiber

2.8) Concrete Mix Proportion

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength as economically as possible.

Mix design for each set having different combinations are carried out by using IS: 10262-2009 method. The mix proportion obtained for normal M 25 grade of concrete is 1:1.58:2.71 with a water-cement ratio of 0.45.

3) TEST METHODS

3.1) Compressive Strength Test

Compression is a major characteristic property of concrete. To test the compressive strength, cube specimens of dimensions 150 x 150 x 150 mm were casted for M 25 grade of concrete. After curing of specimen for 7 and 28 days, their testing was done with the help of Compressive Testing Machine. The load was applied on the specimen till the specimen failed. The failure load was noted. For each test 3 specimens were prepared and tested and their average value is taken as final value. The compressive strength was calculated according to following formulae, Compressive Strength of Concrete = Ultimate Compressive Load (N) / Area of cross section (mm square)

3.2) Split Tensile Strength

Concrete is usually weak in tension, so to enhance this property of concrete basalt fibers were added.

Split tensile strength= 2P/3.14*d*L

Where

P= failure load

d=diameter

L=length of cylinder.

3.3) Flexural Strength

After 28 days curing, prismatic specimens are placed on flexure strength machine having a maximum capacity of 100KN

Flexural strength (MPa) fcr = (P x L) / (b x d^2)

Where

P = Failure load

L = length of the specimen

b = depth of the specimen

d = width of the specimen

4) RESULTS AND DISCUSSIONS

4.1) Compressive Strength Test

The compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine. Compressive strength was measured at 7 and 28 day of testing. The test results are shown in the following table 5.

V. Compressive strength of the specimens (cubes) in N/mm^2 for 7 & 28 Days

Mix No	% of Fly Ash	Compressive Strength(N/mm^2)	
		7 Days	28Days
M1	0%	23.13	32.05
M2	5%	25.93	35.81
M3	10%	26.48	37.84
M4	15%	30.37	39.65
M5	20%	28.72	36.02
M6	25%	26.05	31.10
M7	30%	22.57	30.50

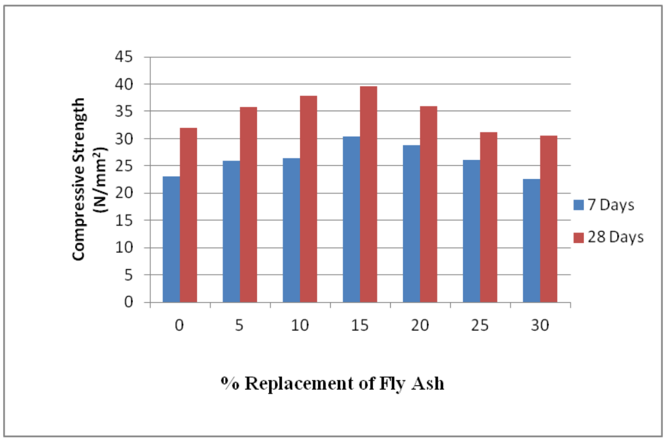

Fig-2: Compressive Strength of % replacement of Fly Ash

The Fig-2 indicates the comparison of result of compressive strength using cube specimen of M25 grade concrete. It is observed that for replacement of 15% fly ash gives more compressive strength than other volume fraction.

4.2) Splitting Tensile Strength Test

The split tensile strength is observed for 7 and28 days and values are mentioned in table 6.

VI. Splitting Tensile Strength of the specimens (cylinders) in N/mm^2 for 7 & 28 Days

Mix No	% of Fly Ash	Split Tensile Strength(N/mm^2)	
		7 Days	28Days
M1	0%	2.68	3.54
M2	5%	2.71	3.59
M3	10%	2.76	3.63
M4	15%	2.82	3.67
M5	20%	2.94	3.74
M6	25%	2.69	3.47
M7	30%	2.57	3.42

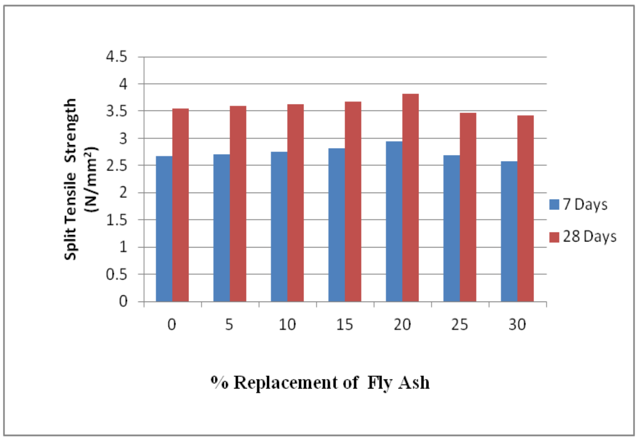

Fig-3: Split Tensile Strength of % replacement of Fly Ash

The Fig-3 indicates the comparison of result of Split Tensile strength using cylinder specimen of M25 grade concrete. It is observed that for replacement of 20% fly ash gives more Split Tensile strength than other volume fraction.

4.3) Flexural Strength Test

The flexural Strength was tested for 7 and 28 day. The test results are presented in the table 7.

VII. Flexural Strength of the specimens (prism) in N/mm^2 for 7 & 28 Days

Mix No	% of Fly Ash	Flexural Strength(N/mm^2)	
		7 Days	28 Days
M1	0%	2.61	28Days
M2	5%	2.88	3.50
M3	10%	2.94	3.82
M4	15%	3.19	3.94
M5	20%	3.35	4.02
M6	25%	2.88	4.44
M7	30%	2.5	3.76

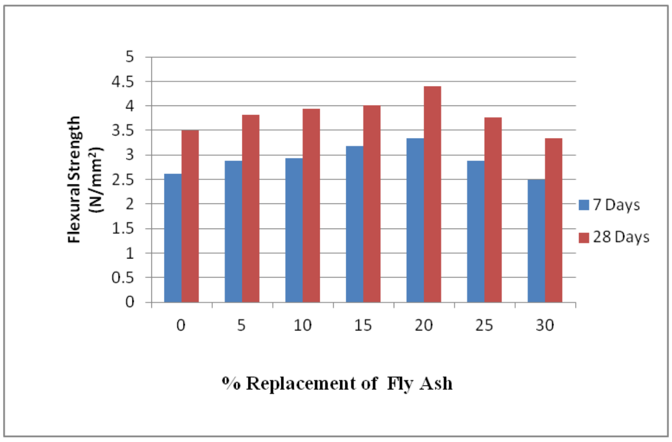

Fig-4: Flexural Strength of % replacement of Fly Ash

The Fig-4 indicates the comparison of result of Flexural strength using prism specimen of M25 grade concrete. It is observed that for replacement of 20% fly ash gives more Flexural strength than other volume fraction.

Test Results with cement partially replaced by fly ash are obtained, with that optimum value again the compressive strength, split tensile strength and flexural strength tests were done by using basalt fibers of length 6mm are added as 0.5%, 1%, 1.5%, 2%, 2.5% and 3% to volume of cement.

Mix details:

For Compressive Strength optimum value of fly ash replacement is 15%.

M1=Conventional
M2=15% Fly Ash+85% cement
M3=M2+Basalt Fiber 0.5%
M4=M2+ Basalt Fiber 1%
M5=M2+ Basalt Fiber 1.5%
M6=M2+ Basalt Fiber 2%
M7=M2+ Basalt Fiber 2.5%
M8=M2+ Basalt Fiber 3%

A. Effect of percentage of basalt fiber on compressive strength of concrete

VIII. Compressive Strength of Basalt Fiber (% by weight of cement)

Mix No	% of Basalt Fiber	Compressive Strength(N/mm^2)	
		7 Days	28Days
M1	_	23.13	32.05
M2	_	30.12	39.36
M3	0.5%	29.42	39.54
M4	1%	31.21	41.18
M5	1.5%	32.04	43.12
M6	2%	33.45	44.01
M7	2.5%	26.57	34.86
M8	3%	24.72	32.95

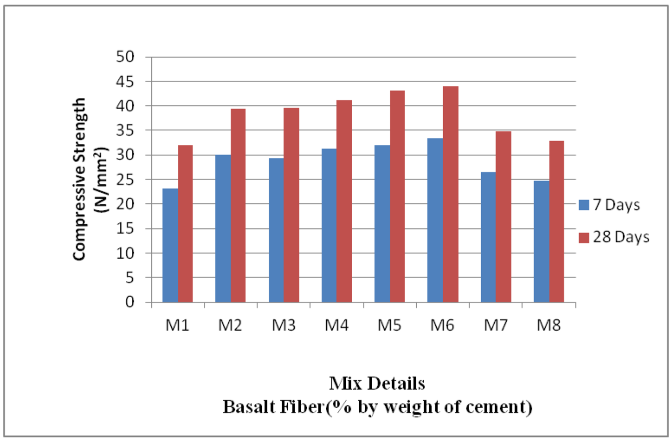

Fig-5: Compressive Strength of Basalt Fiber (% by weight of cement)

The Fig-5 indicates the comparison of result of Compressive strength of Basalt Fiber Reinforced Concrete. It is observed that for 2% basalt fiber gives more strength than other volume fraction.

Mix details:

For Split Tensile and Flexural Strength optimum value of fly ash replacement is 20%.

M1=Conventional
M2=20% Fly Ash+80% cement
M3=M2+ Basalt Fiber 0.5%
M4=M2+ Basalt Fiber 1%
M5=M2+ Basalt Fiber 1.5%
M6=M2+ Basalt Fiber 2%
M7=M2+ Basalt Fiber 2.5%
M8=M2+ Basalt Fiber 3%

B. Effect of percentage of basalt fiber on Split Tensile strength of concrete

IX. Split Tensile Strength of Basalt Fiber (% by weight of cement)

Mix No	% of Basalt Fiber	Split Tensile Strength(N/mm^2)	
		7 Days	28Days
M1	_	2.68	3.54
M2	_	2.94	3.84
M3	0.5%	3.18	4.24
M4	1%	3.33	4.45
M5	1.5%	3.59	4.79
M6	2%	4.06	5.42
M7	2.5%	3.60	4.81
M8	3%	3.09	4.12

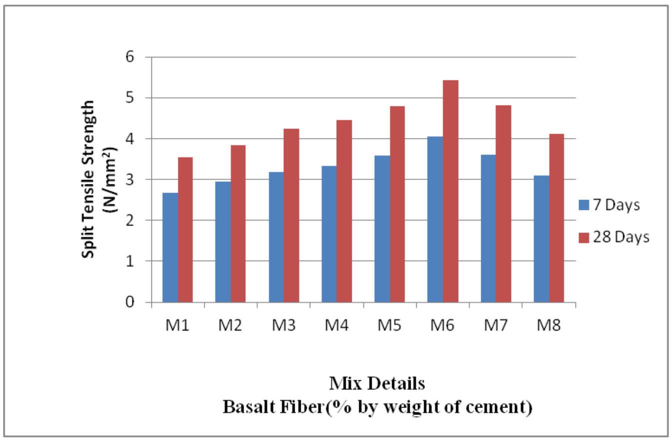

Fig-6: Split Tensile Strength of Basalt Fiber (% by weight of cement)

The Fig-5 indicates the comparison of result of Split Tensile strength of Basalt Fiber Reinforced Concrete. It is observed that for 2% basalt fiber gives more strength than other volume fraction.

C. Effect of percentage of basalt fiber on Flexural strength of concrete

X. Flexural Strength of Basalt Fiber (% by weight of cement)

Mix No	% of Basalt Fiber	Flexural Strength(N/mm^2)	
		7 Days	28Days
M1	_	2.61	3.50
M2	_	2.88	3.82
M3	0.5%	3.01	4.12
M4	1%	3.29	4.37
M5	1.5%	3.61	4.69
M6	2%	4.04	5.21
M7	2.5%	3.68	4.84
M8	3%	3.26	4.17

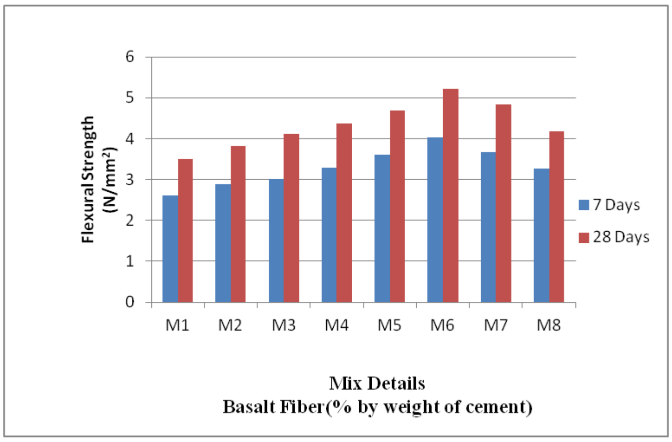

Fig-7: Flexural Strength of Basalt Fiber (% by weight of cement)

The Fig-7 indicates the comparison of result of Flexural strength of Basalt Fiber Reinforced Concrete. It is observed that for 2% basalt fiber gives more strength than other volume fraction.

5) CONCLUSIONS

Based on the research studies the following conclusions can be made. Due to addition of fly ash there is considerable improvement in strength of the concrete. With the replacement in concrete by fly ash the concrete prepared is environment friendly and cost effective.

- The compressive strength obtained for 28 days containing fly ash optimum value 15% is found to be 39.65 N/mm2 increased by 23.7% further replacement there is decrease in strength.
- The split tensile strength obtained for 28 days containing fly ash optimum value 20% is found to be 3.58 N/mm2 increased by 14.7% further replacement there is decrease in strength.
- The flexural strength obtained for 28 days containing fly ash optimum value 20% is found to be 4.37 N/mm2 increased by 21.3% further replacement there is decrease in strength.
- It was observed that 37.3% of compressive strength has increased containing fly ash optimum value 15% and 2% Basalt fiber reinforced concrete over plain concrete.
- Split tensile strength has increased 53.1% containing fly ash optimum value 20% and 2% Basalt fiber reinforced concrete when it was compared with plain concrete.
- Flexural strength has also significantly increased up to 48.8% containing fly ash optimum value 20% and 2% Basalt fiber reinforced concrete when it was compared with plain concrete.

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