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STRENGTH PROPERTIES OF REPLACEMENT OF AIR COOLED BLAST FURNACE SLAG IN FINE AGGREGATE

K.Spandana
P.G. Student, Department of Civil Engineering, Krishna chaitanya institute of technology & sciences, markapur, Andhra pradesh, India.
E-mail id: spandana.kande@gmail.com

K.Raja Sekhar
Assistant Professor, Department of Civil Engineering, KITS, markapur, A.P., India
E-mail id: sekhar.raj541@gmail.com

E.V.Chandra Sekhar
Assistant Professor, Department of Civil Engineering, KITS, markapur, A.P., India.
E-mail id: evcsekhar@gmail.com

Abstract
Now days, the blast furnace slag is one of the non-biodegradable waste material from the iron and steel industries in India. The slag would cause a severe problem both in disposal and environmentally. The blast furnace slag can be effectively used as an artificial aggregate which is replaced in fine aggregate to reduce the effective usage of natural fine aggregate. The present study is to investigate the properties such as physical properties, workability and strengthening properties of concrete, in which the fine aggregate is replaced by air cooled blast furnace slag. This study gives the results about optimum replacement usage of air cooled blast furnace slag (ACBFS) in the concrete to increase the strength properties. Here, the slag is replaced at different percentage levels in the place of fine aggregate in M30 grade of concrete. A total of five different percentage concrete mixes 0%, 12.5%, 25%, 37.5% and 50% replacement of fine aggregate with air cooled blast furnace slag are investigated in laboratory. These mixes were tested to determine axial compressive strength, split-tensile strength, and flexural strength for 7days, 28days, 56days and 90days.
Key words: Fine aggregate, Air cooled Blast furnace slag (ACBFS), Strength properties.

1. INTRODUCTION

Fine aggregate is one of most useful construction material in concrete around the world in any type of structures. Fine aggregate becomes demand, because of expansive utilization in all types of construction works. Now it is one of the challenges in concrete construction industries to satisfy the needs of human in society. To protect the environment and also to meet the requirements of global population, we can use some of the waste materials in concrete to decrease the waste materials and as well as to improve the properties such as physical and mechanical properties of concrete to achieve the global needs. In this work, we can

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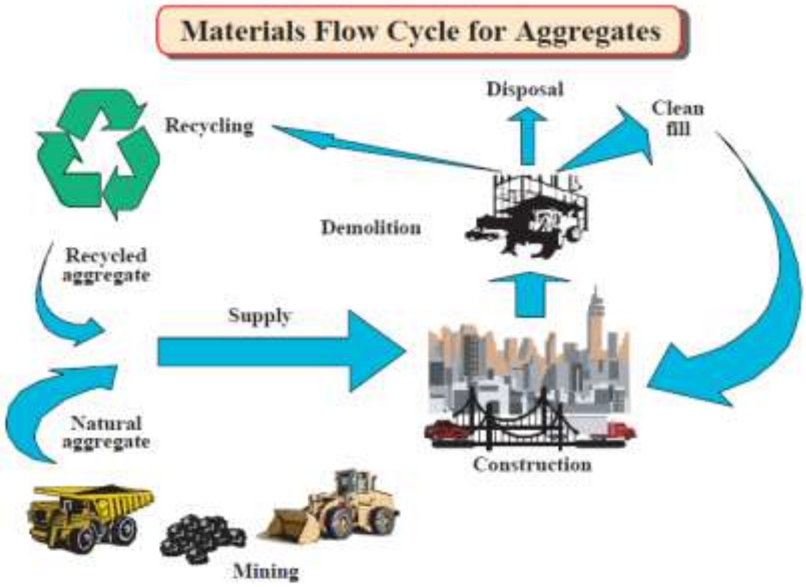
produce the concrete without any restrictions by partially replacing the air cooled blast furnace slag in fine aggregate.

1.1. Air Cooled Blast Furnace Slag (ACBFS):

Blast furnace slag generally consists of silicates, alumino silicates of calcium and magnesium together with sulphur, iron, and manganese as other compounds as trace elements. The blast furnace slag is produced from a molten state simultaneously with pig iron. The solidified molten state iron is further classified, based on the process of solidified molten iron brought. After that, the molten blast furnace slag is relatively slow under atmospheric conditions which results in crystalline mineral formation to produce air-cooled blast furnace slag. Air cooled blast furnace slag is the commonly used waste material to reduce the natural materials in the construction it is being used as fine aggregate in the Portland cement concrete. There are more benefits by the use of air cooled blast furnace as fine aggregate material than to disposal in all aspects such as environmental, economic and social. ACBFS is inexpensive reclaimed aggregate materials when compared to naturally derived material and also it is an economic benefit to the direct user of ACBFS who financially benefit from the sale of material to avoid the disposal costs.By the use of ACBFS we can reduce the overall cost required for materials in the construction and also we get the environmental benefits as well as social benefits. If the waste material ACBFS produced from iron plants is used, we will get the benefits like the cost of extraction of materials from mines and transportation will be reduced. Also the consumption of energy, disruption of land, pollution, and green house gaseous effects are reduced for the extraction of natural aggregate. Here, the below Figure shows the life cycle of aggregates, how reducing natural aggregate use can enhance sustainability by eliminating the extraction and transportation phases.



Materials flow cycle for aggregates

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1.2. Chemical Composition of ACBFS:

The calcinated stone have alumina and silica components in iron ore. The four major oxides present in ACBFS are CaO, SiO_2, Al_2O_3, and MgO. These oxides are account for approximately 95% of the ACBFS composition, the remaining 5% consisting of sulfur, manganese, iron, titanium, fluorine, sodium, and potassium, as given below. High magnesia content is generally attributed to the use of dolomite as a fluxing agent.

Typical Composition of ACBFS

COMPOSITION	PERCENTAGE (%)
Major Components	95
Lime (CaO)	30–40
Silica (SiO_2)	28–42
Alumina (Al_2O_3)	5–22
Magnesia (MgO)	5–15
Minor Components	5
Sulfur (CaS, other sulphides, sulfates)	1–2
Iron (FeO, Fe_2O_3)	0.3–1.7
Manganese (MnO)	0.2–1

2. MATERIAL PROPERTIES

Materials and their Properties:

Raw materials required for the concrete use in the present work are

- Ordinary Portland Cement
- Coarse Aggregates
- Fine Aggregates
- Water
- Air cooled blast furnace slag

2.1. Ordinary Portland cement: Generally, the ordinary Portland cement is classified into 33 grade, 43 grade and 53 grade according to the 28days characteristic compressive strength of the concrete. The OPC cement has different physical properties such as standard consistency, specific gravity according to the chemical composition present in it. In this study, a single lot of Hemadri cement is used throughout the investigation. The physical properties of cement are given below:

Physical properties of cement

S. No	Properties	Test results
1	Normal consistency	29%
2	Specific gravity	3.09
3	Initial setting time	86 minutes
4	Final setting time	182 minutes

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5	Compressive strength at 3days 7days 28days	 27.40 N/mm^2 38.23 N/mm^2 53.62 N/mm^2

2.2. Fine Aggregate (sand): The size of the fine aggregate is below 4.75mm. Fine aggregates can be natural or manufactured. The grade must be throughout the work. The fine aggregate used in this test is collected from the local river which zone-II is confirming to IS: 383-1987. The results of various tests on fine aggregate are given below.

Properties of fine aggregate

S. No.	Property	Test Results
1	Specific gravity	2.62
2	Fineness modulus	2.46
3	Bulk density: Loose Compacted	 15kN/m^3 16kN/m^3
4	Grading	Zone-II

Sieve analysis of fine aggregate

S.No.	Sieve size in mm	Retained	% retained	Cumulative % retained	% passed
1	10	-----	----	-----	100
2	4.75	-----	----	-----	100
3	2.36	42	4.2	4.2	95.8
4	1.18	183	18.3	22.5	77.5
5	600	316	31.6	54.1	45.9
6	300	354	35.4	89.5	10.5
7	150	102	10.2	99.7	0.3
8	Pan	3	0.3	100	0

2.3. Coarse aggregate: The aggregates which are retained on the IS sieve of particle size 4.75mm are termed as Coarse aggregate. The coarse aggregate used in this investigation is confirming to IS: 383-1987.

Physical Properties of Coarse Aggregate

S. No.	Properties	Test Results
1	Specific gravity	2.70

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2	Fineness modulus	8.83
3	Bulk density Loose Compacted	 14 kN/m^3 16 kN/m^3
4	Nominal maximum size	20 mm

Sieve Analysis of Coarse Aggregate

S.No	Sieve size in mm	Retained	% retained	Cumulative % retained	% passed
1	80	0	0	0	100
2	40	0	0	0	100
3	20	1.72	17.2	17.2	82.8
4	16	5.54	55.4	72.6	27.4
5	12.5	2.12	21.2	93.8	6.2
6	10.0	0.58	5.8	99.6	0.4
7	4.75	0.04	0.4	100	0
8	pan	0	0		0
	Total			383.2+500 =883	

$$\text{Fineness Modulus} = \frac{\text{Cumulative \% reatained}}{100}$$

= 883.2÷100

= 8.832

2.4. Water:

This is the least expensive but most important ingredient of concrete. The quantity and quality of water is required to be looked in to very carefully. In practice very often great control on the properties of all other ingredients is exercised, but the control on the quality of the water is often neglected. Since quality of the water effects strength, it is necessary for us to go in to the purity and quality of water.

Physical Properties of Water

S. No	Properties	Test Results
1	pH	7.1
2	Taste	Agreeable
3	Appearance	Clear
4	Turbidity(NT units)	1.75

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2.5. Air Cooled Blast Furnace Slag: AIR COOLED BLAST FURNACE SLAG is collected from Vizag steel plant, Vishakhapatnam, Andhra Pradesh. Specific gravity test was conducted for air cooled blast furnace slag and the result obtained is 2.52.

Air Cooled Blast Furnace Slag

3. MIX DESIGN

Mix designs place an important role in the concrete. Mix design is the process of calculating the suitable proportion of materials required for the concrete by the properties of cement, fine aggregate, coarse aggregate and water to achieve the required durability, workability and strength properties in early age of concrete. Here, we conducts the tests in two states namely, fresh and hardened to achieve properties of concrete.

Ratio of Mix Proportion

Cement: Fine aggregate: Coarse aggregate = 377.77: 683.74: 1222.9

Cement: Fine aggregate: Coarse aggregate = 1 : 1.809 : 3.24

4. EXPERIMENTAL WORK

It was proposed to investigate the properties of concrete, cast with partial replacement of fine aggregate with 0%, 12.5%, 25%, 37.5%, 50% proportions of ACBFS and cured in water for 7days, 28days, 56days, and 90days.

No. of specimens prepared to test hardened concrete

Type of Specimens	No. of specimen cured in water				
	Mix 1 0%	Mix 2 12.5%	Mix 3 25%	Mix 4 37.5%	Mix 5 50%
Cubes	12	12	12	12	12
Cylinders	12	12	12	12	12

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Beams	12	12	12	12	12

5. RESULTS AND DISSCUSSIONS

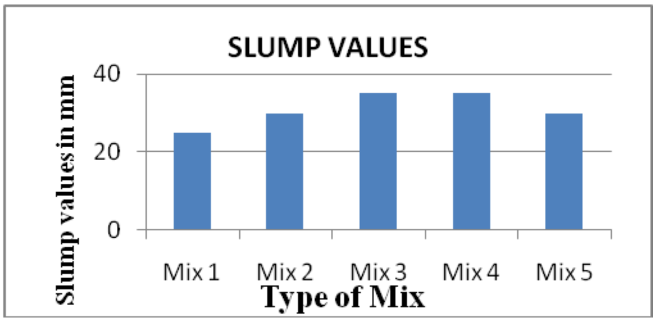
5.1. Workability:

Workability is a property of fresh concrete. It is, however, also a vital property as far as the finished product is concerned because concrete must have workability such that compaction to maximum density is possible with a reasonable amount of work or with the amount that we prepared to put in under given conditions.

Slump Cone Test: The slump cone test was conducted for all the five mixes. Slump for different mixes are shown below.

Slump Cone Results

S. No	Mix	% of replacement	Slump Value in mm
1	Mix 1	O	25
2	Mix 2	12.5	30
3	Mix 3	25	35
4	Mix 4	37.5	35
5	Mix 5	50	30



Slump Vs Mix

5.2. Hardened Properties of Concrete: The test results such as compressive strength, split tensile strength and flexural strength of hardened concrete of M30 grade replacement of sand with 0%, 12.5%, 25%, 37.5%, and 50% proportions of air cooled blast furnace slag mixes at the ages of 7, 28, 56 and 90 days are detailed.

5.2.1. Compressive Strength Test:

The compressive strength of the concrete was done on 150 x 150 x 150 mm cubes. A total of 12 cubes were prepared for each mix. The specimens were tested for each mix at the age of 7days, 28days, 56days and 90days at the rate of three cubes on that particular day. The average value of the 3 specimens is reported as the strength at that particular age.

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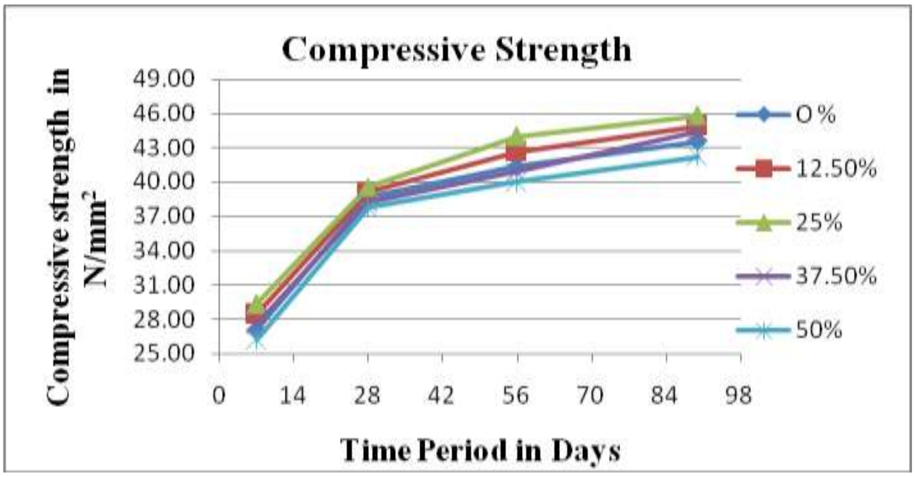
Compressive Strength Test Results

S.No.	Mix	% of ACBFS	Compressive strength in N/mm^2			
			7days	28days	56days	90days
1	Mix 1	0	27.11	38.67	41.33	43.56
2	Mix 2	12.5	28.44	39.11	42.67	44.89
3	Mix 3	25	29.33	39.56	44.00	45.78
4	Mix 4	37.5	27.56	38.22	40.89	44.44
5	Mix 5	50	26.22	37.78	40.00	42.22



Compressive Strength test Vs Time Period

5.2.2. Split tensile Strength Test:

The indirect tensile strength was measured on 150 x 300 mm cylinders and the results were shown below. A total of 60 cylinders were cast for the five mixes. Three specimens were tested each time and the average value at the particular age was reported as the tensile strength of the concrete.

Split Tensile Strength Test Results

S.No.	Mix	% of ACBFS	Split tensile strength in N/mm^2			
			7days	28days	56days	90days
1	Mix1	0	1.70	2.12	2.41	2.55
2	Mix 2	12.5	1.84	2.41	2.69	2.83
3	Mix 3	25	1.98	2.26	2.83	2.97
4	Mix 4	37.5	1.84	2.12	2.55	2.69
5	Mix 5	50	1.90	1.98	2.26	2.41

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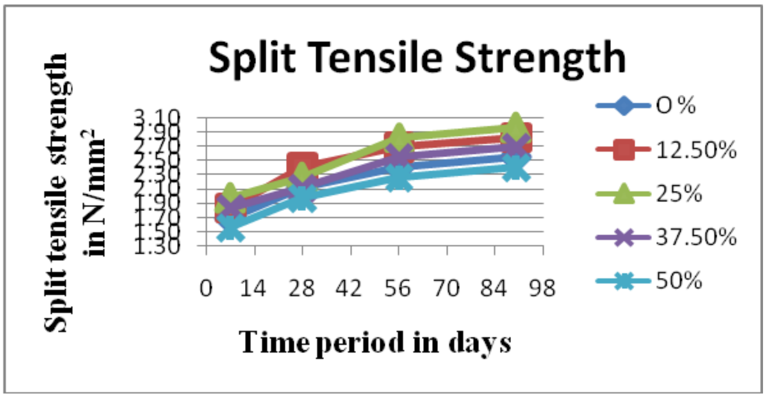


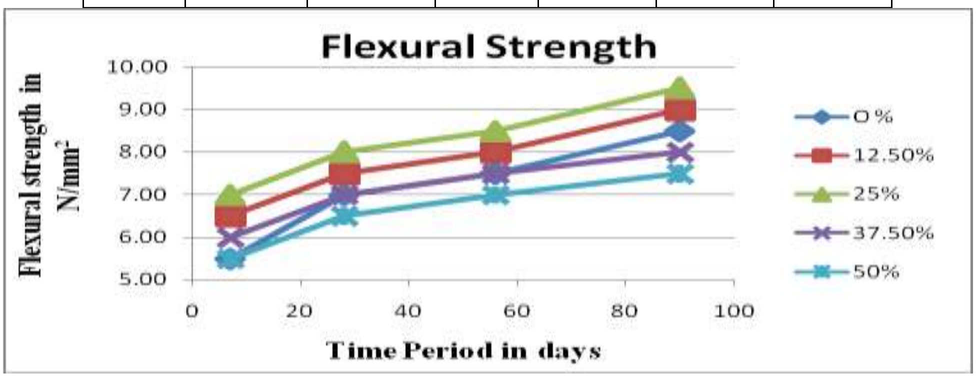
Split Tensile Strength Test Vs Time Period

5.2.3. Flexural Strength Test:

Flexural strength of the concrete was determined from modulus of rupture test on beam as shown below for specimens of 100 x 100 x 500 mm size. Here also, a total of 60 specimens were cast out of which three specimens were tested for each mix at 7days, 28 days, 90days and 90 days.

Flexural strength test results

S.No.	Mix	% of ACBFS	Flexural strength in N/mm^2			
			7days	28days	56days	90days
1	Mix 1	0	5.50	7.00	7.50	8.50
2	Mix 2	12.5	6.50	7.50	8.00	9.00
3	Mix 3	25	7.00	8.00	8.50	9.50
4	Mix 4	37.5	6.00	7.00	7.50	8.00
5	Mix 5	50	5.50	6.50	7.00	7.50



Flexural Strength Test Vs Time Period

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6. CONCLUSIONS

The workability and strength properties of concrete mixes have been calculated at the replacing of 0%, 12.5%, 25%, 37.5% and 50% ACBFS in fine aggregate. On this study, the following conclusions are drawn.

- Slump value is more when sand is replaced with 25% and 37.5%. So we can conclude that for 25% and 37.5% workability would be more compared to remaining mixes.
- The Compressive strength is maximum of 45.78 MPa with the replacement of 25% ACBFS at the age of 90 days.
- The Split tensile strength is maximum of 2.97 MPa with the replacement of 25% ACBFS at the age of 90 days.
- The Flexural strength is maximum of 9.5 MPa with the replacement of 25% ACBFS at the age of 90 days.

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