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Original Article

Experimental Investigations on Mechanical Properties of Alkali Activated Coarse Aggregate in Concrete

M. P. Naveena[1], G. Narayana[1]

[1] *Department of Civil Engineering, SJC Institute of Technology (Visvesvaraya Technological University), Karnataka, India*

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Abstract - *The present study focused on developing Alkali Activated Fine Aggregate (AAFA) by palletization method. AAFA was manufactured using Ground Granulated Blast Furnace Slag (GGBS) and alkali activator solution at ambient conditions. Sodium hydroxide of six molarity and sodium silicate to sodium hydroxide ratio of 2.5 was used. AACA's properties are similar to Natural Aggregate except for flakiness and elongation index. The water absorption and Abrasion value have high for AACA compared to natural aggregate. The slump value is an increase in replacement level up to 40% replacement of AACA by Natural aggregate further replacement level there are decrees in a slump. Compressive, Split, and Flexural strength has shown noticeable strength increase for all replacement levels of AACA by natural aggregate. However, beyond the increase of 40 % replacement level, there is a decrease in strength. It may be attributed to the reduced bond between aggregate and paste.*

Keywords *- Pellitization, Molarity, Strength, GGBS.*

1. Introduction

Many supplementary cementitious materials are used to improve the properties of concrete. Ground Granulated Blast Furnace Slag (GGBS) is one of the promising alternatives to cement. India has the largest producer of cement next to china in the world. By 2025 the requirement of cement in India may be 550-600 million tons per annum. It is predicted that 53.9 million tonnes may be produced per annum production from steel plants as a byproduct by the end of 2022. The utilization of GGBS as a replacement has solved the environmental issue. High-volume replacement of cement by GGBS decreases the strength. The optimum replacement of GGBS is 10% cement, which helps increase concrete strength by 15-20%. Microstructure Analysis shows that a higher SiO2 content in GGBS helped the hydration process of concrete by forming the additional layer of C-S-H. XRF results show that significant oxides CaO, SiO2, Al2O3, Fe2O3, MgO, SO3, and alkalis (Na_2O &K_2O) are available in GGBS. Energy analysis of concrete with GGBS can reduce by 3.6% energy consumptions.

2. Objectives of Work

Feasibility of using Manufactured AACA with replacement of Natural Aggregate in concrete.

3. Materials and Methodology

3.1. Materials

The cement OPC 53 grade of ACC cement was used, and tests on cement were carried accordance with the IS 12269-1987, while the Manufacturing Sand (M sand) and Natural coarse aggregate were obtained from locally available properties according to IS 383-2016 and IS 2386-2002 respectively. Water requirement is used for mixing and curing concrete following IS 456-2000. Fosroc Conplast SP 430 uses a chemical admixture to obtain the desired workability. The raw materials for the preparation of Alkali Activated Coarse Aggregate were Ground Granulated Blast Furnace slag (GGBS) and Alkaline Solution. GGBS)is obtained from iron making process in Bellary, Karnataka, India, and properties were found to be in accordance with IS 12089-1987. Sodium silicate and sodium hydroxide were used as alkaline solutions, and both alkalis were commercial-grade procured from local suppliers.

3.1.1. Preparation of Alkali Activated Coarse Aggregate

Sodium hydroxide flakes were added to tap water based on the required concentrations to make a sodium hydroxide solution. A measured quantity of sodium silicate was added to make an alkaline solution. The prepared solution was allowed to cool for 24 hours before using for the preparation of AAFA.GGBS was thoroughly dry-mixed in a drum mixer. The alkaline solution was then slowly added and thoroughly mixed until the formation of a fine aggregate. The AAFA was formed in the mixer by maintaining a rotation angle of 45 degrees. The speed of the mixer is 20 rpm for 2 Minutes. The aggregates were prepared by the method of agglomeration, where GGBS is moisturized in a drum mixer by adding an alkaline solution. When moisturized GGBS is rotated at a specific speed, the mix slowly converts into aggregates. The liquid film on the particles of GGBS increases the bonding force with the solution by centrifugal and gravitational force. Once aggregates were formed in the mixer, they were collected and kept for curing at ambient temperature. The developed Alkali activated coarse aggregates, as shown in Fig. 1.

Fig. 1 Manufactured Alkali Activated Coarse aggregate

3.2. Methods

Conventional and non-conventional concrete samples are produced. Conventional concrete is produced using Cement, M sand, and Natural Coarse Aggregate with a calculated quantity of water. The non-conventional samples are produced using different proportions of Alkali Activated Coarse Aggregate (20%, 40%, 60%, 80%, and 100%) with the aggregate weight. The concrete mix proportion of M25 grade of concrete is calculated as per IS 10262-2019 [1] for conventional and Non-conventional concrete. The fresh and hardened properties of concrete were studied. The fresh properties of concrete were studied by slump test by IS 1199-1959 to measure the workability of fresh concrete of conventional and non-conventional concrete. The slump of concrete is determined by measuring the height before and after removing the concrete slump cone. The hardened properties of concrete were studied by compressive, split, and flexural strength tests in accordance with IS 516-1959 by casting a cube, cylinder, and Prism, respectively. The 54 cube specimens of (150mmX150mmx150mm), 54 cylinders of dimensions (150mmX300mm), and 54 prism dimensions (100mmX100mm x500mm) were cast as 9 samples of conventional and 45 samples of non-conventional concrete and tested under laboratory conditions. The strength of concrete is determined after the curing age of 7, 14, and 28 days.

4. Experimental Investigations

The experimental investigation is carried out by characterization of raw materials and Physical Properties of Manufactured AACA were carried out. The properties of OPC 53-grade cement are tabulated in Table 1.

5. Results and Discussions

The 54 cube specimens of (150mmX150mmx150mm), 54 cylinders of dimensions (150mmX300mm), and 54 prism dimensions (100mmX100mm x500mm) were cast as 9 samples of conventional and 45 samples of non-conventional concrete and tested under laboratory conditions. The strength of concrete is determined after the curing age of 7, 14, and 28 days and results are tabulated in Tables 7,8, 9, and Fig 2,3 and 4.

Table 1. Physical Characteristics of cement

Sl No	Details	Results	12269 -1987
1	Normal Consistency (in %)	32%	-------
2	Specific Gravity	3.1	3.15
3	Setting Time (in Minutes) Initial Setting Time Final Setting Time	 240 580	 ≥ 30 ≤ 600

Table 2. Physical Characteristics of GGBS

Sl No	Details	Results	12269 -1987
1	Specific Gravity	3.2	-------

Table 3. Physical Characteristics of M Sand

Sl No	Details	Results
1	Specific gravity	2.7
2	Water absorption (%)	1.01
3	Fineness modulus	2.9
4	Loose bulk density (kg/m^3)	1550

Table 4. Physical Characteristics of M Sand

Sl No	Details	NCA	AACA	2386 -2002
1	Specific gravity	2.7	2.62	-------
2	Water absorption (%)	0.6	6.4	3.15
3	Loose bulk density(kg/m^3)	1400	1320	1500-1600
4	Crushing value	23.5	26	Less than 30%
5	Impact Value (%)	23	24	Less than 30%
6	Abrasion value(%)	26.2	89	Less than 30%
7	Flakiness index(%)	13	0	Less than 30%
8	Elongation Index(%)	19	0	Less than 30%

Table 5. Mix Proportion of concrete

Percentage Replacement	0	20	40	60	80	100
Cement (kg/m^3)	360	360	360	360	360	360
Fine Aggregate (kg/m^3)	714	714	714	714	714	714
Coarse Aggregate(kg/m^3)	1219	975	731	487	243	----
AACA(kg/m^3)	---	243	487	731	975	1219
Water (kg/m^3)	160	160	160	160	160	160
W/C ratio	0.44	0.44	0.44	0.44	0.44	0.44

Table 6. Slump of concrete

Percentage Replacement	0	20	40	60	80	100
Slump (mm)	80	81	85	79	78	72
Density(kg/m^3)	2476	2442	2431	2420	2410	2390

Table 7. Compressive strength of concrete (MPa)

Sl No	Percentage Replacement	Compressive Strength (MPa)		
		7 days	14 days	28 days
1	0	16.50	22.50	36.2
2	20	14.25	20.56	32.52
3	40	13.6	19.52	30.56
4	60	12.5	16.54	27.52
5	80	11.9	14.56	24.61
6	100	11.5	13.65	18.68

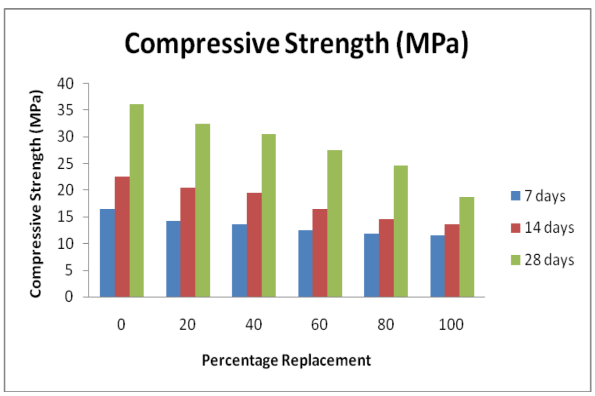

Fig. 2 Compressive strength of concrete

Table 8. Split Tensile strength of concrete (MPa)

Sl No	Percentage Replacement	Split Tensile Strength (MPa)		
		7 days	14 days	28 days
1	0	2.2	2.8	3.07
2	20	2.1	2.9	3.25
3	40	2.1	2.7	3.2
4	60	1.98	2.5	3.15
5	80	1.9	2.2	3.1
6	100	1.9	2.5	2.9

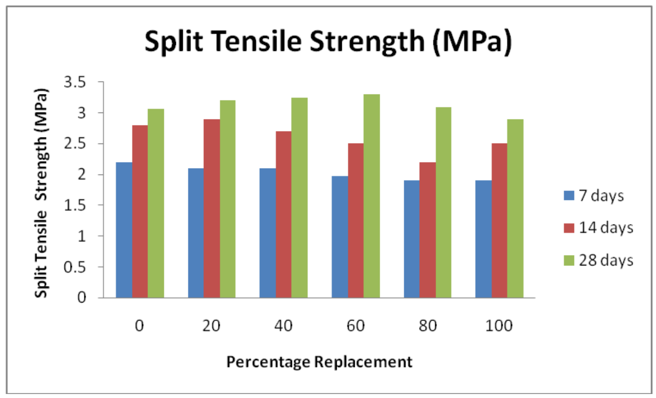

Fig. 3 Split Tensile strength of concrete

Table 9. Flexural strength of concrete (MPa)

Sl No	Percentage Replacement	Flexural Strength (MPa)		
		7 days	14 days	28 days
1	0	3.2	4.1	5.2
2	20	3.1	3.9	4.9
3	40	2.5	3.5	4.5
4	60	1.98	3.3	4.3
5	80	2.1	3.2	4
6	100	2	2.9	3.9

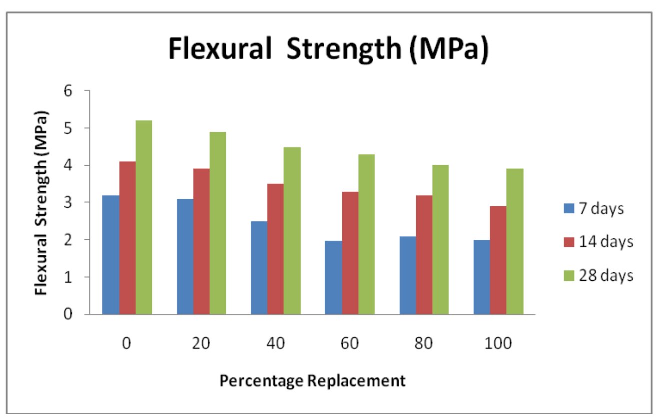

Fig. 4 Flexural strength of concrete

5. Conclusion

The present study focused on manufacturing Alkali Activated Coarse Aggregate using Ground Granulated Blast Furnace Slag as source material. The present work was carried out to check the feasibility of utilization of developed aggregate in concrete as a replacement for Natural aggregate.

(i) AACA's properties are similar to Natural Aggregate except for flakiness and elongation index.
(ii) The water absorption and Abrasion value is higher for AACA than natural aggregate.
(iii) The slump value increases in replacement level up to 40% replacement of AACA by Natural aggregate; further replacement level decrees in a slump.
(iv) Compressive, Split and Flexural strength has shown a noticeable strength increase for all replacement levels of AACA by natural aggregate. However, beyond the increase of 40 % replacement level, there is a decrease in strength. It may be attributed that the bond between aggregate and paste is reduced.

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