Utilization of Cementitious Materials with Cold-bonded Artificial Aggregate in Concrete

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Abstract: This article investigates the slump and compressive strength of artificial lightweight aggregate concrete with Ground Granulated Blast Furnace Slag (GGBFS) and Silica Fume with glass fibres. The increase in usage of cement in the construction industry is a concern for ecological deterioration, in this view; artificial aggregates was manufactured with major amount of fly ash and replacement of cement with various industrial by-products in concrete. An optimum level of GGBFS from 10 to 50% and Silica Fume from 2 to 6% with addition of glass fibres was assessed based on compressive strength values. The compressive strength was conducted for 7 and 28Days of water curing on M30 grade lightweight concrete with constant water to cement ratio as 0.45 and 0.2% of Master Gelenium super plasticizer. The conclusions achieved from the compressive strength of concrete containing GGBFS and Silica Fume was increased as the curing time increases. As a result lightweight aggregate concrete with a cement content of 226 kg/m^3 develops 37.3 N/mm^2 compressive strength.

Keywords: Cold-Bonded artificial aggregate, Lightweight concrete, Cementitious material, Compressive Strength.

I. INTRODUCTION

Construction field has become one amongst the foremost necessary a part of a country's economic and public development [1]. Concrete has been used by the development business for the development of most of the infrastructures that range from construction of foundations to skyscrapers [2]. The most predominately used material for the development of infrastructure in the construction field is cement. The requirement of cement was expected around 5.2 billion metric tons in the year 2020. The increasing in usage of cement in construction activities resulting release of harmful gases into the environment causes a significant increase in earth's temperature [3]. The only option to reduce the harmful gases from cement industry is to increase the usage of supplementary cementitious materials (SCMs) from industrial by-products as replacement of cement in manufacturing of both artificial aggregates and concrete, which results in lesser usage of natural resources. In concrete production, aggregate occupies 60-70% of the total volume, the utilization of artificial lightweight aggregates promotes high volume consumption of fly ash [4-12]. Among various industrial by-products ground granulated blast furnace slag (GGBFS) and fly ash became more popular because of its pozzolanic nature and in market other materials are present which results improved characteristics of artificial aggregates and concrete as well [13].

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In this study three options of cementitious materials like GGBFS, Fly ash and Silica fume were assessed. Maximum amount of fly ash was used in the manufacturing of artificial aggregates and GGBFS and Silica fume were used as partially replacement with cement in concrete. The purpose of this study is to examine the impact on fresh and hardened state of lightweight aggregate concrete with the maximum replacement of cement with GGBFS and Silica fume with the addition of glass fibres.

II. EXPERIMENTAL PROGRAMME

A. Materials and Mix Proportions

Table I presents the physical and chemical properties of materials like fly ash (F-Type), GGBFS, hydrated lime, cement, silica fume and Master Gelenium SKY 8233 super plasticizer (SP) was chosen in manufacturing of lightweight concrete. Cold bonded aggregates as coarse aggregates and local river sand was used as a fine aggregate. Alkali Resistant glass fibres (GF) were added in the manufacturing of aggregates and concrete have length 12mm and diameter as 14microns which is evaluated as per ASTM C1579 as shown in Figure 4.

B. Manufacturing of Cold-Bonded Artificial Aggregate

Artificial coarse aggregate was manufactured using 80% Class-F fly ash, 10% GGBFS, 10% hydrated lime and addition of 0.17% glass fibres by pelletization method. The disc pelletizer was fabricated with a diameter of 0.5m and 0.25m depth as shown in Figure 1. The aggregates were pelletized for 17 min in order to achieve maximum pelletization efficiency, maximum strength and minimum water absorption, based on different trials the pelletizer speed and angle were maintained at 55 rpm and 36^0 respectively along with 28% water content. The physical and mechanical characteristics of cold-bonded coarse aggregate is tested as per IS: 2386 – 1963 which satisfies the structural demand as per IS: 9142 (part 2) – 2018 are given in Table II and Table III. To achieve workability artificial aggregate was presoaked for 30 min before it mixed in to concrete.

C. Replacement of Cement with GGBFS and Silica fume

Lightweight concrete manufactured with cement content of 438 kg/m^3 was selected as control mix without superplasticizer (LM). Based on the different trials superplasticizer quantity was fixed as 0.2% (LM0) and cement replacement with GGBFS in five levels viz., 10%, 20%, 30%, 40% and 50% by weight it marked as Trial-I (LM1-LM5). In Trial-II (LM6-LM8) optimum mix in Trial-I was chosen and three levels of cement replacement with silica fume viz., 2%, 4% and 6% by weight were adopted. In Trial-III (LM9-LM10), the optimum mix in Trial-II was selected and added Alkali resistant glass fibres viz., 0.1% and 0.2% by total volume of concrete. The different trial mix combinations of LWAC were calculated by absolute volume method.

D. Mix Design Proportion

Mix design used in the present work to attain M30 grade lightweight concrete accordance with IS: 10262:2009 and IS: 456:2000. The weight of each material ingredient and the mix design proportions are given in Table IV.

TABLE- I: Chemical And Physical Properties Of Different Binder Materials Utilized In This Study

Observations	*FA (F)	C	HL	SF	GGBFS
Chemical Characteristics					
SiO_2	39.4	22.3	0.3	99.88	35
Fe_2O_3	18.54	3	0.23	0.040	0.95
Al_2O_3	17.9	6.93	0.42	0.043	17.7
CaO	17.45	63.5	69	0.001	41
MgO	2.88	2.54	0.5	-	11.3
TiO_2	0.95	-	-	0.001	-
Na_2O	0.28	-	-	0.003	0.2
K_2O	1.78	-	-	0.001	-
$Ca(OH)_2$	-	-	91	-	-
MnO_2	0.15	-	-	-	2.7
SO_3	1.70	1.72	-	-	-
$CaCO_3$	-	-	-	-	10
P_2O_5	0.45	-	-	-	0.65
Glass content	-	-	-	-	92
Physical Characteristics					
Specific gravity	2.12	3.12	2.24	2.63	2.85
Specific surface area (m^2/kg)	407	290	-	819	409
Loss on ignition	1.76	0.84	-	0.015	0.26
pH Value	-	6.3	12.4	6.90	-
Moisture (%)	0.5	-	-	0.058	0.10

TABLE- II: Sieve analysis of artificial aggregate

Size of aggregate (mm)	Percentage of aggregates produced
16	5.1
12.5	35.6
10	45.1
4.75	14.2

TABLE- III: Physical and Mechanical Properties of cold-bonded artificial aggregate

Properties	Units	Value
Fineness modulus	-	6.44
Production efficiency	%	95.5
Specific gravity	-	2.48
Water absorption (24h)	%	16.3
Loose bulk density	Kg/m3	855
Rodded bulk density	Kg/m3	898
Impact strength	%	16
Individual aggregate compressive strength	N/mm2	16mm: 44.2 12.5mm: 47.8 10mm: 52.3 4mm: 58.1

Fig.1. Disc Pelletizer

Fig.2. Aggregate

Fig.3. UTM

Fig.4. Glass Fibres

III. RESULT AND DISCUSSION

A. Fresh Concrete Properties

- **Super plasticizer dosage and Cement replacement with GGBFS and Silica fume**

The dosage of super plasticizer required to maintain a constant workability, which is connected to the increase in the mix's specific surface. For the reduction of cement content super plasticizer was used and to fix the exact percentage in dosage of super plasticizer based on strength parameter. The optimum dosage of superplasticizer was fixed as 0.2% for all the mixes after different trials based on strength. The increase in workability of artificial lightweight concrete with an increase in GGBFS alone and the combination of GGBFS with silica fume as well is associated to the lesser SSA of GGBFS, silica fume as compared to cement which is given in Table V. For binder content, due to the round shape of artificial aggregates, the workability increases significantly. With the increase in percentage addition of glass fibres the workability decreases which is more than control concrete.

B. Hardened Concrete Properties

The compressive strength test was conducted in universal testing machine as shown in Figure 3. The test results obtained by the replacement of cement with GGBFS and Silica fume were determined at 7 and 28 days is given in Table V and represented in Figure 8.

TABLE- IV. Different Mix Combinations With GGBFS And Silica Fume As Cement Replacement With Glass Fibres

Mix ID	Mix Combinations	Cement (kg/m^3)	GGBFS (kg/m^3)	Silica fume (kg/m^3)	Water (kg/m^3)	Sand (kg/m^3)	Cold-bonded aggregate (kg/m^3)	Super plasticizer (kg/m^3)	Glass fibre (kg/m^3)
LM	100C+0SP	438	-	-	197	758	956	-	-
LM0	100C+0.2SP	384	-	-	173	805	1014	0.768	-
LM1	90C+10GGBFS+0.2SP	345.6	38.4	-	173	805	1014	0.768	-
LM2	80C+20GGBFS+0.2SP	307.2	76.8	-	173	805	1014	0.768	-
LM3	70C+30GGBFS+0.2SP	268.8	115.2	-	173	805	1014	0.768	-
LM4	60C+40GGBFS+0.2SP	230.4	153.6	-	173	805	1014	0.768	-
LM5	50C+50GGBFS+0.2SP	192	192	-	173	805	1014	0.768	-
LM6	58C+40GGBFS+2SF+0.2SP	225.8	153.6	4.6	173	805	1014	0.768	-
LM7	56C+40GGBFS+4SF+0.2SP	221.2	153.6	9.2	173	805	1014	0.768	-
LM8	54C+40GGBFS+6SF+0.2SP	216.6	153.6	13.8	173	805	1014	0.768	-
LM9	58C+40GGBFS+2SF+0.2SP +0.1GF	225.8	153.6	4.6	173	805	1014	0.768	2.38
LM10	58C+40GGBFS+2SF+0.2SP +0.2GF	225.8	153.6	4.6	173	805	1014	0.768	4.75

- **Cement replacement with GGBFS**

The optimum control mix with super plasticizer (LM0) was taken and cement replacement from 10% to 50% (LM1-LM5) with GGBFS was done. The highest 28 days compressive strength of 30.7 N/mm^2 was achieved at 40% cement replacement with GGBFS (LM4) which is around 8% more than control mix (LM0) and again increasing in percentage of GGBFS strength got decreased. At any replacement level of GGBFS, the compressive strength of concrete was higher than that of the corresponding control mix due to more CaO but significantly less Al_2O_3 which forms pozzolanic reaction. Hence, it can be said that 40% replacement of cement with GGBFS is optimal percentage on which safely attained the required strength.

- **Cement replacement with GGBFS and Silica Fume**

The optimum mix at 40% cement replacement with GGBFS (LM4) was taken and again cements replacement from 2% to 6% (LM6-LM8) with Silica fume. The highest compressive strength of 37.3 N/mm^2 was achieved at 2% cement replacement with silica fume (LM6), which is around 30% more than control mix (LM0) and the achieved strength is very nearer to designed target strength, failure pattern of specimen is shown in Figure 5. Silica fume have totally very fine particles size of silicon dioxide which is relatively high pozzolanic nature which is responsible for high strength in concrete. Hence, it can be said that 40% and 2% replacement of cement with GGBFS and Silica fume is optimal percentage on which safely attained the required strength.

- **Cement replacement with GGBFS and Silica Fume with Glass Fibres**

The optimum mix at 40% and 2% cement replacement with GGBFS and Silica fume (LM6) was taken and added Alkali resistant glass fibres at 0.1% and 0.2% (LM9-LM10) by total volume of concrete. The highest compressive strength of 37.1 N/mm^2 was achieved at 0.2% of glass fibres (LM10) which is almost very nearer to LM6 mix which means glass fibres does not affect much on compressive strength of concrete but still it's around 29% more than control mix (LM0) and failure pattern of specimen is shown in Figure 6. From all the mix combinations, compressive strength results recommended that the cement replacement levels can be controlled based on the target strength.

Fig.5. LM6 Specimen

Fig.6. LM10 Specimen

TABLE- V: Slump and Compressive strength values of different mix proportions

Mix ID SiO_2	Slump (mm)	Compressive Strength (N/mm^2)	
		7Days	28Days
LM	100	20.3	26.7
LM0	100	21.2	28.6
LM1	100	24	32.4
LM2	103	22.2	30.2
LM3	109	22.7	30.9
LM4	120	22.6	30.7
LM5	120	20.3	27.7
LM6	117	27.2	37.3
LM7	123	22.7	31.7
LM8	119	20.3	27.9
LM9	108	26.7	36.2
LM10	100	27	37.1

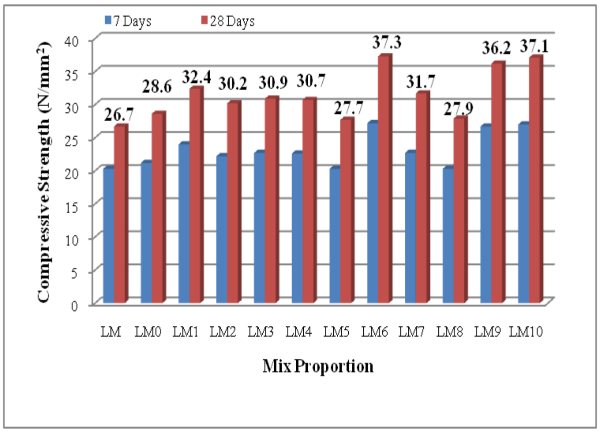

Fig.7. Average Compressive strength on different ages with different mix proportions

IV. CONCLUSION

The conclusions drawn from the present investigation on cold-bonded artificial lightweight aggregate concrete are summarized below:

1). The mix combination of well-researched mineral admixtures such as GGBFS and silica fume does not only manufacture concrete but also improve fresh and hardened concrete properties.

2). The optimum dosage of superplasticizer was fixed as 0.2% for all the mixes after different trials based on strength parameter.

3). By partial replacement of cement with GGBFS, the workability of cold-bonded artificial aggregate concrete increased, while it again increased when cement was replaced with 4% silica fume and decreased with the addition of glass fibres.

4). The lightweight concrete with 40% GGBFS and 2% Silica Fume replacement with cement (LM6) attained the highest compressive strength of 37.3 N/mm^2 than the corresponding control mix (LM0). The strength enhancement was higher with lower cement content as 226 kg/m^3.

5). Thus, it can be said that 40% and 2% replacement of cement with GGBFS and Silica fume is optimal percentage on which safely attained the required strength of concrete which reduce the usage of cement and utilization of industrial by-products.

6). The addition of glass fibres in concrete does not affect much on compressive strength but still it's 29% more than control mix concrete strength (LM0).

7). From all the trial mix combinations, it is noticed that compressive strength results suggested that the cement replacement percentage can be controlled based on the target strength.

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