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Experimental Analysis of Different Supplementary Cementitious Materials in Concrete

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ABSTRACT

The offered research is chiefly focused on reducing the usage of cement and improve the mechanical properties by using supplementary cementitious materials. In this case, supplementary cementitious materials are GGBS, fly ash, silica fume, and POFA - Palm oil fuel ash are considered. Cement is substituted by up to 30% by using the above obligatory materials with different proportions. In this study, the mechanical properties are examined.

Index Terms – GGBS, Fly Ash, Silica Fume, POFA, Mechanical Properties.

1. INTRODUCTION

Growth within housing manufacturing is linked to the expansion of the transportation segment and consequently the building industry [1]. In fresh years, with the event of the development commerce, the demand for cement is increasing rapidly the assets of concrete by incomplete spare of cement with GGBS plus thus the fine aggregate along with Quarry Powder [2]. The Indian calcium bentonite grout combinations exposed complex strengths at 10% standby, compares at 15% then falling about 30% than meticulous mixes [3].

The ordinary Portland cement is only of the only binders within the construction industry, it affects plenty of injury to the environment while construction and hydration procedure to realize strength [4]. Concrete is that the greatest generally cast-off building material consuming several wanted properties similar to high compressive strength, stiffness, and sturdiness under usual environmental conditions [5]. The development structures which are currently in and around coastal areas re severely cope with plenty of problems. This is often because of the penetration of sea salts [6]. Implementations of those programs are likely to extend in demand for ceramic tiles. His successively increase in consumption of ceramic raw materials and certain to increase the worth of feldspar as we are having limited resources of feldspar and significant quantity is being exported [7].

To scale back the CO_2 releases linked to cement-based materials the standard hydraulic OPC is progressively substituted as a folder by additional cementitious materials (SCMs). Heat and sorption capacities presented that ash responded gentler than OPC and had a partial result on the opening structure within the primary month [8]. The incorporation of a giant pozzolan gratified in cement schemes permits greater thermal stability. Pozzolanic additions, like silica fume, are successfully employed to seem high-temperature difficulties. it is additionally understood that silica fume improves motorized assets [9]. Slag powder may be a procedure with fonts of multivariable, strong link, and nonlinearity. The slag can procedure powder after grinding. When the precise part of slag powder is sort of 400 m2/kg, the strength of the cement is improved [10] Using Sugarcane Bagasse Residue as a standby of OPC in concrete, the emission of greenhouse gases are often reduced up to a bigger extent [11]. Silica fume theatres a neighborhood within the hydration response amid cement then water through responding by the lime to make calcium silicate hydrate (CSH) gel, which is that the folder among the aggregates and delivers HPC its intensity [12].

Biomedical waste is being generated from hospitals, health clinics, and laboratories. The disposal of this waste ash is an environmental concern, potentially cause the spread of infectious diseases [13]. 45% ultra-fine ash in production requests not including conciliatory the standard. The optimum mix scopes are RFA is 15%, GFA is 30%, AGFA is 45% correspondingly [14]. The consequence of EDM process parameters on the shallow properties of variant Al/SiC mixtures [15]. Contempt the superb helpful mechanical belongings and sturdiness performance of cementitious compound, the modulus of elasticity is low-slung because of the non-appearance of coarse aggregate and this has delayed within the sole request in structures [16].

2. INVESTIGATIONAL DETAILS

2.1. Raw Material Used

- Binding Materials: binding resources like cement, silica fume, GGBS, fly ash, and POS were used. OPC of grade 43 was cast-off. The physical and mechanical properties conforming to IS:8112- 2013 [17]. The physical besides mechanical properties are existing in Table:1. a and 1.b. respectively.
- Aggregates: the fine aggregates conforming to less than 4.75 mm particle size river sand and C. A 20mm size stood used. The belongings of aggregates are shown in Table 2.a. and 2.b. respectively.
- Water: Portable water was used for all test specimens.
- Superplasticizer: Conplast SP-430 (Fosroc) was used.

S.No.	Properties	Cement	GGBS	Fly Ash	Silica Fume	POFA
1.	Specific Gravity	3.15	2.9	2.2	2.2	2.2
2.	Bulk Density (Kg/m^3)	1865	1000 to 1100	540 to 860	750 to 850	966
3.	Shape	Spherical	Spherical	Spherical	Irregular	Spherical
4.	Particle size	1.5µ	4.75mm down	0.5µm-300µm	0.1µ	--

Table 1. a. Binding Materials - Physical Properties

Binder	Cao	SiO_2	Al_2O_3	MgO	K_2O	Na_2O	SO_3	Fe_2O_3	LOI
OPC [2]	63.54	19.82	5.36	1.27	0.09	-	2.83	3.72	1.82
GGBS [2]	37.42	34.44	13.31	9.89	0.47	0.34	1.23	0.47	1.65
Silica fume [2]	0.89	93.06	-	0.69	1.15	0.63	1.28	2.06	0.24
Fly ash [3]	3.13	63.24	16.62	1.21	1.39	0.54	-	6.41	-
POFA [4]	3.97	67.5	4.2	2.72	8.45	0.115	0.535	8.12	1.48

Table 1.b. Binding Materials - Chemical Properties

IS Sieve Size	% Passing Through I.S Standards	Requirements (I.S: 383-1970)	
10	100	100	Fineness modulus = 2.2
4.75	99.6	90-100	Specific Gravity – 2.66
2.36	99	75-100	Bulk Density – 1625 kg/m^3
1.18	92.6	55-90	Bulking of sand -23%
600 microns	48.6	53-50	Silt content – 0.25%
300 microns	8.2	8-30	
150 microns	2	0-10	
Zone	2		

Table 2. a. Fine Aggregates (River Sand) Properties

IS Sieve Size	% Passing Through I.S Sieve	Requirements as per are: 383-1970	Specific Gravity = 2.82 Water absorption = 0.40
40mm	100	100%	Aggregates Impact value =12%
20mm	94.60	85 -100	Bulk Density = 1660 kg/m^3

16mm	--	--	Flakiness =14% Elongation = 15%
12.5mm	--	--	
10mm	14.30	0 – 20%	
4.75mm	2.82	0 – 5%	
2.36mm	--	0.10	

Table 2. b Properties of Coarse Aggregates

2.2. Concrete Mixture Proportion

By using all the above materials concrete mix is prepared for M40 grade of concrete. For these mixes except binding materials, all other materials are kept constant percentages. Binding materials are used in different proportions and prepared 15 – types of mixes. The different types of proportions of cementitious materials are explained in Table 3. These mixed designs are conforming to IS: 10262-2019 and IS 456-2000.

Mix id	Composition	Mix id	Composition
NM	100 % Cement	CGS2	80% Cement + 10% GGBS + 10% S. F
CGFS1	85% Cement + 5% GGBS + 5% F.A + 5% S. F	CGS3	70% Cement + 20% GGBS + 10% S. F
CGFS2	70% Cement + 10% GGBS + 10% F.A + 10% S. F	CFS1	80% Cement + 10% F.A +10% S. F
CGFS3	55% Cement + 20% GGBS + 15% F.A + 10% S. F	CFS2	75% Cement + 10% F.A +15% S. F
CGF1	70% Cement + 15% GGBS + 15% F. A	CFS3	75% Cement + 22% F.A +8% S. F
CGF2	60% Cement + 20% GGBS + 20% F. A	CP1	90% Cement +10% POFA
CGF3	50% Cement + 25% GGBS + 25% F. A	CP2	90% Cement +20% POFA
CGS1	90% Cement + 5% GGBS + 5% S. F	CP3	90% Cement +30% POFA

Table 3. Different Proportions of Cementitious Materials

Mix IDS	Cement	GGBS	Fly Ash	Silica Fume	POFA	Fine Agg	Coarse Agg	Water	Super Plasticizer
NM	394	0	0	0	0	667.49	1306.62	157.6	2.4
CGFS1	368.39	21.67	21.67	21.67	0	671.28	1235.76	157.6	2.4
CGFS2	303.38	43.34	43.34	43.34	0	665.49	1225.11	157.6	2.4
CGFS3	238.37	86.68	65.01	43.34	0	660.67	1216.23	157.6	2.4
CGF1	303.38	65.01	65.01	0	0	665.49	1225.11	157.6	2.4
CGF2	260.04	86.68	86.68	0	0	665.49	1225.11	157.6	2.4
CGF3	216.7	108.35	108.35	0	0	665.49	1225.11	157.6	2.4
CGS1	390.06	21.67	0	21.67	0	665.49	1225.11	157.6	2.4
CGS2	346.72	43.34	0	43.34	0	665.49	1225.11	157.6	2.4
CGS3	303.38	43.34	0	86.68	0	665.49	1225.11	157.6	2.4
CFS1	325.05	0	65.01	43.34	0	672.24	1237.53	157.6	2.4
CFS2	346.72	0	65.01	21.67	0	675.23	1243.04	157.6	2.4
CFS3	303.38	0	95.34	34.67	0	673.2	1239.31	157.6	2.4
CP1	348.4	0	0	0	38.72	798.37	1093.46	157.6	2.4
CP2	309.76	0	0	0	77.44	792.13	1084.23	157.6	2.4
CP3	271.04	0	0	0	116.16	785.39	1075.00	157.6	2.4

Table 4 Mix Quantities

2.3. Investigational Approaches

To know the mechanical properties of the chosen materials, the following experiments are performed. All the below experiments are done with a curing age of 7 and 28 days.

- Dry Density: are calculated for all the mixes from mix quantities.
- Compressive Strength: to distinguish the compressive strength of the concrete, 50 x 150 x 150 mm^3 cubes are prepared, cured in portable water, and tested in a Compressive testing machine (CTM).
- Split Tensile Strength: For this test, the concrete cases of 150mm diameter and 300mm length cylinders are cast, cured for 7 and 28 days, future tested in the CTM.
- Bending Strength: to examine the bending strength of the considered mix proportions, specimens of size 500mm x 100mm x 100mm, prisms are considered, later cured, and tested under two-point loading.

3. RESULTS AND DISCUSSIONS

Composition	Compressive - Strength in Mpa		Split Tensile - Strength in Mpa		Bending - Strength in Mpa	
	7Days	28Days	7Days	28Days	7Days	28Days
NM	30.21	49.89	2.33	3.28	7.13	8.63
CGFS1	36.12	51.22	2.4	3.54	7.98	8.92
CGFS2	39.34	53.89	2.98	4.11	8.74	9.17
CGFS3	34.16	51.67	2.19	3.12	7.51	8.7
CGF1	32.4	32.4	3.11	4.43	4.46	5.95
CGF2	34.4	52.4	3.39	4.61	5.95	6.62
CGF3	32	51.3	2.9	4.36	5.46	6.29
CGS1	34.44	50.25	2.61	3.76	7.61	8.7
CGS2	38.59	53.68	3.11	4.38	8.52	9.12
CGS3	35.76	51.91	2.54	3.57	7.45	8.71
CFS1	31.11	48.36	2.25	2.75	4.89	5.49
CFS2	23.95	50.23	2.4	2.89	5.88	6.66
CFS3	23.33	46.42	2.35	2.61	3.52	4.31
CP1	30.79	46.9	1.915	2.91	6.65	10.1
CP2	33.46	50.93	2.54	3.86	7.315	11.03
CP3	23.1	35.18	1.4	2.14	4.95	7.59

3.1. Dry Densities

The dry densities are calculated for all 16 mixes are presented in figure: 2. In the X-axis the densities are presented in $kN/m^3$and on the Y-axis all 16 – Mix Ids are shown. From figure: 1 it is observed that the Mix ID NM is showing High density and CP3 is showing the least Density.

GGBS | Fly ash | Silica Fume | POFA

Figure 1 Mineral Admixtures

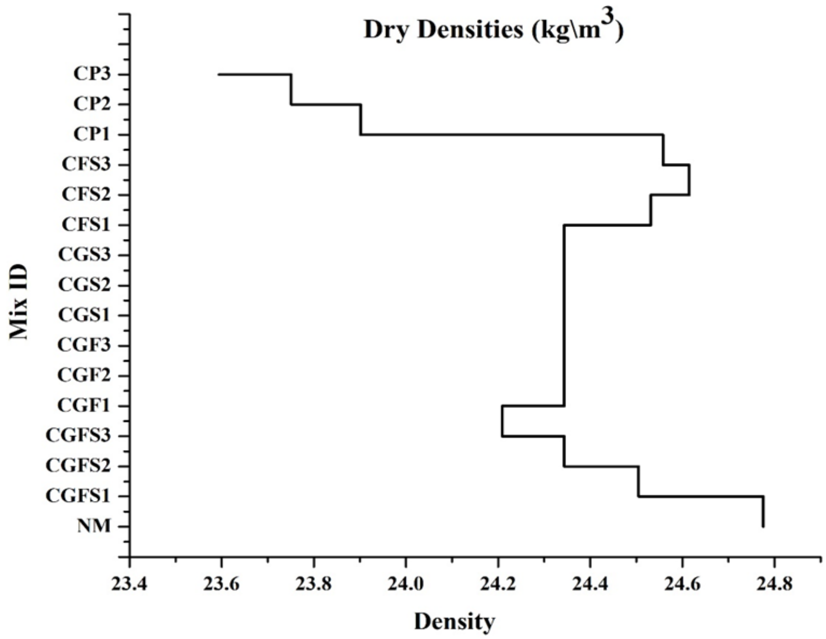

Figure 2 Dry Densities

3.2. Compressive Strength

Compressive Strength are calculated in the laboratory for the 5 – combinations of cementitious materials with 16 Mix ids. All the compressive strengths are plotted in the figure:3. From it is observed that all the mix ID's the strength is increasing with curing age and the graph is non – linear.

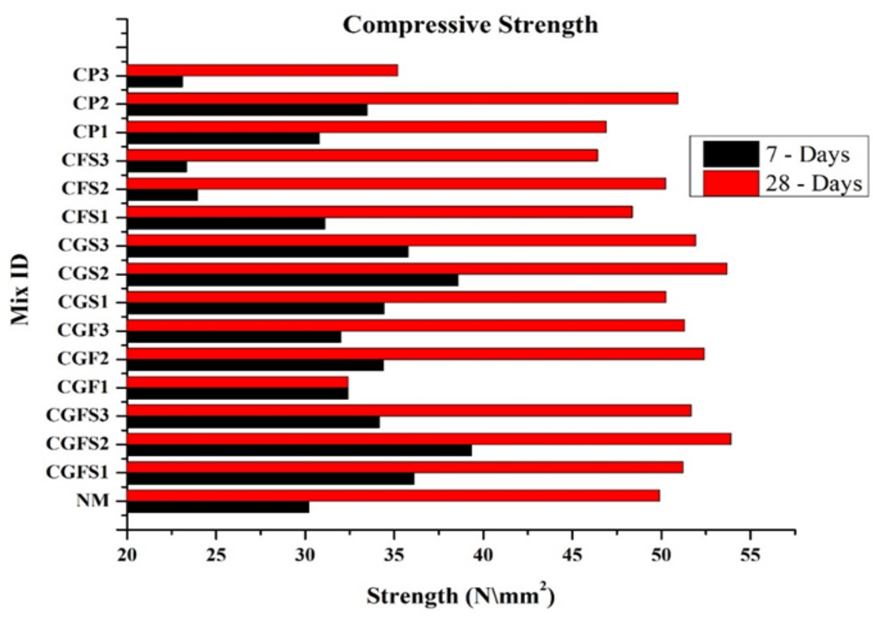

Figure 3 Compressive Strength

3.3. Split Tensile Strength

Split Tensile Strength also calculated for all groups of combination mineral admixtures and plotted in the figure:4. From figure :4, it is observed that the graph growth is non – linear.

3.4. Bending Strength

For the above four mineral admixtures the modulus of rupture or bending strength are calculated for all 16- combinations of mixes and shown in figure:5. In the graph, both 7 and 28 days of curing period strengths are shown. From the graph, CFS3 is showing very little strength compared with the other 15 mixes.

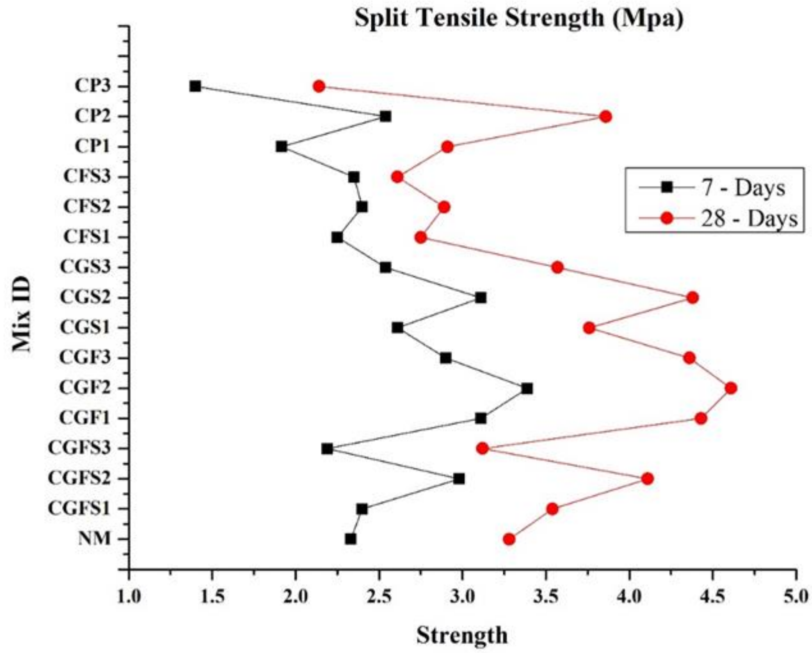

Figure 4 Split Tensile Strength

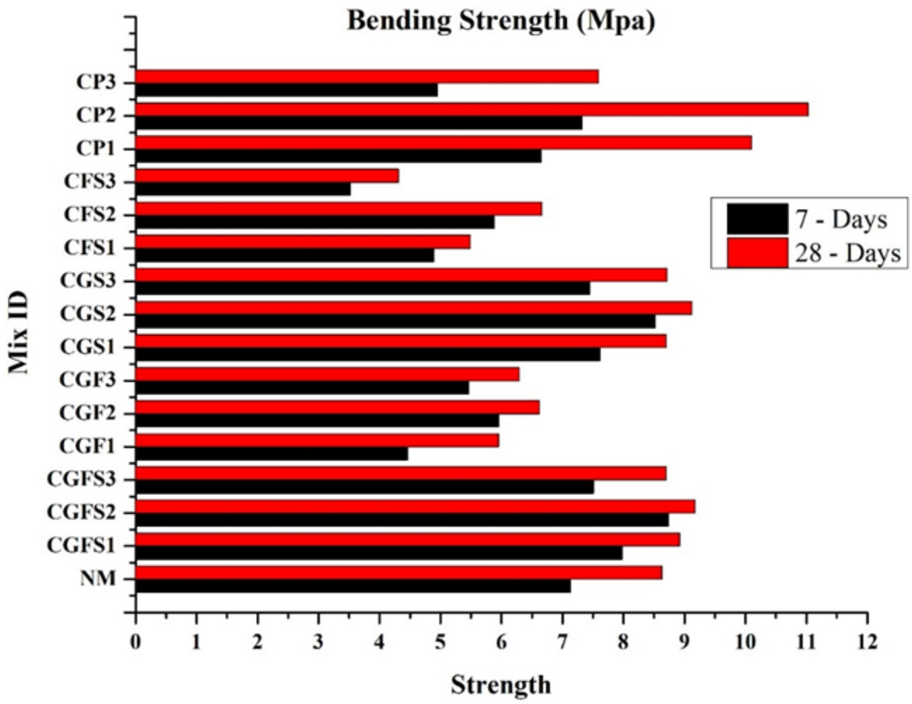

Figure 5 Bending Strength

4. CONCLUSION

Created on the trial investigation accepted out on the supplementary cementitious materials and conservative Portland cement concrete, it can be decided that:

- The chosen mineral admixtures are behaving like cement in all aspects. Due to less bulk density for the mineral admixtures, the dry density is showing less compared to the nominal mix.
- Comparing with the nominal mix, the supplementary cementitious mixes attain good results.
- The replacement of cement with mineral admixtures is allowed up to 30% in this present research.
- The CGFS and CP combinations are shown good strength, by using the mineral admixtures we can reduce Co_2 emissions from Cement up to 30%.

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