

IMPLICATION OF PARTIAL REPLACEMENT OF CEMENT WITH FA AND SAND BY GBS ON SETTING TIME AND WORKABILITY OF MORTAR

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Abstract

Fly Ash (FA) and Ground Blast Furnace Slag (GBS) are by-products obtained from the burning of coal in the thermal power plants and blast-furnace used to produce iron respectively. With a view to preserve natural materials like river sand and high energy consuming cement efforts are made to explore the possibility of replacing them with alternate materials including the industrial solid waste materials in the production mortar and concrete. It is in this context the setting time of FA and the workability of mortar are examined with these replacements. In the present investigation, 25% and 50% of Cement (C) is replaced by FA; and 25%, 50%, 75% and 100% of Sand (S) by GBS. Normal consistency and setting time increased with increasing replacement of cement with fly ash. However, the addition of 2% Calcium Chloride reduced the setting time of all pastes. Also, the results indicated that cement with upto 50% of FA can be considered without seriously jeopardizing the setting time. The workability test on 1:3 mortar on all combinations were performed to get a flow value of 110 ± 5 as per IS 2250 -1981. To enhance the workability and consequently increase their strength 2% of super plasticizer has been incorporated. The water cement ratio increased with increase in replacement of sand by GBS. The replacement by FA upto 50% did not reduce the water cement ratio of normal cement mortar. Also, workability tests on mortar samples have shown that, GBS can be used up to 50% of sand.

Keywords: Cement, FA, GBS, mortar, natural sand, replacements.

1. INTRODUCTION

Cement manufacturing is highly energy and emissions intensive because of the extreme heat required to produce it. Producing a ton of cement requires 4.7 million BTU of energy, equivalent to about 400 pounds of coal, and generates nearly a ton of CO₂. Given its high emissions and critical importance to society, cement is an obvious place to look to reduce greenhouse gas emissions. Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The composition of sand is highly variable, depending on the local rock sources and conditions. The construction industry demands only specific type of sand, for making mortar and concrete. This has led to a huge demand and degradation of natural sources. Therefore, finding of alternative ways to meet the growing demand is of high priority in modern times. In order to achieve reduced environmental pollution and impact use of by-products to replace cement by Fly Ash (FA) and sand by Granulated Blast furnace Slag (GBS) has been proposed in this research. Radwan et al (2012) in their research paper had worked on substitution of Portland cement (C) pastes by GGBS. Priyanka et al (2013) experimental program studied the effect of replacement of natural sand by manufactured

sand on the properties of cement mortar. Swaroop et al (2013) studied on the durability properties of concrete with the replacement of cement by Fly Ash and GGBS. Essam et al (2013) carried out a research work on Effect of calcium chloride on the hydration characteristics of ground clay bricks cement pastes. Marthong et al. (2012) conducted a research on effect on use of fly ash as an additive on concrete properties. Isa et al. (2006) in their research paper had studied the effect of replacement of sand by GBS and coal bottom ash in concrete strength and durability. These earlier researches have shown that of GBS and FA, in mortar and concrete can be used as a substitute material for sand and cement respectively. Based on the review, research has been carried out on evaluating normal consistency, initial and final setting time, and with effect on flow characteristics on substituting FA and GBS in place of cement and natural sand respectively.

2. RESEARCH SIGNIFICANCE

The objectives of the research are to study effect of FA on cement and GBS on sand. They are used in preparation of mortar with replacement materials. FA was substituted as 25% and 50% in place of cement with GBS substituted as

25%, 50%, 75% and 100% in place of sand. The cementitious material to sand ratio considered was 1:3 and the water cement ratio which gave a flow value of 110-115 using a flow table are being used to cast 50mm cube specimens and cured under varying conditions for 28 days and tested for durability and compressive strength. For FA and GBS to be used as substitute materials, they have to satisfy certain desirable properties. The researches on cement mortar with both these materials used simultaneously are less; thus highlighting the necessity for experimentation.

3. MATERIALS

GBS was collected from KALYAN steel Industry (4.75 mm to 75 micron) which is located in Karnataka. FA (Class F) was collected from Raichur Thermal Power Plant which is located in Raichur District in Karnataka. The calcium chloride used in this work was collected from locally available chemical laboratory. The type of calcium chloride used is in the form of pellets. In the present project the calcium chloride with more than 97% purity was used i.e., percentage of CaCl_2 is more than 97%. The Superplasticizer used in this research was collected from locally available concrete admixture store. The type of Superplasticizer used is chloride free, SNF polymer based. It was supplied as a brown solution which instantly disperses in water. It conformed to IS 9103:1999 specifications. OPC 53 Grade was used to prepare the mixes for the evaluation of all properties. There were no lumps formed when unpacked and was stored in air tight containers. It conformed to IS 12269:2013 specifications. The sand was collected from a nearby construction site (4.75 mm to 75 micron). It was oven dried for 24 hours to remove moisture before evaluation of properties and preparation of mixes. It conformed to IS 650-1991 specifications. Potable water was used in all mixes. Salts and other organic impurities were absent. The results of Sieve analysis and material properties of GBS and Sand are given in Table 1, Table 2 and Figure 1.

Table 1: Sieve analysis

IS sieve designation	Cumulative %		IS	IS
	wt. passing		383:1970	383:1970
	SAND	GBS	ZONE 1	ZONE 2
4.75 mm	98.4	99.076	90-100	90-100
2.36 mm	92.6	96.016	60-95	75-100
1.18 mm	73	82.186	30-70	55-90
600μ	39.4	31.510	15-34	35-59
300μ	20.4	10.406	5 to 20	8 to 30
150μ	0.8	1.488	0-10	0-10

Table 2: Material Properties

Sr. no.	Property	SAND	GBS
1.	Specific gravity	2.62	2.25
2.	Moisture	4%	1%

	absorption		
3.	Fineness Modulus	2.754	2.79
4.	Indian standard zone	Zone 2	Fluctuates between Zone 1 and Zone 2
5.	Fines	8%	1.49%

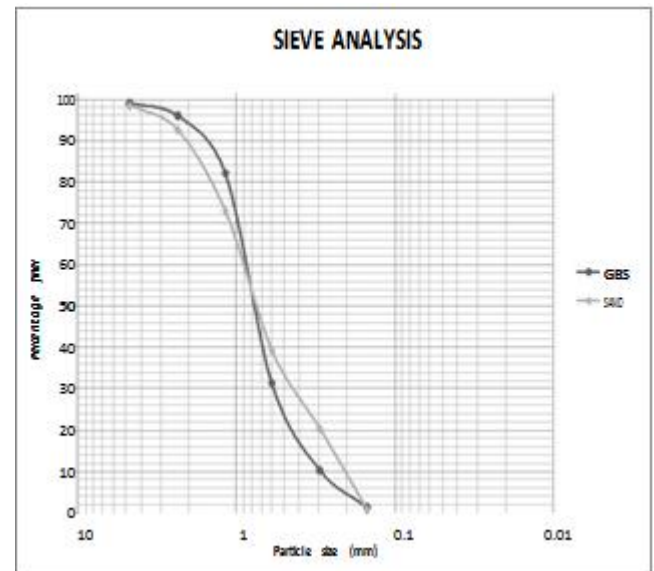


Fig 1: Sieve Analysis of GBS vs sand

4. EXPERIMENTAL PROGRAM

FA was added in percentages of 0, 25 and 50 in place of cement and tested for normal consistency, initial and final setting time to check the suitability of usage in study of workability, durability and compressive strength. **Calcium chloride was added 2%** by mass of cementitious material. After evaluation of the above properties, the experiment work involves finding of water cement ratio, casting, curing and testing of specimens. **Mortar specimens with proportion of 1:3** were evaluated to note down the water cement ratio for a **flow value of 110 to 115** without appreciable segregation and bleeding. GBS was added in percentages of 0,25,50,75 and 100 in place of sand to observe the changes in water cement ratio. The mortar ingredients were dry mixed first. Water and Superplasticizer were added and hand mixed, followed by mechanical mixing to get a good homogeneous mix. The sample was filled in two layers with 20 blows each layer in a mould placed on flow table. The mould was lifted and the sample was given 25 drops in 15 seconds. A **Superplasticizer dosage of 2%** by mass of cementitious material was added to all mortar samples.

5. RESULTS AND DISCUSSIONS

5.1 Sieve Analysis, Specific Gravity and Moisture

Absorption of GBS and Sand

With reference to Table 1, Table 2 and Figure 1 the particle size Distribution is one of the significant parameter to classify and to inspect the strength variations. The use of

GBS and sand in mortar needs a superplasticizer to achieve higher workability and compressive strength with reduced water- cement ratio. GBS unlike sand has glassy granular structure compared to spherical particles in sand. This leads to bleeding and segregation when the replacement levels with sand is appreciable. On the contrary, the structure of GBS improves compressive strength as the particles interlock with the cement matrix unlike the spherical particles present in sand. Thus a balance needs to be established between good workability and achieving higher compressive strength. The water absorption of GBS is lower than sand and hence it can be used as a substitute material for sand. The specific gravity of GBS being lower adds to more coverage of surface area in plastering etc., for the same amount of material compared to sand. Also the use of GGBS will improve the workability due to introduction of finer cohesive material.

5.2 Studies on Scanning Electron Microscopy Images on Cement and FA

Figure 2 and Figure 3 shows the SEM images obtained at 50µm on cement and FA samples respectively. As it is evident from the images, the particles in Cement are not spherical with predominant anomalous shapes. The reason behind this is milling of cement during its manufacture. FA comprises of several hollow to dense spheres, termed as cenospheres which have varying texture.

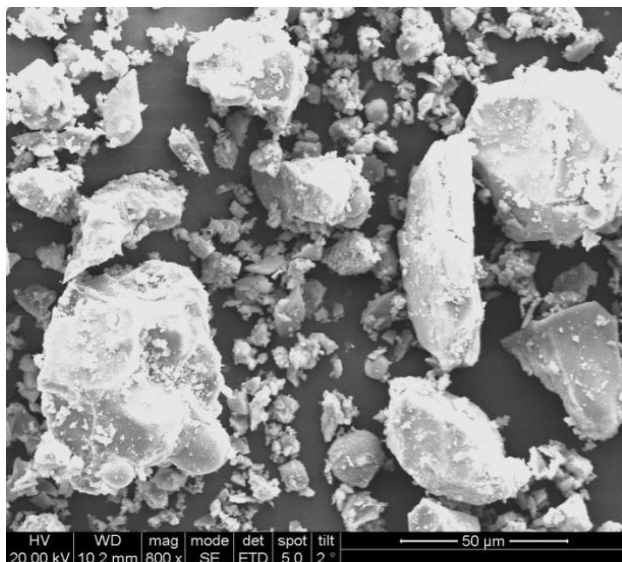


Fig 2: SEM image of cement

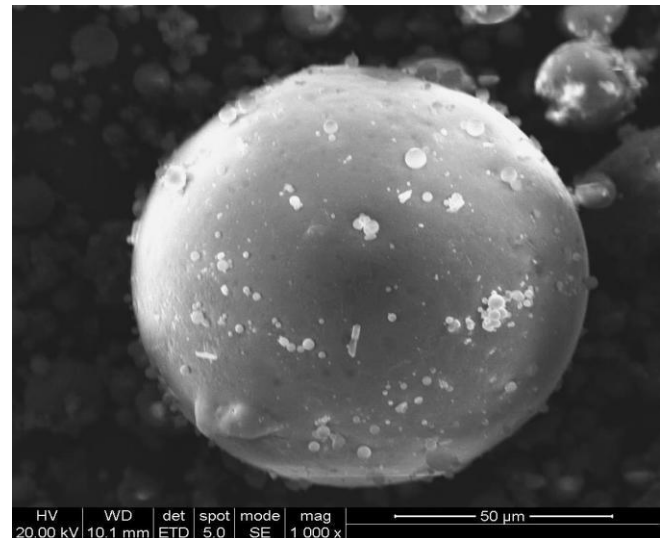


Fig 3: SEM image of FA

5.3 Normal Consistency(NC), Initial and Final Setting Time

From the Table 3 and Figure 4 it is evident that the normal consistency value increases with higher percentages of replacement of Cement by FA. This can be accounted on the basis of fineness of material. Since FA is a finer material than cement, it requires more water to form a stiff and consistent paste compared to cement. From Table 4, Table 5, Figure 5 and Figure 6, it can be observed that initial setting and final setting time also increase with increase in FA content which is preferred as it allows hauling of cementitious mix for longer distances and time without getting set. The delay in final setting time of a 50% replaced cement paste is quite appreciable. The increase in set times is due to the presence of more silica content w.r.t calcium content in FA. The effect of CaCl_2 on setting time was studied. CaCl_2 was added 2% by mass of cementitious material. It appreciably affected both the initial and final setting time of cementitious paste. It reduced the initial and final setting time. This has applications where lower setting times are required for suitable constructional activities. Despite the use of CaCl_2 , longer set times are to be expected for cementitious pastes containing FA by mass. Values in () indicate the percentage increase in setting time in comparison with cement. The values in [] indicate the percentage decrease when CaCl_2 was added to the pastes in comparison with primary pastes. 100C implies 100% Cement.

Table 3: Normal Consistency

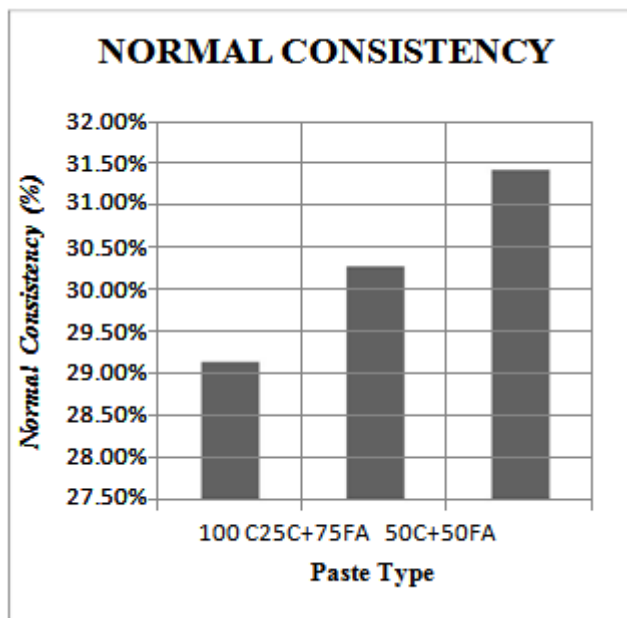
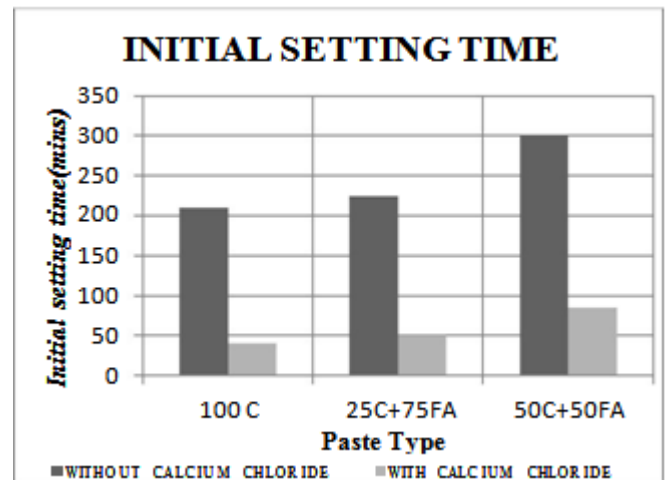
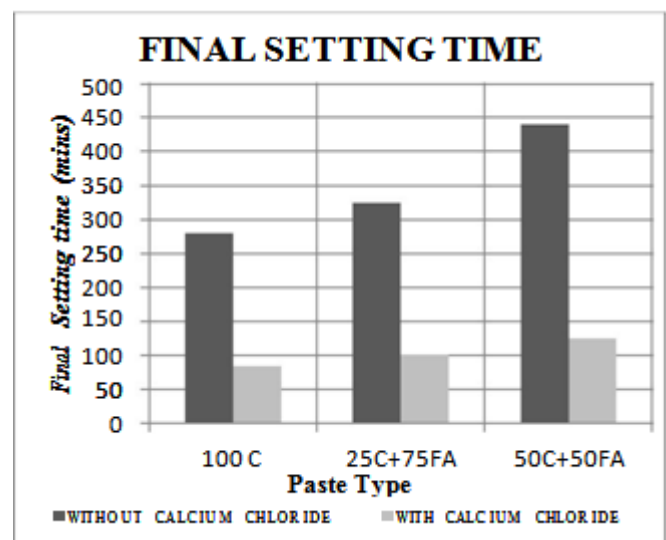
Sr.no.	PASTE TYPE	VALUE IN %
1	100 C	29.14%
2	25C+75FA	30.28%
3	50C+50FA	31.43%

Table 4: Setting Time without CaCl_2

Sr. no.	PASTE TYPE	INITIAL SETTING TIME (MINS)	FINAL SETTING TIME(MINS)
1	100 C	210	280
2	25C+75FA	225(7.14)	325(16.07)
3	50C+50FA	300(42.86)	440(57.14)

Table 5: Setting Time with CaCl_2

Sr. no.	PASTE TYPE	INITIAL SETTING TIME (MINS)	FINAL SETTING TIME(MINS)
1	100 C	40[80.95]	85[69.94]
2	25C+75FA	50(25)[77.78]	101(18.82)[68.92]
3	50C+50FA	85(112.5)[71.67]	125(47.06)[71.59]

**Fig 4:** Variation in normal consistency value on replacing Cement by GGBS**Fig 5:** Variation in Initial setting time on usage of Calcium Chloride**Fig 6:** Variation in Final setting time on usage of Calcium Chloride

5.4 Specific Gravity of Cement and FA

The specific gravity of cement and FA was found to be 3.07 and 2.8 respectively. This indicates that lower quantity of FA material can be used for same constructional applications compared to that of cement. Thus there is a saving of material and also economy in large scale applications. It was also found that in finding the normal consistency, initial setting time and final setting time, the amount of material required to fill the Vicat mould reduced with higher replacements of cement with FA ranging from 20% to 50% with replacement levels from 25% to 100% respectively. As per IS code the amount of cement to be used is 400gms for finding normal consistency, initial and final setting time for a cement paste.

5.5 Study on Flow Value

The use of water alone leads to very high water cement ratio (>.9) along with segregation and bleeding. As evident from the sieve analysis, the use of GBS beyond 50% as a

substitute material for Sand was not possible as it caused bleeding despite the use of Superplasticizer and cement replacements by FA. The use of mechanical mixer reduced the bleeding and segregation compared to manual mixing as binding of materials had to be achieved at lower water cement ratios with Superplasticizer dosage of 2%. FA when substituted upto 25% initially increased the water cement ratio. This can be accounted on the fact that, the overall fineness of cementitious material had not increased appreciably upto 25% replacement levels. But it was observed that, the mortar sample achieved the flow value with no visible segregation or bleeding. At 50% replacements of cement by FA reflected same water cement ratios as that of only cement mortar samples. Thus, it is evident that despite, the increase in overall fineness of cementitious material, the water cement ratio did not reduce. Table 6 and Figure 7 show the results obtained. 100C and 100S imply 100% Cement and 100% Sand respectively.

Table 6: Flow Table Test Results

Sr.no.	MORTAR TYPE	W/C RATIO
		OBTAINED
1.	100C+100S	0.55
2.	100C+75S+25GBS	0.675
3.	100C+50S+50GBS	0.80
4.	75C+25FA+100S	0.575
5.	75C+25FA+75S+25GBS	0.70
6.	75C+25FA+50S+50GBS	0.90
7.	50C+50FA+100S	0.55
8.	50C+50FA+75S+25GBS	0.675
9.	50C+50FA+50S+50GBS	0.80

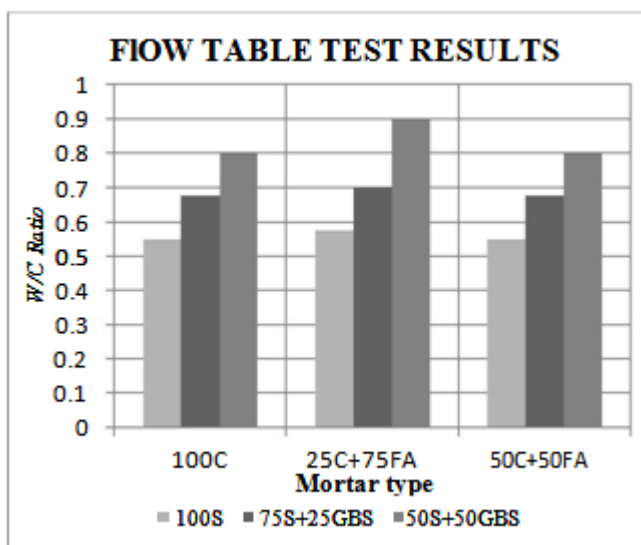


Fig 7: Variation in W/C Ratio on partial replacement of cement with FA and sand by GBS

6. CONCLUSION

1. The normal consistency increases with increasing replacement of cement by FA along with increase in initial and final setting time.
2. As FA contains relatively more silica, it will cause an increase in setting times but corresponding strength loss is to be expected because of lower calcium content.
3. Use of CaCl_2 effectively reduces the set time of all pastes.
4. The replacement of sand by GBS increases water cement ratio of all mortar samples and with consequent effect on compressive strength.
5. The lower specific gravity of FA and GBS compared to cement and sand respectively will enhance to cover more area compared to same weight conventional cement sand mortar.
6. From the workability point of view GBS can be used upto 50% of sand.
7. The use of mechanical mixer has to be implemented to ensure proper uniformity and homogeneity of materials in the mortar samples.

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