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Effect of elevated temperature on compressive strength of mortar with alkali activated slag

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Abstract: Steel industries facing a threat on disposal of its waste (GGBFS) leading to environmental problem. This study investigates effect of elevated temperature on compressive strength of alkali activated ground granulated blast furnace slag (GGBFS) mortar cubes. Cube specimens of size 70.7 mm x 70.7 mm x 70.7 mm were cast with three different percentages of GGBFS namely 10, 20, 30 and 40% as a partial substitute to cement. Mortar cubes were prepared with cement to sand proportion of 1:2.75 with a w/b ratio of 0.5. Three sets of specimens were tested for compressive strength. First set was prepared with cement with slag and cured in normal water. Second set was prepared with cement-slag mixture and cured in saturated lime water. Third set was prepared with cement-slag mortar with 0.4 N NaOH solution used alkaline activator. Third set of specimens were subjected to an elevated temperature of 500º C for the duration of 5 hours. After thermal curing, they were subjected to normal curing for a period of 3, 7 and 28 days. Comparison of results compressive strength of slag based cement mortar was done with specimens cured in normal water and saturated lime water. From the results it was understood that specimens cured in alkali activated solution have yielded better strength than the other two combinations.
Key words: Elevated temperature, GGBFS, compressive strength, alkali activation, replacement.

Introduction

It was assessed from literature that around 5-8% of green house gases are produced only from construction industry in the total vale. An alarming issue is that this percentage will be geared up in the near future due to the production more and more concrete from Ordinary Portland cement (OPC). All of us are very much aware that OPC is one of the predominant culprit in producing such carbon di oxide emissions. Though cement industries took number of steps to minimize this, the result was not encouraging [1]. Seeking an alternate material to cement in terms of supplementary cementitious materials is one of the viable option in our hand. Supplementary cementitious materials might be of GGBFS or Fly ash [2,3,4]. In the present scenario, use of alkali activated slag has become the more viable alternative resulting in reduction of CO2 emissions and achievement of high strength even at the early age of specimen [5]. If alkali activated slag is used in construction, it was estimated that only 20% of greenhouse gas will be produced compared to concrete with OPC [6]. Use of alkali activated slag yielding number of benefits such as strength development at early age and higher sensitivity on curing conditions [7]. Higher concentration of hydroxyl ions in the mix greatly affects alkaline activation of ground granulated blast furnace slag [8,9,10]. It was ascertained that, effect of elevated temperature, curing conditions, alkali and silicate content had significant effect on development of compressive strength of slag based mortar [11-16].

Experimental Investigations

Materials

The cement used was Ordinary Portland cement of grade 43 having a specific gravity of 3.16. The chemical composition of the cement is presented in Table 1.The Slag was obtained from steel industries in Salem, Tamil Nadu, INDIA and its specific gravity was 2.4. The chemical composition of Slag is given in Table 1. Raw Slag could be used as replacement for cement from 5% to 70 % depending upon the requirement. The average size of slag used in the present work was 45 microns. River sand was used as fine aggregate. The specific gravity of the fine aggregate was 2.63. In the present work a cement mortar was prepared with a 1:2.75 (Cement and Sand: Fine aggregate). Water cement ratio was taken as 0.50.

Specimen details

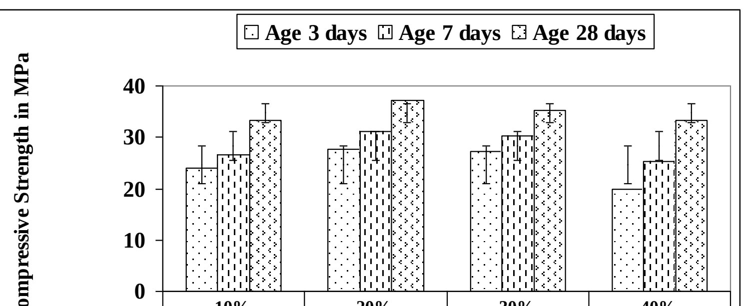
Specimens of mortar cubes of size 70.7 mm x 70.7 mm x 70.7 mm were prepared to study the compressive **s**trength. The specimens were prepared by partially replacing cement in the mortar mix in 10, 20, 30 and 40% of slag. Specimens were cast for testing at different ages such as 3, 7 and 28 days.

Table 1 Chemical composition of Cement and GGBFS

Formula	Concentration (%)		Formula	Concentration (%)	
	Cement	GGBFS		Cement	GGBFS
CaO	68.05	34.85	K_2O	-	0.46
SiO_2	25.91	34.01	MnO	-	0.27
Al_2O_3	5.85	16.62	BaO	-	0.10
MgO	0.07	9.11	P_2O_5	-	0.04
Fe_2O_3	0.12	1.71	SrO	-	0.04
SO_3	-	1.55	Cl	-	0.03
TiO_2	-	0.69	ZrO_2	-	0.03
Na_2O	-	0.48	As_2O_3	-	37 ppm

Results and Discussion

Compressive Strength of mortar specimens subjected to elevated temperature



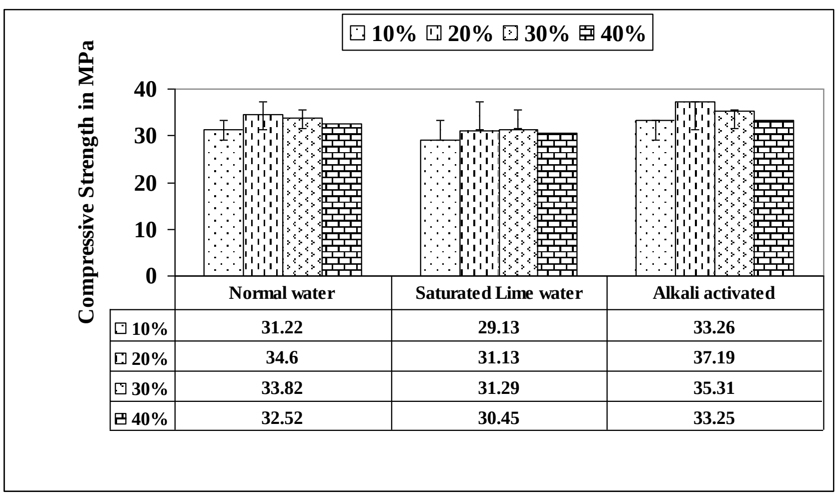
	10%	20%	30%	40%
Age 3 days	24.00	27.70	27.14	19.81
Age 7 days	26.51	31.04	30.20	25.28
Age 28 days	33.26	37.19	35.31	33.25

Figure 1 Effect of age on compressive strength of alkali activated slag mixed mortar

The variation of compressive strength of mortar specimens cured in alkali activated solution for different age with varied percentage of slag as substitute to cement is depicted in Figure 1. From the results it was inferred that alkali activation yielded better strength at the early age. In all the cases of slag substitution around 65 to 75% of 28 days strength was achieved at the age of 3 days. This process of gaining strength at the early age made possible due to acceleration of strength due to thermal curing with 500º C temperature in muffle furnace for a period of 5 hours followed by curing of specimens in alkali activated solution for a designated period. Due to the above two processes, specimens gained dual benefits in attaining strength. Use of GGBFS as substitute till 20% in mortar increased the strength and further replacement of cement with GGBFS (30 and 40%) shown a reverse trend. This is applicable for all the ages of mortar cubes. At the age of 7 days a strength of 80 to 93% of 28 days strength. Maximum strength gain at the age 7 days was achieved in mortar with 30% slag. Similarly maximum strength was observed as 37.19 MPa for mortar cube with 20% GGBFS specimens. Hence in the case of alkali activated slag, mortar with 20% GGBFS was found to be an optimum percentage among four different percentages used.

Compressive Strength of mortar subjected to different curing conditions

Figure 2 depicts the results on variation of compressive strength of slag admixed cement mortar specimens subjected three different curing medium namely normal water, saturated lime water and alkali activated slag. Specimens cured in normal water exhibited a compressive strength of 31.22, 34.6, 33.82 and 32.52 MPa for 10, 20, 30 and 40% of GGBFS based mortar respectively at the age of 28 days. Rate of gain in strength from 10% GGBFS mortar to 20% GGBFS mortar was about 11%. Further increase of GGBFS to 30% shows a reverse trend and the same trend continues for 40% addition of GGBFS also. Similar trend was observed for the specimens cured in saturated lime water and alkali activated solution also. Compressive strength of specimens cured in lime water have more than 80% of compressive strength of control concrete and hence ensured the pozzolanic activity of slag. The compressive strength of alkali activated slag mixed mortar yielded higher strength than that of specimens cured in normal curing and hence the results proved that alkali activation improves the compressive strength.



	Normal water	Saturated Lime water	Alkali activated
10%	31.22	29.13	33.26
20%	34.6	31.13	37.19
30%	33.82	31.29	35.31
40%	32.52	30.45	33.25

Figure 2 Effect of curing conditions on compressive strength of slag mixed mortar

Conclusions

Experimental investigations were carried out on compressive strength of GGBFS mixed mortar under normal conditions and alkali activated slag subjected to elevated temperature. From the experiments conducted, following conclusions were arrived:

- Cement might be replaced with GGBFS in mortar to an extent of 20% beyond which strength gets reduced to some extent irrespective of curing conditions.
- Slag based mortar subjected to ASTM lime test fulfills the standard prescribed and ensured the pozzolanic activity.

- Among the specimens cured in normal water, saturated lime water and alkali activated slag subjected to elevated temperature cured in normal water, alkali activated slag gave highest compressive strength.
- From the results it was inferred that, mortar with 20% cement replacement with slag found to be an optimum percentage in terms of compressive strength.

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