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EFFECT OF FINENESS ON STRENGTH OF ALKALI-ACTIVATED BLAST FURNACE SLAG PASTES

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Abstract: In recent years, the usages of by-products and wastes in industry have become very important. The importance of the sustainable development is also increasing. In this study the effect of fineness of ground granulated blast furnace slag (GGBS) on compressive strength and water absorption of alkali - activated blast furnace slag (AAS) paste has been investigated. The paste was produced by activating sodium silicate and sodium hydroxide solution. Four types of finenesses of GGBS were used in the present study. The effect of fineness on compressive strength and water absorption were studied. It was found that the compressive strength of AAS depends on the fineness of GGBS. Increase in fineness increases the compressive strength. The maximum compressive strength achieved was 49 MPa for GGBS paste having fineness less than 45 µm.

Keywords: Alkali activation, compressive strength, fineness, ground granulated blast furnace slag, water absorption.

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INTRODUCTION

The Alkali activated ground granulated blast furnace (AAS) slag is one of the recently developed green construction materials. Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces while manufacturing iron. The cooling process of slag is responsible for generating different types of slag required for various end users. It may be noted here that though Portland cement is the most widely used binder in the world but involves energy consumption and pollution generation [1] during its manufacturing. The cement industry contributes 5 - 7 % of the global carbon dioxide emission into the atmosphere every year and is the second fastest growing source of CO_2 emissions. Therefore, major reductions in CO_2 emissions are necessary [2]. These reductions will be achieved not only as a result of modifications to existing cement production methods, but through the development of alternative cement binders such as AAS. These binders showed comparable or better properties and costs compared to the existing ordinary Portland cement. By comparison with ordinary Portland cement (OPC), manufacture of AAS binder requires less than a fifth of energy and can reduce around 80 % of CO_2 emission caused by the cement industries. Each year, India produced up to eleven million tons of GGBS which can be significantly utilized in manufacturing of construction material which is environment- friendly and will greatly reduce primary energy, saves bulk of quarrying as well as potential landfill. Blast furnace slag consists primarily of silicates, alumina-silicates and calciumalumina-silicates and can be good source material for making high performance alkali-activated materials which can be utilized in various Civil engineering applications [3,4,5,6,7]

The major factor of blast furnace slag quality is its fineness. It is reported that increase in fineness increases reactivity and the strength of cementitious materials. It was found that, up to seven days, the strength of NaOH activated slag cement pastes linearly increased with the Blaine fineness of the slag up to 650 m^2/kg[8]. It is reported that the compressive strength of cement increases with fineness and cement with narrow size distribution have higher strength than those with a wider one. [9,10,11]

The object of the present research is carryout the systematic study on the effect of fineness of GGBS on the compressive strength and water absorption of AAS paste.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1. Blast furnace Slag Ground granulated blast furnace slag used in this investigation obtained from the Tata Metaliks Ltd., Kharagpur, India. Its chemical composition in terms of the main oxides was (in weight %) SiO_2 (32.50), CaO (33.50), Al_2O_3 (18.50), MgO (8.0), Fe_2O_3 (0.40), S (0.5) and MnO (0.55). Its density was 2900 kg/m^3.

The moisture content was less than 1 %. GGBS was prepared by grinding and sieving. Four types of fineness used are

< 45 µm, < 60 µm, < 75 µm and < 90 µm.

2.1.2. The alkaline activator The alkaline activator liquid was the combination of sodium silicate solution and sodium hydroxide pellets. Laboratory grade sodium hydroxide in pellet form (97 % purity with Na_2O = 77.5 % and 22.50 % water) was supplied by Merck

India Ltd. and sodium silicate solution (Na_2O = 8 %, SiO_2 = 26.50% and 65.50 % water) with silicate modulus ~ 3.3 and a bulk density of 1410 kg/m^3 was supplied by Loba Chemie Ltd. India, were used to adjust the desired composition of alkali activated blast furnace slag paste.

2.2 Preparation of AAS paste The AAS paste was prepared according to the composition shown in Table 1. For making AAS paste, the blast furnace slag and activating solution in desired proportion were first mixed together for five minutes in a Hobart Mixer to get homogeneous paste. The fresh mix was then transferred into 50 mm ×50 mm ×50 mm steel moulds and vibrated for two minutes on vibrating table to remove any entrapped air. The specimens were left at room temperature for 24 hours, then demoulded and kept in water in fully immersed condition at room temperature until testing was done.

2.3 Tests Conducted

2.3.1 *Direct compressive strength*

The alkali activated GGBFS paste specimens (50mm x 50mm x 50mm) were tested for compressive strength using 20 ton capacity digital compressive testing machine with a loading rate of 20 MPa/min. The compressive strength tests were conducted at the age of 3, 7 and 28 days. Six specimens of each series at each age were crushed in a digital compression testing machine in accordance with ASTM C-109-02 [12] and the average strength of six specimens is reported as the compressive strength.

2.3.2 **Water absorption**

Water absorption of specimens was determined as per ASTM C-642 [13]. To determine the water absorption, cube specimens were oven dried at a temperature of 85^0 C for 24 hours and its weight was determined (initial weight). The specimens were then immersed in water for 24 hours and its saturated surface dry weight was recorded (final weight). Water absorption is reported as the percentage increase in weight.

Table 1: Details of Mix composition of AAS paste

Fineness	Mix ID	Composition of AAS mix			
		% Na_2O #	% SiO_2 #	SiO_2 / Na_2O	Water / Slag
< 45 µm	AAS1	8	8	1	0.31
< 60 µm	AAS2	8	8	1	0.31
< 75 µm	AAS3	8	8	1	0.31
< 90 µm	AAS4	8	8	1	0.31

% of mass added with respect to the total mass of slag.

3. RESULTS AND DISCUSSION

3.1 Water absorption

The water absorption of 8.8% ,10.7 %, 12.5 % and 15.5 % [Fig. 1] was observed in specimens with the fineness of <45µ, < 60 µm, < 75 µm and < 90µ respectively, indicating, increase in fineness reduces voids in the specimens, which in turns make the specimen more dense and compact.

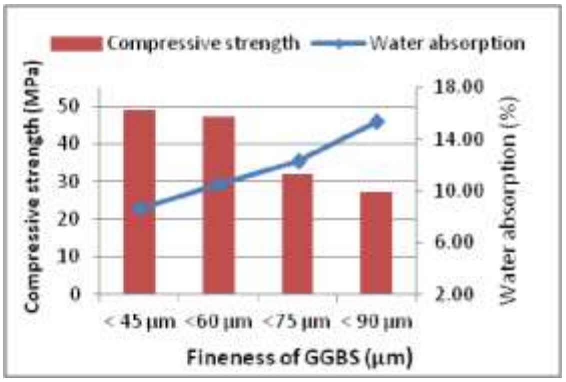

Figure 1. Effect of fineness of GGBS on compressive strength and water absorption.

3.2 Compressive strength The compressive strength of AAS paste was determined at the age of 3, 7 and 28 days. Figure 2 show the development of compressive strength of the AAS paste for the specimen having different finenesses. From Fig. 2, it was observed that the compressive strength of the specimen increases with increase in fineness of GGBS on all test ages. The well-known physical filler effect of fine pozzolans, packing the space between large particles and thus increasing density, may be partially responsible for the high strength of the finer pozzolans GGBS [10]. The finer the GGBS was ground, the higher the strength of the paste that could be achieved. The compressive strength of 49 MPa, 47.2 MPa, 32 MPa and 27.1 MPa was observed for GGBS fineness of < 45 µm, < 60 µm, < 75 µm and < 90 µm respectively. This follows from the fact that finely ground fractions were more reactive compared to the coarser fractions which in turns resulted in higher compressive strength for finer fractions of GGBS paste. The development of the compressive strength of AAS paste increases with age as shown in Fig. 2. The strength increment is more effective at early ages, rather than later ages to increase in fineness of GGBS. It can also be concluded that finer fractions play a very important role in strength development.

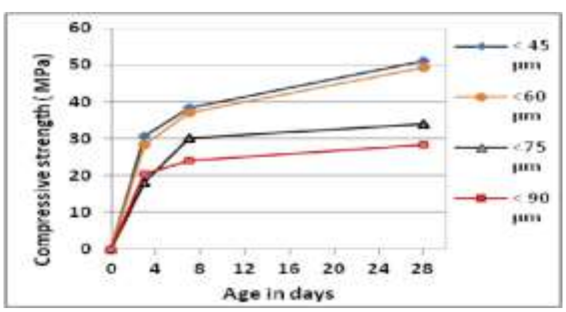

Figure 2. Compressive Strength development of AAS paste having different fineness's of GGBS.

4. CONCLUSIONS:

On the basis of experimental investigations, the following conclusions were drawn.

The compressive strength of AAS depends on the fineness of GGBS.

Increase in fineness increases the compressive strength. The maximum and minimum compressive strength of 49 MPa and 27.1 MPa at 28 days was obtained for GGBS having fineness <45 µm and < 90 µm respectively.

The strength increment is more effective at early ages, rather than later ages with increase in fineness of GGBS. (Fig. 2). Compressive strength up to 30.1 MPa was obtained at 3 days of moist curing for fineness less than 45 µm.

A dense and compact matrix of AAS paste was observed in specimens having a higher fineness of GGBS.

The alkali activated paste having a higher fineness had a lower water absorption (Fig. 1).

The compressive strength and porosity can be improved significantly by judiciously controlling the fineness of GGBS used in alkali activation of blast furnace slag.

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