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Effect of Partial Replacement of Ordinary Portland Cement With Ggbfs On Compressive Strength Performance.

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Abstract: *This study investigated the compressive strength performance of partially replaced Ordinary Portland cement with ground granulated blast furnace slag (GGBFS). The replacement was done at 5%, 10%, and 15 % GGBFS. A blank OPC was used as a control. Mortar prisms were prepared and cured with accordance to KS EAS 18:1-2001. The resultant compressive strength was determined at 2nd, 7th, 14th and 28th daysof curing.Chemical composition of GGBFS and the setting times of the resultant cement was also determined. Results obtained showed that the compressive strength increased significantly at 10% and 15% GGBFS replacement at 28 days of curing. GGBFS can thus be used as a suitable additive in partial replacement of OPC.*

Key Words: *GGBFS, OPC, Mortar Prism, Compressive Strength.*

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I. Introduction

Portland cement is the most common type of cement in general use around the world as a basic ingredient of concrete, mortar, stucco and non-specialty grout. OPC is normally used for the reinforced concrete structures, roads, bridges, and in conditions where the concrete is not subject to special sulfate hazard or where the heat generated by the hydration of cement is not objectionable. According to Kenyan Standard, the composition of Portland cement consists of 95% Portland clinker with a maximum insoluble residue of 5% [1].

The production of OPC is decreasing all over the world in view of the popularity of the blended cements on account of lower energy consumption, environmental pollution, economic and technical reasons such as susceptibility to aggressive ion attack. In Kenya, there is a vast availability of Pozzolans which have been used extensively for manufacture of pozzolanic cements. However, this material cannot be used exhaustively as a substitute in OPC because of the insoluble residue requirement as per the KS EAS [1].

Studies have shown that concrete made with pure OPC exhibited substantial damage within a few years of construction in the aggressive environment. Ground granulated blast furnace slag, a by -product of steel industry when in contact with water possesses hydraulic properties. The granulated slag when finely ground and combined with OPC has been found to exhibit excellent cementitious properties. When mixed with Portland cement, GGBFS is activated by the alkalis and sulphates from the hydration of Portland cement resulting to a decrease in risks caused by alkali-silica reaction. This is because of the low Ca/Si ratio in the hydration products [9].Suresh, D. and Nagaraju, K. on their review document in 2015 on Ground Granulated Blast Slag in Concrete observed that concrete containing ground granulated blast furnace slag was less permeable and chemically more stable than normal concrete. These properties enhanced the concrete resistance made with GGBFS to many forms of deleterious attack and in particular disintegration due to sulphate attack, chloride related corrosion of reinforcement and cracking caused by alkali silica reaction [11]. Munyao et al, 2015 while studying the effect of sulphate ions in mixing water observed that OPC exhibited decreased compressive strength in mix waters with high sulphate ion content. The authors attributed this to a higher aluminate phase (C3A) which increases the uptake of SO_4^{2-} in OPC hence making it prone to sulphate attack [12].

The study investigated the effect of partial replacement of OPC with GGBFS on compressive strength performance. It is therefore expected that this work would help establish a clearer guidance on the acceptable replacement levels of GGBFS to OPC in Kenyan cement industries. This will result to an improved OPC in terms of durability and resistance to chemical attack and reduced CO_2 emissions.

II. Experimental Procedure

The chemical analysis of GGBFS test samples was conducted using XRF. The test cements were prepared in a laboratory ball mill at 0%, 5%, 10%, and 15% GGBFS replacement respectively. The resultant test cement was properly labelled and kept in a sealed polythene bags. Mortar preparation and curing was done in accordance with KS EAS 148-3: 2000 [3]. Test prisms of 40 mm x 40 mm x 160 mm size were prepared from a batch of a plastic mortar. Mortar was mixed mechanically using an automated mixer model JJ- 5. Compressive strength was determined at 2nd, 7th, 14th, and 28th day of curing as described in KS EAS 18-1:2001[1].The compressive strength was determined using compressive strength machine model YAW-300. The mortar prism to be tested was centered to the platens of the compressive machine within ± 0.5 mm and longitudinally such that the end face of the prism overhang the platens or the auxiliary plates by about 10 mm. The load was increased smoothly at the rate of 2400 ± 200 N/s over the entire load application until fracture. Compressive strength was calculated and expressed in Mpa [2].

The cement paste for determining setting time was prepared in accordance with KS EAS 148-3:2000 using cement paste mixer model NJ- 160. 125 g of water was weighed and poured in the mixer bowl to which 500 g of test cement was carefully added in about 5 to 10 seconds and the paste mixer switched on. The cement paste was mixed vigorously in a paste mixer and transferred immediately in a mould placed on a lightly greased plane base plate. The mortar paste was filled into the mould and the excess was removed by a gently sawing motion with a straight-edged steel ruler in such a way as to leave the paste filling the mould and having a smooth upper surface. The mould was placed in a humidity cabinet set at a temperature of 25 ± 1 °C. Initial and final setting times of each test cement was determined using vicat apparatus.

III. Results and Discussion

a) Chemical Analysis of GGBFS Test Sample

The chemical analysis of GGBF test sample is presented in table 1 below

Table 1: Test Results for GGBFS

Parameter	Unit of Measure	Result
LOI	%	**0.86**
Fe_2O_3		**0.34**
Al_2O_3		**13.87**
CaO		**42.03**
MgO		**7.73**
SiO_2		**35.10**

The chemical tests of the GGBFS test sample conformed to BS EN 15167-1:2006 standard [4].

b) Compressive Strength Test Results

Table 2: Compressive Strength Test Results

Clinker	GGBFS	Gypsum	Compressive Strength (Mpa)			
			2 Days	7 Days	14 Days	28 Days
95%	0%	5%	24.65	39.8	43.2	48.13
90%	5%	5%	24.5	39.7	43.6	48.15
85%	10%	5%	23.05	38.55	44.4	52.20
80%	15%	5%	23.05	37	45.1	54.3

The compressive strength performance of test cement at various GGBFS additions was conducted as described in KS EAS18:1-2001 as shown in table 2 above.

Fig. 1 below shows the compressive strength performance of test cements at different GGBFS addition at different curing ages whereas figure 2 shows the percentage loss/gain in compressive strength at different curing ages.

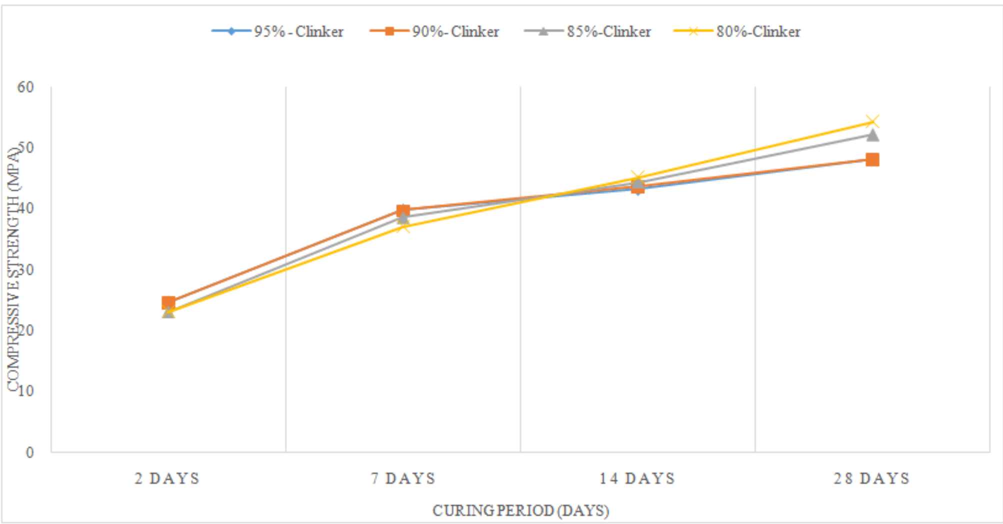

Fig.1:Compressive strength performance of test cements at different GGBFS addition

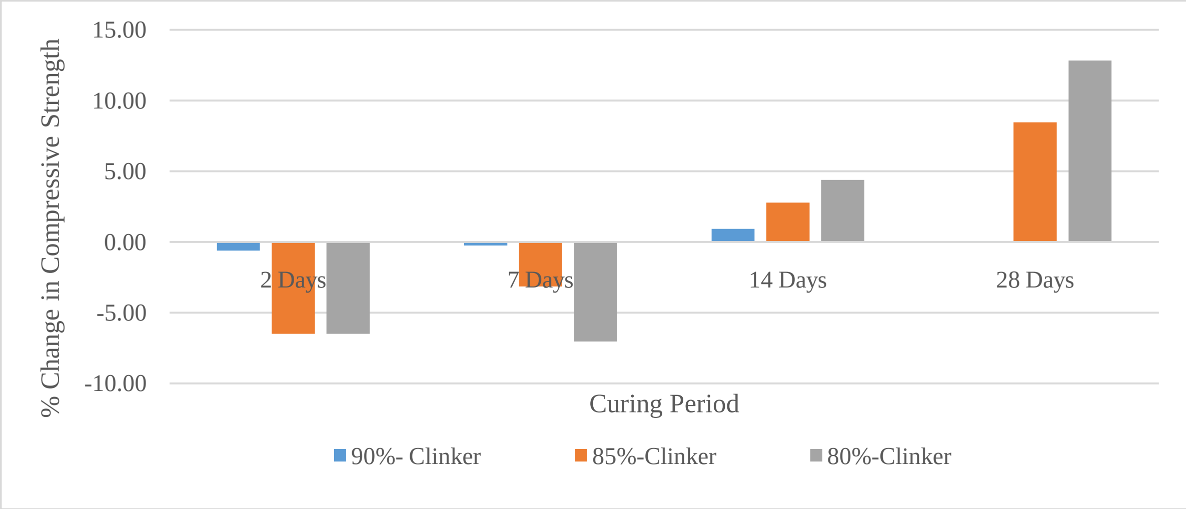

Fig.2: Percentage loss/gain in compressive strength at different curing ages

From the compressive strength test results in figure 1, the compressive strength increased with increase in curing period at all different GGBFS additions. This was as expected. The degree of hydration increases with increase in curing period and thus increasing the gel/ space ratio. Similar observations were made by Munyao et al, 2015 while studying the effect of sulphate ions in mixing water on cement mortar performance [12].

The results shows that there was a significant decrease in compressive strength at 2nd and7th day of curing at 10and 15 % addition of GGBFS respectively. This could be attributed to increased initial setting time and less heat of hydration. It was however noted that at 28 days of curing, the compressive strength at 10 and 15% GGBFS addition increased significantly. This could be attributed to prolonged hydration process that increases the late age strength. 5% GGBFS addition gave comparable results with the control (0% GGBFS addition).

Some workers have shown that concrete with GGBFS has improved resistance to sulphate attack. This is due lower concentration of calcium hydroxide and calcium aluminate hydrate in the pore solution. Jain and Pal (1998) reported that replacement of 50% OPC by GGBFS improved the sulphate resistance of concrete [8]. Similar observations were made by Wee at, al, 2000 [6]. The benefits of using GGBFS has been observed by many authors. Kumar et.al,(2002) presented the results of depth of chloride penetration in concrete after 6 months exposure in 3.5% sodium chloride solution. The authors observed that penetration decreased with increase in GGBFS content [5]. Similar observation were made by Brooks, J.J; and Al-Kaisi, A.F; in 1990 [7] and ACI, 233R-95 Committee Report, 1997, [10].

C) *Setting Time Test Results*

Figure 3 below shows the setting time performance at different GGBFS additions. The test results shows that at 10 and 15% GGBFS addition, there was an appreciable increase in both initial and final setting times as compared to 5% and the control sample. This could be attributed to lower heat of hydration that prolongs the setting time as percent GGBFS increases. Increase in setting time improves concrete workability and especially in warm weather conditions. Increased setting time can result to reduced w/c ratio while keeping the concrete slump constant. This will result to an increase in compressive strength.

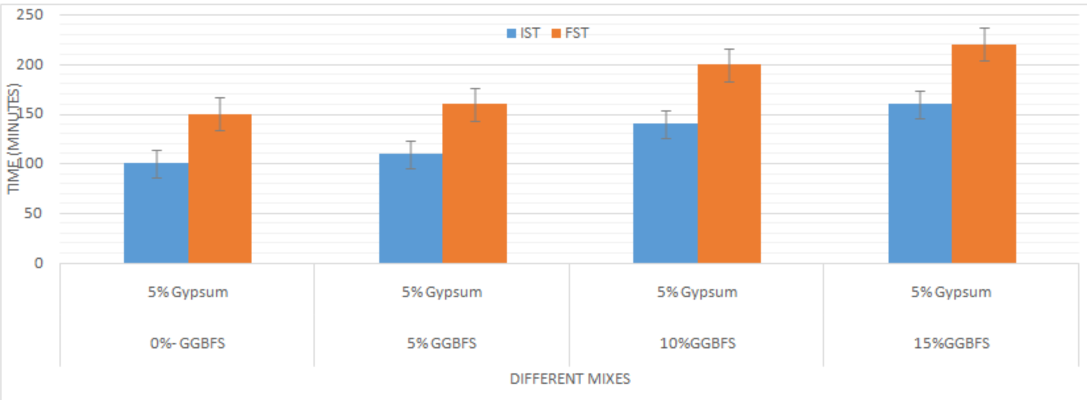

Fig. 3: Setting Time Performance

IV. Conclusion

The results of this work shows that GGBFS can be used as a suitable additive for the replacement of OPC due to its enhanced compressive strength. GGBFS also gives a greener approach in construction industry and sustainable development of concrete structures. It is therefore necessary for the Kenyan cement industries to incorporate GGBFS in their cement manufacturingprocesses.

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