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Alkali Activated Blast-Furnace Slag Cement: The Opportunity to Solve Sustainable Issues

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ABSTRACT

This paper aimed at investigating the possibility of alkali activated blast-furnace slag (BFS) to produce cement powder that could be alternative to ordinary Portland cement. It was found that an alkali activated BFS cement with 90% of BFS free clinker showed a trend similar to OPC sample, respectively. The concrete based on activated BFS are of lower environmental impact and have great potential for engineering applications.

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INTRODUCTION

Intensive research over the last decades paved the way for ordinary Portland cement to become the most used binder system for construction purposes worldwide. But because of the high emission of CO_2 during ordinary Portland cement manufacture alternative binders attract more and more attention for ways to reduce that figure, or at least to avoid its growth. One of the possibilities is the massive usage of industrial wastes like Blast furnace slag BFS, to turn them to useful environmentally friendly and technologically advantageous cementitious materials. Blast furnace slag (BFS) is a by product of pig iron production, a stage process in the production of steel; approximately 300 kg of slag are generated per ton of pig iron [1,2]. BFS is a low performance cementitious material, which can achieve high compressive strength when an alkaline activator is used. Alkali activation with sodium silicate (waterglass) of BFS produces high strength binder under highly alkaline conditions (pH = 12–14.5). This binder has great potential as an environmentally favorable alternative to Portland cement. It could produce a binder with the advantages of Portland cement but at a lower cost, with a large reduction in CO_2 emissions and will recycle an industrial waste material as a raw material [3, 4].

The purpose of this study was to produce“greener” cement from blast furnace slag (BFS) using alkali activation. By eventually developing “greener” cement, the ultimate goal of this research project would be to reduce the amount of Portland cement used in concrete, therefore reducing the amount of carbon dioxide emitted into the atmosphere during cement production. This study also presents an investigation of strength development of concretes with different percentage of BFS as a cementitious component.

Experimental:

Materials:

Ordinary Portland cement from Cement Industries Of Malaysia Berhad (CIMA), Malaysia was used in this work. Samples of blast furnace slag (BFS) were collected from Ann Joo Integrated Steel Sdn. Bhd, Penang, Malaysia and ground to −70µm using a ring mill to improve its reactivity. Metakaolin was prepared by calcining the above kaolin at 800 °C for 2 h. Metakoalin was used as Si-Al cimentitious materials. The chemical composition of both metakaolin and BFS is given in Table 1. Industrial grade sodium silicate and NaOH were used as alkaline activators with 1.5 M $(Na_2O)(SiO_2)_2$ solution (modulus 2).

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Table 1: Chemical composition of blast furnace slag and metakaolinite.

Compound (%)	CaO	SiO_2	Fe_2O_3	MgO	Al_2O_3
Blast furnace Slag	39.32	33.87	0.52	8.10	14.15
Metakaolin	0.02	50.06	0.89	0.09	44.17

Methodology:

A mechanical mixer firstly mixed 10% metakaolin, ground BFS and alkali activator. Following a further 5 min of mixing, the samples were set at 60 °C for 3 h in a sample-drying oven. The detail of mixture proportion is shown in Table 2. Compressive strength tests were carried out after 7, 28, and 90 days using the Instron machine series 5569 mechanical tester as refer to ASTM C109.

Table 2: Detail of mixture proportions.

Samples	OPC (%)	Metakaolin (%)	BFS (%)
C1 (reference)	100	-	-
C2	30	10	60
C3	20	10	70
C4	10	10	80
C5	-	10	90

RESULTS AND DISCUSSION

Figure 1 presents the results of compressive of concrete by varying alkali activated BFS cement contents. It can be seen that the compressive strengths of alkali activated BFS concrete for each sample progressively increase with increase of curing ages from 7 days to 90 days. The alkali activated BFS concrete by mixing amount of 60% BFS displays the highest compressive strengths at the different curing ages of 7 d, 28 d and 90 d, respectively. As a general pattern, it was noted that in the presence of alkali activated BFS, the strength is higher compared 100% OPC sample. However, it is interesting to note that sample with 90% of BFS free OPC showed a trend similar to OPC sample. It was observed that the strength were higher as the BFS consumption is decreased. It was in evidence that alkali activator solution and addition of metakoalin have great effect on the compressive strength [5, 6]. Metakaolin can impart high strength to concrete and can also substantially improve durability. It is a highly reactive aluminosilicate pozzolan that when hydrated in the presence of alkali, forms a strong slow-hardening cement.

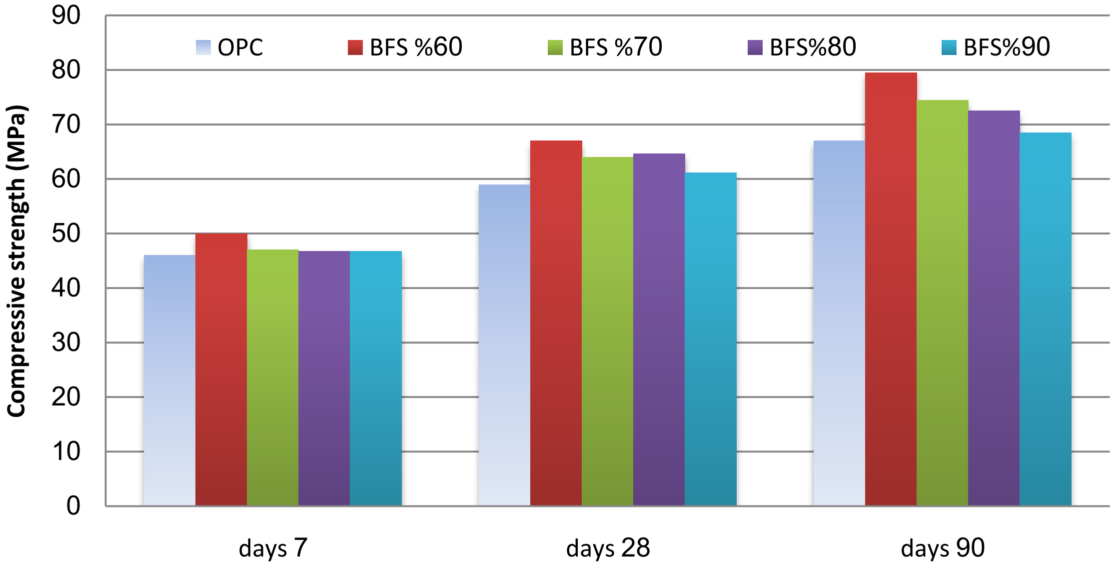

Fig. 1: Compressive strength of concrete by varying alkali activated BFS cement contents.

Conclusion:

A set of alkali-activated blast furnace slag cement with metakaolin was synthesized. It was found that a concrete with 90% of BFS free clinker showed a trend similar to OPC sample, respectively, produced the same strength, reducing the environmental impact and cost. The processing route suggested has the potential to produce cement powder. The concretes based on activated BFS are of lower environmental impact and have a great potential for engineering applications.

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