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LIME ACTIVATION OF FLY ASH IN MORTAR IN THE PRESENCE OF METAKAOLIN

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Abstract

The effect fly ash activated with lime in the presence of metakaolin on selected properties of mortars is investigated. This work is aimed at producing mortar without the use of cement as a binder in order to reduce the environmental impact of traditional mortar or concrete applications. Two mortar mixes were prepared to conduct this study. The first mix was the control mix with proportion 1 (cement): 3 (sand) and the water to cement ratio was 0.6. In the second mix, the binder consisted of 80% fly ash, 5% lime and 15% metakaolin (by weight). Specimens were cured for different time at 20°C and no elevated temperatures were used. The result shows that the mortar containing fly ash had its highest compressive strength of 0.46MPa and it is much lower than the control. Also the density of the predominantly fly ash mix had a lower density at all ages when compared with the control mix.

Keywords: Geoploymer, Fly ash, Activation, Lime, Metakaolin

1 INTRODUCTION

The demand for cement in the construction industry is continuously increasing due to the ongoing growth in the world's population and the need to provide infrastructure for the growing population. Cement which is the traditional binder in concrete production is responsible for about 8% of the world's man-made greenhouse gas emission. For every 1ton of cement produced, 1ton of CO_2 gas is emitted into the atmosphere and this has made cement production a treat to the environment. (Sarker et al 2013). In order to reduce the effect of cement on the environment, cement replaced materials have been used in concrete. These materials can be pozzolanic materials such as fly ash (Khatib and Mangat 2002; Khatib and Mangat 2003; Siddique and Khatib 2010), flue gas desulphurisation residues (Khatib et al 2008; Khatib et al 2013a; Khatib et al 2013b; Khatib 2014; Khatib et al 2014; Mangat et al 2006) slag (Khatib and Mangat 2002), fired brick clay (Wild et al 1996), wheat husk ash (Zhang and Khatib 2008), and silica fume, novel materials such as metakaolin (Khatib et al 1996; Khatib 2008; Khatib et al 2009) and other material such as limestone fines (Kenai et al 2014).

Davidovits (1999) was the first to use the term "geopolymer" to describe binder that could be obtained from reaction of alkaline materials containing silicon and aluminium. These materials are mainly by-products of industrial wastes such as fly ash and rice husk ash or from geological origin such as metakaolin (Davidovits, 1999). Modern definition of Geopolymers are inorganic polymers aluminosilicates formed by the synthesization of pozzolanic composites or aluminosilicate source materials, and these materials are less expensive and more sustainable as they result in low gas emission, and they are considered "green materials." (Ferone et al. 2013). These materials have been used in partially replacing cement in concrete production with the view of reducing the unit cost of concrete products and partially reducing the environmental effect (Morsy et al. 2012).

This paper will be concerned with using fly ash and metakaolin in the production of mortar and lime will be added as an activating agent. Fly ash is a fine grey colour, it is an alumino-silicate based material, and it is acquired as an industrial waste material from the combustion of coal. There are many types of fly ash; class F fly ash which is low in calcium oxide (less than 20% lime (CaO)), and the class C fly ash high in calcium oxide (more than 20% lime-i.e.CaO). Class F fly ash was used for this research work. Metakaolin is a pozzolanic material derived from the calcination of kaolinite at a temperature range of 650OC to 800OC; it is produced from kaolin clay, and it is been used in many applications (Morsy et al. 2012).

This paper reports limited results on compressive strength, density and ultrasonic pulse velocity (UPV) of mortar containing fly ash and metakaolin activated with lime. Testing was conducted at different ages of curing.

2 EXPERIMENTAL

Mortar cubes were produced using class F fly ash, metakaolin (Metastar501) and lime ($Ca(OH)_2$) as an activator. Two mortar mixes were produced; a control mix using cement as the only binder and the other mix containing fly ash, lime and metakaolin as binder. Both mortar mixes had water to binder ratio of 0.6 and sand to binder ratio of 3:1. In the first mix, the binder was cement whereas in the second mix the binder consisted of fly ash, metakaolin and lime. Further details about the mortar are presented in the Table 1.

Tab. 1: Mortar mix composition

	Binder by % (weight)	
	70%FA-15%MK-15%L	100%PC
W/B	0.6	0.6
Fly ash (FA)	80	0
Metakaolin (MK)	15	0
Lime (L)	5	0
Cement (PC)	0	100%

The mortar cubes were prepared by properly compacting the mortar mix in a steel cube of dimensions 50mmx50mmx50mm. The mortar cube was demoulded immediately and was stored in a sealed, airtight container at room temperature. A compressive test, ultrasonic pulse velocity test and a density test (using the total immersion method) was conducted for 1 day, 7 days and 28 days.

3 RESULTS AND DISCUSSION

The density of the two mortar mixes were recorded at different curing ages and a graph of density was plotted against curing day as seen in Figure1. From the graph, the density of mortar containing fly ash had a lower density when compared to the control mix at all ages. The density of the control mix ranges from about 2136 to about 2205 kg/m^3. However the density of the fly ash activated mix ranged from about 1753 to 1679 kg/m^3. The density fly ash mortar had its lowest density at the 90 days with 1679 kg/m^3. The density of the mortar with 70% of fly ash was lower than that of 60% of fly ash from a previous investigation. This reveals that the fly ash in mortar reduces the density of the mortar. This is partly due to the lower density of fly ash compared to cement. The low density of the fly ash mortar makes it suitable for the production of lightweight concretes. Also, the loss in weight could be attributed to the presence of metakaolin in the mortar mix (Barbhuiya et al. 2009).

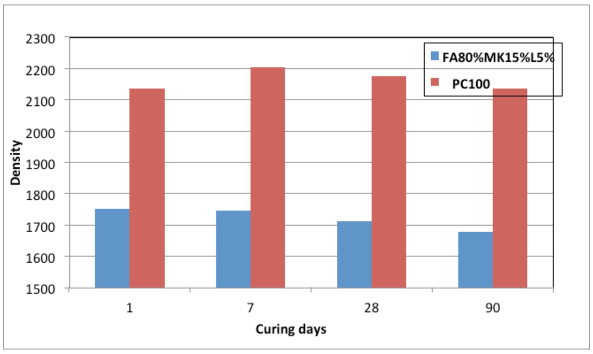

Fig. 1: Density profile of mortar mixes.

The strength of the fly ash activated mortar containing fly ash at different curing ages was much lower than the control mortar as can be observed in Figure 2. Figure 3 shows the strength development for the fly ash activated mortar only. The fly ash mortar had its highest strength at the 28 days of curing with strength of 0.46MPa. Figure 4 shows the relative strength of the two mortar mixes with respect to the 28 days strength. At one day of curing the relative strength of the fly ash mix is higher than that of the control mix. Figure 5 shows the relative strength profile for fly ash mix compared with the control. The relative strength seems to reduce with curing time unlike what was observed in previous investigation. From previous work involving the activation of fly ash based mortar using binder composition of 60% of fly ash, 15% of metakaolin and 25% of lime as an activating agent showed a higher strength at all ages and an increase in the relative strength at 28 days. Therefore it can be concluded that the reduction in the lime in the binder resulted in a reduction in compressive strength.

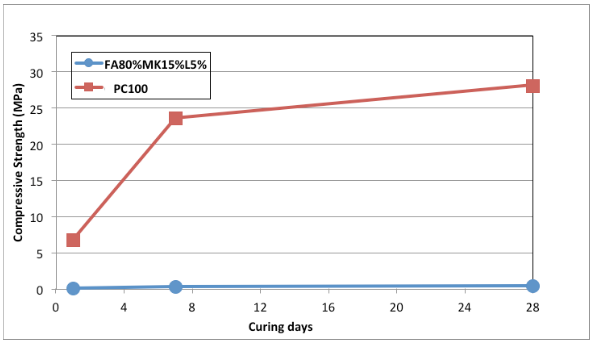

Fig. 2: Compressive strength of both mortars.

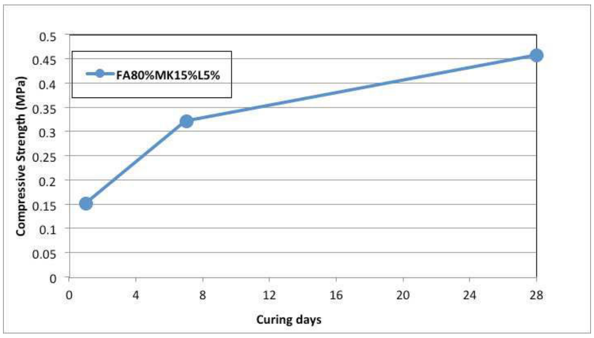

Fig. 3: Compressive strength of the fly ash activated mix.

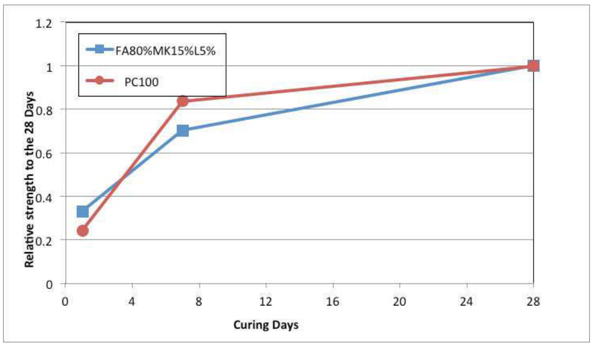

Fig. 4: Pore size distribution of paste P4 containing a blend of 30%C and 70%SDW.

Figure 6 shows the ultrasonic pulse velocity profile for the control mix and the fly ash activated mix at the age of 1 day and 28 days of curing. The results show that the UPV values for the mortar mixes increases at 28 days compared with those at 1 day. Also the UPV for the control mix is much higher than the fly ash activated mix.

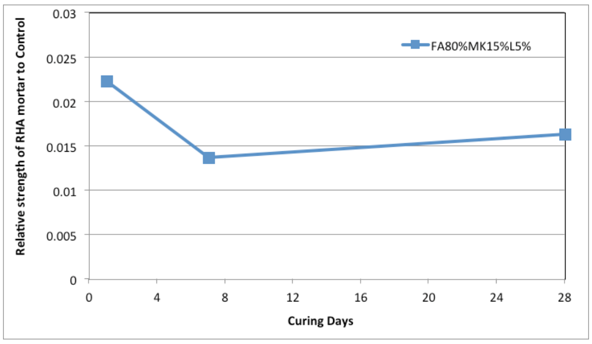

Fig. 5: Variation in relative strength of FA/MK/L mortar mix

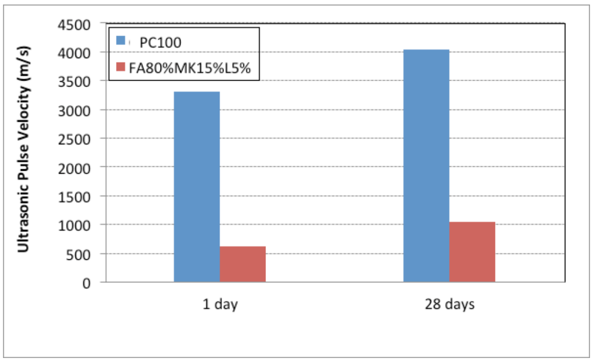

Fig. 6: Ultrasonic Pulse velocity for mortar mixes.

4 CONCLUSIONS

In conclusion, it was noted that it may be possible that fly ash mortar activated with lime and metakaolin can be used to completely replace cement in concretes. Fly ash could be used to produce lightweight concretes due to its ability in producing low density mortars and also introduction of metakaolin in the mortar help reduce the density of the mortar. It was noted that the reduction in the percentage of lime in the binder composition resulted to the reduction in the strength of the mortar. However, more research is required for enhancing the compressive strength. This can be achieved by curing the mortar containing activating fly ash at elevated temperatures and by altering the mix constituents. Despite the fact that the mortar made from cement had a higher quality, fly ash based binder can be used in the production of less expensive and more environmentally friendly concrete.

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