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Engineering Properties of Concrete Mixed with Varying Degrees of Fly Ash

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ABSTRACT: *The rate of carbon dioxide emission is on the high side globally and very few of this emission are being used. Bulk of this emission comes from cement manufacturing industries. There is urgent need to look for alternatives to cement in other to preserve natural resources globally. This study is aimed at determining the possibility of fly ash as substitute for cement in concrete production. In this study, ordinary Portland cement (OPC) and fly ash were obtained from Lafarge Group Nigeria Limited, Ewekoro Cement Plant, Itori, along Lagos-Abeokuta Express way, Ogun State, Nigeria. Cement was replaced with fly ash at 5%, 10%, 15%, 20% and 25% to determine the workability characteristics, with 0% serving as control. Concrete cubes in ratio of 1:2:4 were prepared in accordance with BS 1881 parts 1-4, 1970, part 6, 1971 and crushed at 28 days and 90 days to determine the compressive strength. From the result of this study, the fly ash of about 20% showed similar characteristics to that of normal concrete. It shows the possibility of using up to 20% fly ash in concrete for normal concrete works. It is therefore evidently clear that cement could be replaced with fly ash in engineering construction works. Therefore, environmental risks and hazard associated with cement production would be greatly reduced.*

Keywords: *Fly Ash, Carbon Dioxide, Cement, Concrete, Engineering, Strength Workability*

I. INTRODUCTION

In the present day construction activities, the demand for concrete has increased as the demand for infrastructural development has increased. The composition of concrete are aggregate (coarse and fine), cement and water. The manufacturing of ordinary Portland cement, OPC requires the burning of large quantities of methane coal gas as well as the decomposition of limestone, resulting in significant emissions of carbon dioxide (Kong, 2008). This production and utilization of cement pollutes the environment and it also reduces relevant natural resources such as limestone. According to Davidovits (1994), for every ton of OPC manufactured, nearly one ton of carbon dioxide is produced, depending on the production process adopted. Cement manufacturing plants have been reported to emit up to 1.5 billion tons of carbon dioxide into the atmosphere annually. According to Malhotra (2002), the total worldwide environmental release of carbon dioxide in 1998 was estimated at 23 billion tonnes, with Portland cement production accounting for approximately 7% of the total carbon dioxide emissions (Mehta, 1999). Therefore, replacing Portland cement with fly ash could reduce cement production and hence reduction in carbon dioxide emissions. According to the same source, the current annual worldwide production of fly ash is approximately 500 million tonnes, but only approximately 20% is being used by the cement and concrete industry. This study is aimed at determining the usability of fly ash as substitute for cement in concrete production, so that if fly ash could be used as substitute in engineering works, then environmental risks and hazard associated with cement production would be greatly reduced.

II. BACKGROUND STUDY

Fly ash, an inorganic, non-combustible, is a by-product of the combustion of pulverize coal in electric power generating plants (Fig. 1 a). It is a finely divided powder resembling Portland cement (Fig. 2 a and b). Upon ignition in the furnace; most of the volatile matter and carbon in the coal are burnt off. As coal is burnt at high temperatures, carbon is burnt off and most of the mineral impurities are carried away by the flue gas in the form of ash. The molten ash is cooled rapidly and solidifies as spherical, glassy particles (Malhotra, 2002). During combustion, the coal's mineral impurities such as clay, feldspar, quartz and shale fuse in suspension and are carried away from the combustion chamber by the exhaust gases. In the process, the fused material cools and solidifies into spherical glassy particles called fly ash. The fly ash is then collected from the exhaust gases by electrostatic precipitators (Fig. 1). This is a filtration device that remove fine particle like dust and smoke, from a flowing gas using the force of an induced electrostatic charge minimally impeding the flow of gas through the unit or by bag filters (Malhotra, 2002).

There are clearly economic and environmental benefits associated with the use of high levels of fly ash in concrete, however, there is relatively little information on the behavior of such concrete and almost no guidance on its production or use. Studies have demonstrated that well-cured high-volume fly ash concrete with very low water/cement ratios has good properties when mature, but there have been relatively few studies on the performance of concrete at higher water/cement ratio when produced and cured under normal conditions most especially in Nigeria. There are also indications that low quality concrete may be more similar to the quality of fly ash being used. With increase in the demand and consumption of Portland cement in Nigeria, it is important for the cement and concrete industries to start utilizing more fly ash to meet these demands rather than increase Portland cement production. The low cost and widespread available of the limestone, shale, and other naturally occurring material used in Portland cement production make it one of the lowest materials widely used over the last century throughout the world. However, Portland cement is readily available for use in the construction market, while fly ash is not readily available for the reach of people around the world. On the other hand, it is difficult to get fly ash directly from cement industry and other sources while cement is readily available in the construction market.

Fig. 1: Electrostatic Precipitator *(Lafarge Group Nigeria Ltd*)

(a)

(b)

Fig. 2: (a) Fly ash **(b)** Cement

III. METHODOLOGY

Cement (OPC) and fly ash were obtained from Lafarge Group Nigeria Limited, Ewekoro Cement Plant, Itori, along Lagos-Abeokuta Express way, Ogun State, Nigeria. Cement was replaced with fly ash at 5%, 10%, 15%, 20% and 25% to determine the workability characteristics with 0% serving as control. Concrete cubes were prepared in accordance with BS 1881 parts 1-4, 1970, part 6, 1971 to determine the workability. Three cubes were cast for each percentage, cured and crushed at 28 days and 90 days to determine the compressive strength.

IV. RESULTS AND DISCUSSIONS

The results of sieve analysis for aggregates as well as cement and fly ash are graphically presented in Figures 3 (a and b) respectively while the results of compacting factor test and water absorption rate are graphically presented in Figure 4. Finally, the results of compressive strength for different proportions of fly ash are graphically presented in Figure 5. From the results of this study, it was observed (Figures 3 and b) that fly ash contain finer particle. The finer the particle, the more water it absorbs. This is in agreement with the submission of Malhotra (1994). The specific gravity of fly ash is higher than that of cement. Setting time increases in all the percentage of fly ash investigated while penetration also increases in the same proportion. For slump test, at up to 25% fly ash true slump was observed, which is similar to that of the control. Compacting factor results (Figure 4a) are similar for all the percentages investigated up to 25% and also similar to that of the control. From the results of the slump test shown in Figure 4 (a), the compacting factor increases as the percentage fly ash increases. In addition, the water absorption rate (Figure 4b) increases as the percentage of fly ash increases. This is due to the fact that much water is consumed during the hydration process. The heat of hydration is more in cement (0%) than that of fly ash (Figure 4a). This must have contributed to the decline in compressive strength observed in Figure 5 compared to the of the 0% fly ash (control).

The reduction in the rate of heat produced and hence the internal temperature rise of the concrete has long been an incentive for using fly ash in mass concrete construction (Mustard, 1959). In massive concrete pours where the rate of heat loss is small, the maximum temperature rise in fly ash concrete will primarily be a function of the amount and composition of the Portland cement and fly ash used, together with the temperature of the concrete at the time of placing (Langley 1992). Replacing Portland cement with fly ash can reduce the exothermic reaction between cement and water. Because of the slower Pozzolanic reaction, partial replacement of Portland cement with fly ash results in a release of heat over a longer period of time. Therefore, the concrete temperature remains lower because heat is dissipated as it is produced (Joshi, 1997). It has been estimated that the contribution of fly ash to early age heat generation ranges from 15-30% of that of an equivalent mass of Portland cement (Berry, 1986). In general, the rate of heat evolution parallels the rate of strength development. Some high calcium ashes react very rapidly with water, generating excessive heat rather than reducing the heat of hydration (Berry, 1986).

Density is similar up to about 10% fly ash to that of the control but the density reduced after 20% at age 90 days. Increasing the fly ash from 5% to 10% and 30% upward resulted in reduction in the density of concrete at age 28 days, the percentage of cement decreases in concrete and that of compressive strength. To an extent, there is similarity in compressive strength at 90days for fly ash up to 20% but with reduction in compressive strength after 25% fly ash. Also fly ash can be replaced with cement up to 15% at 28 days of curing, which will give reasonable compressive strength to the concrete. From the results of this study it is hereby suggested that up to 20% fly ash in concrete could be used for normal concrete works. However, the fly ash percentage should not be more than 20% in order to show similar characteristic to that of normal concrete. Consequently in order to reduce environment pollution cause by fly ash it could be used as substitute in concrete up to 20%. Therefore the environmental risk and hazard cause by fly ash will be greatly reduced.

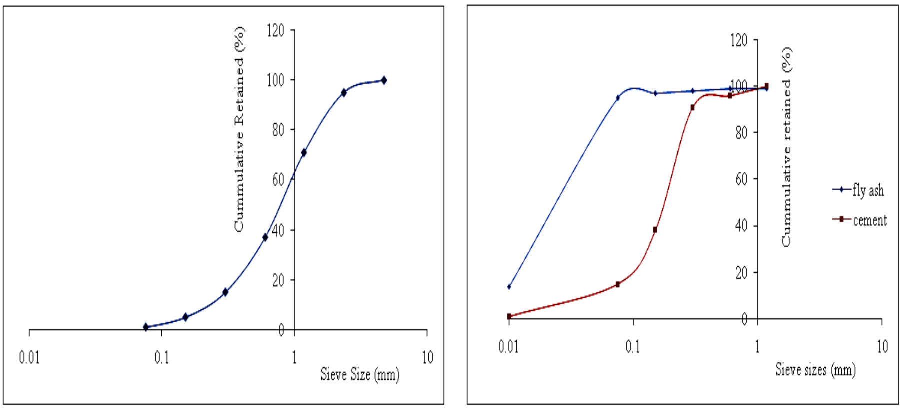

Fig. 3: Results of sieve analysis for **(a)** aggregates; **(b)** cement and fly ash

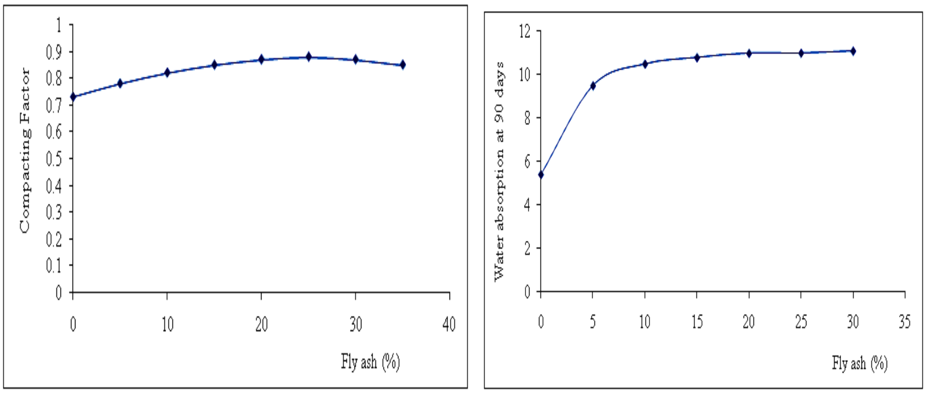

Fig. 4: Results of **(a)** compacting factor test; **(b)** Water absorption rate

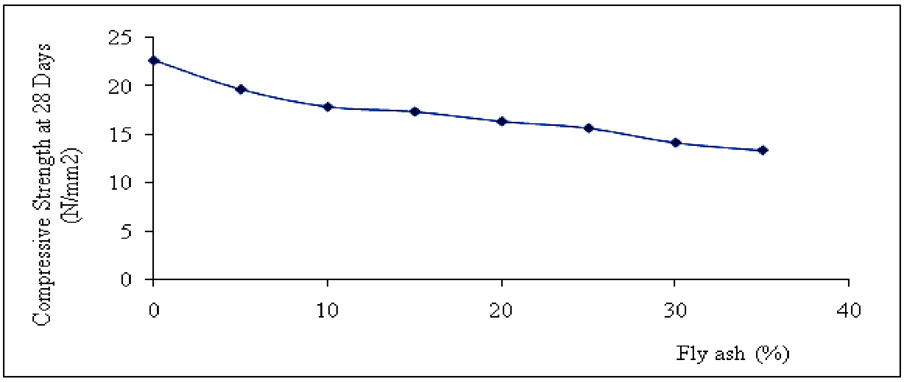

Fig. 5: Compressive strength for different proportion of fly ash

V. CONCLUSIONS

This paper has examined the possibilities of replacing cement with fly ash for engineering construction works. Workability of concrete partially mixed fly ash was study while the compressive strength was equally observed. Certain percentage of fly ash to be substituted in concrete was also specified. With the reduction in the production of cement as a result of the use of fly ash, environmental risks and hazards experienced in the cement production process leading to emission of carbon dioxide would be greater reduced if not completely eliminated.

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