Research Paper

The Production of Pozzolana Using High Calorific Waste

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Abstract

Plastic waste such as polyethylene, with a calorific value of 46.2 kJ/g, has the potential to greatly supplement the energy requirements of clay pozzolana production. This was tested when 0.08 g of plastic was embedded in 8 g of clay before its calcination in a furnace. It was observed that the energy consumption of the furnace was reduced significantly with increasing plastic to clay ratio. The compressive strength of the pozzolana-OPC (Pozzolana-Ordinary Portland Cement) composite blocks was also comparatively higher. The use of plastic waste in the production of pozzolana can thus reduce the cost of building as well as reduce carbon dioxide emissions.

Keywords: Pozzolana, Calorific Waste, Plastic Waste, Portland Cement

1. Introduction

Cement is the vital binding agent in concrete, mortar and renders, and is used for the production of walling blocks and roofing tiles. The most widely used and available cementitious material is Ordinary Portland Cement (OPC). Portland cement is relatively expensive to produce and is often in short supply in developing countries. There is the need therefore to promote the use of alternate forms of cement derived from indigenous cementation materials. Local cementation materials have a huge relative advantage due to highly demonstrated knowledge on efficient methods of production (Hammond, 1983).

Alternative cements including pozzolana are not capable of replacing Portland cement totally due to its strong binding ability. Pozzolana is used in the preparation of mortar, renders and non-structural concrete but is not normally considered suitable for structural applications such as reinforced concrete beams and columns (Atiemo, 1998).

Pozzolana is a material which on its own is not cementitious but with the addition of lime reacts to form a material which sets and hardens. Thus, for the purpose of construction, pozzolana is not an end in itself but rather a means of achieving the ultimate product (Jackson et al, 2003). In Ghana clay is the most abundant artificial pozzolana which can be found in every locality (Atiemo, 2006).

The production of cement involves high consumption of expensive energy. The average energy demand for the production of 1 ton of cement is about 3.3 GJ, which corresponds to 120 kg of coal with a calorific value of 27.5 MJ per kg. Energy costs account for 30-40 % of the total costs of cement production (Mokrzycki & Uliasz-Bochenczyk, 2003). This much quantity of energy makes the manufacture of cement rather energy intensive and as such makes the possibility of utilizing an alternate source of energy apart from the conventional very attractive (Mokrzycki & Uliasz-Bochenczyk, 2003).

The use of Solid Recovered Fuels (SRF) in the cement industry is on the ascendancy due to the high cost of fossil fuels and its unavailability. The limitation to the utilisation of Refuse Derived Fuels (RDF) as fuel material in cement kilns as an alternative to the use of conventional fuels is the development of systems that utilise RDF in cement kilns (Genon & Brizio, 2008). Given the high temperatures usage, these plants would in
principle seem ideal for the thermal destruction of residuals without causing adverse environmental impacts. The use of RDF is also being encouraged because of its ability to reduce total worldwide carbon dioxide gas emissions and reduce the number of landfill sites needed by cities for waste disposal. RDF includes plastic waste, paper and other waste of high calorific value (Genon & Brizio, 2008).

The use of polyethylene (PE) as fuel is very viable due to its high calorific value. PE provides 46.20 kJ/g (Walters et al, 2003) of energy at optimal combustion conditions and as 102.6 g of PE would be needed to produce 1 kg of cement. Plastic materials production was at 260 million tonnes globally in 2007 (Mokrzycki & Uliasz-Bochenczyk, 2003).

Major advantages of alternatives to Portland cement are that they are usually cheaper to produce, needing much lower or even negligible capital inputs to get started, and requiring far less imported technology and equipment. They can also be produced on a small scale to supply a local market resulting in greatly reduced transportation costs and a much greater degree of local accountability in the supply of building materials. Alternatives to Portland cement include quicklime, hydrated lime, gypsum plaster and pozzolana cements (Hammond, 1983).

Pozzolanas can replace up to 30% of OPC. They have high water retention, improve workability of OPCs and provide an improved resistance to sulphates and alkali aggregates. It has a lower heat of hydration which refers to the heat release upon addition of water. It also reduces bleeding in mortars. They are environmentally friendly both in their production and usage (Atiemo, 2005).

The production of clay pozzolana in Ghana is spearheaded by the Building and Road Research Institute, which uses palm kernel shells as an energy supplement during the calcination of clay. Plastic (polyethylene) has a higher calorific value (46.2 kJ/g) than palm kernel (15.9 kJ/g) and as such can be used to replace palm kernel shells. It is also readily available and easily accessible. In Ghana it is estimated that the plastic waste per capita stands at 0.016-0.035 kg/person/year (Fobil & Hogarh, 2006) which amounts to about 3×105 tonnes of plastic waste been generated in households alone yearly (Fobil & Hogarh, 2006).

2. Material and Methods

2.1. Clay Processing

Mined clay form Mfensi, in the Ashanti Region of Ghana, is dried for 5 to 7 days. The clay is then mixed with water to form a solution. The solution is then passed through a sieve to remove organic materials, silt, sand, stones etc. The filtrate is dried in an open pit to remove moisture until a smooth even paste is formed. The paste is then dug from the pit and rolled into bars of even sizes for storage.

2.2. Nodule Making

Cylindrical nodules, 8 g each, were made with pieces of polyethylene carefully and evenly embedded in each slab of clay before it is rolled into a cylindrical shape. The nodules were then dried to reduce the moisture content to about 18 % dry mass basis.

2.3. Calcination and Classification

The dried clay is charged into a VECSTAR® HFI FURNANCE with a charge to volume ratio of 3.18% (Unit volume of clay nodule = 0.3186 cubic inch; Bulk volume of charge = 3.8224 cubic inch). The furnace has an integrated R-type thermocouple. The initial and the final temperatures i.e. T1 and T2, were recorded. The time taken to heat the material from T1 to T2 (actual firing temperature) is recorded as tR. After reaching T2 the material dwells at this temperature for a time tD. After tD is attained the furnace is stopped and the calcined clay allowed to cool before offloading. The calcined clay is grinded in a ball mill. It is then classified to obtain a particle size of 150 micrometers (Figure 1-2).

The following conditions were varied during firing:

- Firing temperature ( 600-800 °C )
- Plastic (polyethylene) content in each clay nodule ( 0.04-0.08 g)
- Dwelling time (tD) during firing (80 minutes)
3. Results

3.1. Rate of Heating

The dried clay embedded with the plastic is heated from an initial temperature to the calcination temperature of 800 °C and held there for 40 minutes. The time taken for the material to heat from the feed temperature to the calcination temperature is an indication of the energy consumption of the process since the electric energy consumption of the furnace was fairly constant within the limits of normal operation. It was observed that the rate of heating of clay from an initial Feed Temperature to the calcination, the final temperature increased with increasing plastic to clay ratio.

The internal generation of heat when the plastic-clay composite reaches the combustion temperature and liberates 42.6 kJ/g of thermal energy causes a significant increase to the amount of energy available for heating. The increase in the rate of heating corresponding to the increase in the plastic-clay ratio is proof of this (Figure 3).

![Figure 2. Various Samples a) Calcined Clay b) Crushed Clay c) OPC and d) Clay Pozzolana](image)

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3.2. Compressive Strength

A test for the compressive strength (Figure 4) of the pozzolana produced with the various plastic to clay ratios was done, the following procedure was employed:

- OPC-clay pozzolana composite cement was prepared by adding 1 part of clay pozzolana to 2 parts of cement (BRRI i.e. Building and Road Research Institute). The composite formed was mixed with sand in 1:3 ratios and then mixed with water (IS: 4031 part 4, 1988).

- The mortars were placed in wooden moulds of 2500 mm³ dimension. These cubes were demoulded after one day and stored in water for curing at 27 °C at a relative humidity of 100%.

- The cubes were taken out of water prior to testing. The compressive strengths were determined after 7 days (IS: 4031 part 4, 1988).

- The compressive strength of OPC mortar without clay pozzolana was tested and used as a control.

![Figure 3. Rate of Heating](image)

Figure 3. Rate of Heating

![Figure 4. Compressive Strength](image)

Figure 4. Compressive Strength

4. Discussion

From the results obtained, the compressive strength obtained was consistent with that of pozzolana-OPC composite over the same time of testing (BRRI). The compressive strengths obtained were also comparatively higher than that for standard sandcrete blocks cured over the same duration (Abdullahi, 2005). The results also showed an increase in the plastic to clay ratio caused a corresponding increase in the compressive strength.

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The increase in the compressive strength of the pozzolana can be attributed to the enhanced thermal distribution due to the presence of the plastic. The two way generation ensures an even distribution of heat and increases the overall thermal efficiency of the process which results in a corresponding increase in the compressive strength as the clay-plastic ratio is an indication of this fact.

5. Conclusion

From the work done, it can be inferred that it is feasible to incorporate plastic waste into the production of clay pozzolana. The incorporation of plastic into the clay pozzolana decreases the amount of energy needed for calcination. The thermal distribution is also enhanced thereby ensuring an even calcination and a higher quality of product. This is evident from the increase in the compressive strength being directly proportional to the increase in the clay-plastic ratio. The use of polyethylene a RDF in the production of pozzolana cement production would decrease the cost of production and this would in turn reduce the cost in building. The use of polyethylene in pozzolana production would also help mitigate the waste management menace currently plaguing the country.

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References


