



Research paper

The development of unfired clay building material using Brick Dust Waste and Mercia mudstone clay

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ABSTRACT

This work reports the potential of using Brick Dust Waste (BDW) as a partial substitute for clay in the development of unfired clay building materials (brick, block and mortar). BDW is a waste material from the cutting of fired clay bricks. There are various reasons necessitating the cutting of bricks – corner bricks, construction of chimneys, and other uses needing bricks of various shapes and sizes. This results in the disposal of BDW as an environmental problem of concern. In order to investigate the clay replacement potential of BDW, four types of mixes were designed at varying BDW replacement levels – 5%, 10%, 15% and 20%. Ground Granulated Blastfurnace Slag, an industrial by-product from steel manufacture was activated using quick lime and the mixture was used to stabilise Mercia mudstone clay for unfired clay production. The 56 day compressive results using cylinder test specimens showed a significant strength gain (up to 2.1 N/mm²). Overall, the results suggest that it is possible to develop unfired clay building material using up to 20% BDW as partial substitutes for primary clay.

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1. Introduction

In order to boost environmental technologies while strengthening economic growth and competitiveness, the development of products using recycled and secondary raw materials as an alternative to primary raw materials should be encouraged worldwide. This will preserve natural resources while reducing waste to landfill. There has been a number of efforts to reduce the use of the virgin raw material (clay soil), and conventional binders for unfired clay building material development (Galán-Marín et al., 2010; Kinuthia and Nidzam, 2011; Oti, 2010; Oti and Kinuthia, 2012). The emphasis is therefore in the use of virgin materials only when the alternative of recycled materials for stabilised building product manufacture is not available.

Previous work by Oti and Kinuthia (2012) used Lower Oxford Clay for unfired clay building material production. The study combined fired and unfired clay technologies and also combined energy use and carbon dioxide emission for the evaluation of unfired clay bricks relative to those bricks used in conventional construction; this is an attempt to come up with one parameter rating. Kinuthia and Nidzam (2011) reported on the potential of utilising Brick Dust Waste (BDW) in combination with Pulverised Fuel Ash. The results showed that partial substitution of BDW with PFA resulted in a stronger material compared to

using BDW on its own. Galán-Marín et al. (2010) reported on the possibility of producing building material using stabilised soils with natural polymers and fibres; the outcome of the work showed that the addition of fibre doubles the soil compression resistance. Regardless of the materials, test methods and specimens used, the investigators conclude that the use of various waste and by-product materials for stabilised clay building material production has high environmental benefits and will facilitate best practice in waste management and waste reduction.

This paper reports on investigative work aimed at developing stabilised clay building material using Brick Dust Waste (BDW) and Mercia mudstone clay. The overall aim is to capitalise on the already identified high cementitious potential BDW as a pozzolan, to enhance the strength of a blend by using up to 20% BDW as partial substitutes for Mercia mudstone clay (primary clay material). In order to explore further enhancement of the benefits, lime was only used as an activator to Ground Granulated Blastfurnace. The work reported on this paper will potentially offer a step-change in development of unfired clay building material beyond current knowledge and provide a means to enhance 'green growth' strategies. Brick Dust Waste and filter cake waste, glass waste, concrete wastes are largely inert waste and they make up a huge proportion of the 24.4 million tonnes of construction and demolition waste that went to the landfills in England and Wales in 2008 (DERA, 2012). The re-use of Brick Dust Waste within the building industry will help to conserve the dwindling landfill resources worldwide.

This paper has significant valuable data for researchers in the field of sustainable construction material development and other related disciplines. The commercial private sector will also benefit from this paper

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through understanding the potential application of the new technology. In turn, there are probable future impacts of this paper for international development, through the development of techniques that will be transferable. The paper will have a high impact on the Engineering and scientific communities involved in alternative building and construction material development.

2. Research hypothesis

Pozzolans are some of the materials identified as capable of partially replacing raw materials in infrastructure development while fulfilling the technical, economical and environmental benefits. Pozzolans are materials that are not cementitious in themselves but contain constituents which will combine with lime at ordinary temperatures in the presence of water to form stable compounds possessing cementing properties (Lea, 1980). The strategy in this research therefore involves capitalising on the already identified high cementitious potential of Brick Dust Waste as a pozzolan, to enhance the strength of a blend. The pozzolanic properties of brick dust were attributed to the fact that during the high temperature firing of bricks, a liquid phase develops, which subsequently forms an amorphous glassy phase upon cooling. It is this glassy phase that cements the crystalline and any other phases that make up the brick (Khatib and Wild, 1996 and O'Farrell, 1999). The pozzolanic properties of ground brick have also been found to result in enhanced resistance to chemical attack in cementitious mixtures (Gonçalves et al., 2009; O'Farrell, 1999; Poon and Chan, 2006 and Sherwood et al., 1977). Considering the fact that Brick Dust Waste is currently being dumped in landfill sites, the economic and environmental benefits of utilising significant amounts of these as a clay replacement material are immense.

The environmental advantages are further increased as the main binding agent is activated GGBS which is a locally available by-product material. There are also economic gains to be made although these may be short and long term, as the cost of GGBS is significantly lower than that of conventional binder. Previous work (Oti, 2010) used only about 1.5% lime for GGBS activation to stabilise Lower Oxford Clay. This is a very low level of usage of lime that is not comparable to, or sufficient for, most road construction applications, where far lower strength values are needed and where 3–8% lime is required for effective soil stabilisation. It is anticipated that the level of lime to be used for GGBS activation under this proposed study will be relatively lower than 1.5% because of the Pozzolanic effect of Brick Dust Waste that is present in the current system. Hence, the final pricing of the stabilised clay building material made using BDW–Mercia mudstone clay-activated GGBS system as expected to be relatively low.

Previous work by the authors was on the use of lime–GGBS binders for various engineering applications (Kinuthia and Oti, 2012; Kinuthia and Wild, 2001; Kinuthia et al., 1999; Oti, 2010; Oti and Kinuthia, 2012; Oti et al., 2008, 2009; Wild et al., 1999). This study is to report the development of unfired clay building material using Brick Dust Waste. It is timely therefore to go into manufacturing of building components at this time, using this binder which is very well understood by the authors. The work is utilising waste materials that are in abundance in the brick fabrication plant from the cutting of fired clay bricks. Clay bricks from various parts of the UK are brought to the brick fabrication plant to be cut to the required shape and size giving rise to the brick dust as a waste. The cutting is carried out in a wet process to minimise dust and friction, and a jet of water is used during the cutting process. The brick dust suspension is collected in hessian bags to allow the excess water to drain off. The brick dust remains in the hessian bag for further in-yard drainage, and when light enough transported to a landfill site. To enhance sustainability and care for the environment, this work hopes to provide high quality short and long-term solutions to the problem facing the brick fabrication plant by using Brick Dust Waste for stabilised clay building material development.

3. Methodology

3.1. Materials

Brick Dust Waste (BDW) was used in this study. It was supplied by Brick Fabrication Ltd., Gemini Works, Pontypool, South Wales, UK. It is a waste from the cutting of fired clay bricks. Table 1 shows its mineralogical composition. Table 1 shows the consistency limits and some engineering properties of the material, and its chemical and mineralogical compositions can also be seen in Table 2. The particle size distribution of the BDW is presented in Fig. 1.

The Mercia mudstone clay used for this study was obtained from Bristol Channel, Western England. Mercia mudstone also known as keuper marl is a series of red brown mudstones with subordinate siltstones of Triassic age (Trenter, 2001). Table 3 shows some physical properties of Mercia mudstone clay.

Ground Granulated Blastfurnace Slag (GGBS) used in this study was in compliance with BS EN15167-1:2006 and was supplied by Civil and Marine Ltd, Llanwern, Newport, UK. Some physical properties of GGBS can be seen in Table 4, while its oxide composition is presented in Table 5. GGBS was used as cement replacement material in this study. The quicklime (calcium oxide) used for this research was manufactured and supplied by Ty-Mawr Lime Ltd, Llangasty, Brecon, UK. Some physical properties of quicklime can be seen in Table 4, while its oxide composition is presented in Table 5.

3.2. Mix design

For the purpose of sample preparation it was found necessary to first establish the target dry density and moisture content values for the various material combinations. This was carried out on the basis of the unstabilised clays. Proctor compaction tests were carried out in accordance with British standard BS 1924-2:1990 with a view to establishing values of the maximum dry density (MDD) and optimum moisture content (OMC) for unstabilised Mercia mudstone clay; these values were 1.8 Mg/m³ and 20%, respectively. The approximate range of moisture content over which at least 90% MDD (1.62 Mg/m³) could be achieved was 16–25%. For the Blended Mix composition, a compaction moisture content of 21% was used after several trials with a wide range of mixes, and the samples were therefore expected, within experimental error, to be of the same density and volume for all the material compositions. Table 6 shows the details of the mix compositions of the cylinders made using varying proportions of Brick Dust Waste (BDW) as a clay replacement material; stabilised using lime-activated Ground Granulated Blastfurnace Slag (GGBS) as the main stabilising agent. The control mix for the current research work adopted a mix used on various occasions in previous studies by the authors. This mix had been used to assess the engineering properties of non-fired clay bricks for sustainability and low carbon content (Kinuthia and Oti, 2012; Oti, 2010; Oti and Kinuthia, 2012; Oti et al., 2008, 2009). The control mix (ME) used 3% quicklime, and 11% GGBS to stabilise Mercia mudstone clay. Four major blends were considered for this study after the

Table 1
Consistency limits and other properties of BDW.

Consistency limits	
Liquid limit	–
Plastic limit	–
Plasticity index	Non-plastic
Others	
Specific gravity	2.5
Bulk density (kg/m ³)	1837
Maximum dry density (MDD) (Mg/m ³)	1.5
Optimum moisture content (OMC) (%)	17
Colour	Brick red

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