Journal of Cleaner Production xxx (2015) 1–6

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Use of bio-briquette ash for the development of bricks

Vishakha V. Sakhare, Rahul V. Ralegaonkar*

Department of Civil Engineering, Visvesvaraya National Institute of Technology, Nagpur, India

ARTICLE INFO

Article history:
Received 10 April 2015
Received in revised form
13 July 2015
Accepted 15 July 2015
Available online xxx

Keywords:
Bio-briquette ash
Brick development
Compressive strength
Physico-chemical property

ABSTRACT

The issue of the ever increasing demand for construction materials and waste management has created a need for the development of sustainable materials with the appropriate utilization of wastes. This paper presents the study of the use of bio-briquette ash (BBA) for the development of bricks. Physico-chemical property investigations for a BBA sample were conducted, and the sample was found to be suitable as an alternative raw material for the partial substitution of sand. For the development of the bricks, BBA was added according to the partial replacement method (5–55%) for sand, keeping the cement percentage constant. Six compositions were prepared with 10 wt% variations. The developed product was tested according to the Indian Standards (IS) for density, compressive strength, water absorption and efflorescence along with the durability and thermal properties. The effect of the addition of the BBA on the brick properties was investigated. Thirty-five weight percent BBA, 55 wt% sand and 10 wt% cement were the optimal mix composition for the developed BBA bricks that fulfilled the desired properties of IS. The developed BBA bricks were found to have better mechanical and thermal properties and were more economical than commercially available fly ash and clay bricks. The developed bricks are recommended for non-load bearing walls.

1. Introduction

With the rapid increase of industrialization, solid waste generation and disposal are major issues. The generated solid waste that is otherwise land filled harms the environment and the health of living beings. Various industries use different types of fuels for boiler applications, resulting in the generation of several types of waste with different characteristics. Bio-briquettes are a renewable energy source that are used in different industrial boiler applications. Bio briquetting is the process of converting agricultural waste (soy beans, cotton, sawdust, etc.) into high density and energy concentrated fuel briquettes. The brick and block industry can positively contribute to more eco-efficient construction by incorporating the wastes generated by other industries. This not only prevents an increase in the area needed for waste disposal but also avoids the exploitation of non-renewable raw materials used in the production of masonry units, thus reducing its environmental impact (Torgal et al., 2014). Briquettes have superior qualities and environmental benefits in comparison with coal because they are derived from renewable resources (Maninder et al., 2012). Briquettes produced from the briquetting of biomass offer numerous advantages and are a fairly good substitute for coal, lignite, and firewood. In Maharashtra (India), there are more than 350 briquetting units. Each unit produces approximately 200–250 tons of briquettes, resulting in 7000 tons of briquette ash production per month (Visviva, 2014).

Several attempts were made to utilize waste in the development of bricks. An experimental study was completed on the development of masonry blocks with palm oil fuel ash (POFA) as a partial replacement for 0%, 20%, 40% and 60% cement by mass, satisfying the requirements of the Malaysian Standard. The compressive strength and the breaking load of the masonry blocks were reduced with an increasing percentage of POFA replacement (Rahman et al., 2014). Sadek (2014) examined the effect of using air-cooled slag (ACS) produced by the slow cooling of blast furnace slag (BFS) under atmospheric conditions and with water-cooled slag (WCS) produced by water quenching at 50% and 100% replacement of natural sand (NS) in solid cement bricks. The use of ACS resulted in greater deterioration after exposure to elevated temperatures, although it increased the compressive strength of the unheated specimens. However, the bricks containing WCS were thermally more stable than NS and ACS bricks. Mutuk and Mesci (2014) examined the utilization of boron waste (BW) and investigated RHA as a cement additive. Five percent, 10%, and 15% RHA and 1%,

* Corresponding author. Tel.: +91 2801090.
E-mail address: sanvan28@yahoo.com (R.V. Ralegaonkar).

http://dx.doi.org/10.1016/j.jclepro.2015.07.088
0959-6526/

3%, and 5% BW were added to mortar instead of cement. The results showed that 10% rice husk ash additive specimens gave the highest result with respect to the full factorial experimental design. The effect of substituting the bottom ash for Portland cement in proportions ranging from 10 to 90 wt% demonstrated that the addition of ash increased the block porosity, thereby decreasing its thermal conductivity and compressive strength (Carrasco et al., 2014). Torkaman et al. (2014) investigated the effects of the partial replacement of Portland cement by wood fiber waste (WFW), rice husk ash (RHA) and limestone powder waste (LPW) for producing a lightweight concrete block as a building material. The optimum replacement level of WFW, LPW, and RHA was 25 wt%, which resulted in good mechanical properties. Rajput et al. (2012) utilized recycled paper mill waste and cotton waste to manufacture waste-create bricks (WCB). WCBs with a varying content of cotton waste from 1 to 5 wt%, recycled paper mill waste from 89 to 85 wt% and a fixed content of Portland cement (10 wt%) were prepared and tested as per the IS 3495 (Part 1–3): 1992 standards. The results indicated that the bricks were thermally stable and conformed to the recommended compressive strength test. Raut et al. (2012) developed bricks with the addition of 5–20% cement to recycle paper mill waste (RPMW), which exhibited a compressive strength of 9 MPa, and found the strength to be three times greater than conventional clay bricks (3 MPa). Ling and Teo (2011) developed bricks from the waste rice husk ash (RHA) and expanded polystyrene (EPS) beads. RHA was used as a partial replacement for cement, while EPS was used as a partial aggregate replacement in the mixes. It was found that the properties of the bricks were mainly influenced by the content of EPS and RHA in the mix and also the curing conditions. Ismail et al. (2010) developed bricks by incorporating 20% paper sludge and 20% palm oil fuel ash into cement. Sales and Lima (2010) prepared mortar and concrete with sugarcane bagasse ash (SBA) as a sand replacement and performance tests were conducted. The results indicated that the SBA samples had properties that were similar to those of natural sand. The mortars produced with SBA in place of sand showed better mechanical results than the conventional mortar. Lertsatitthanakorn et al. (2009) developed rice husk ash-based sand-cement bricks and compared them with standard commercial clay bricks. For a wall of 2.5 m length × 2 m height × 0.09 m thick, it was estimated that the RHA-based sand-cement bricks reduce solar heat transfer by 46 W. Celik et al. (2008) characterized different types of fly ash and investigated their effect on the compressive strength properties of ordinary Portland cement. Chiang et al. (2009) produced lightweight bricks by sintering mixes of rice husk ash and dried water treatment sludge. The blending ratio and sintering temperature effects on the properties and micro-structure of the produced materials was reported.

The studied literature implied that agro-industrial waste has the potential to be used as the principal raw material for manufacturing bricks. Researchers used the recommended standards to evaluate the conformance of newly designed masonry products. The potential application of bio-briquette ash (BBA) for the development of novel products has not been investigated. Due to the availability of BBA over the study area, the present paper evaluates its possible application as an alternate raw material for the development of bricks. The physico-chemical properties of BBA were characterized and analyzed. Various mix proportions were designed using BBA, cement and sand. Then, the performance of the mechanical, durability and thermal properties of the developed bricks was analyzed.

2. Materials and methods

The main ingredients proportioned on the basis of wt% for brick development were:

- 53 grade ordinary Portland cement conforming to IS 12269:2013.
- Bio-briquette ash samples (Fig. 1): identified and collected from locally available industrial sources (Shree Baidyanath Ayurved Bhawan Pvt. Ltd., Nagpur).
- Sand conforming to IS 650:1991.

2.1. Tests on the raw materials

The BBA underwent physical tests (sieve analysis, specific gravity and soundness tests), chemical characterization, X-ray diffraction (XRD), thermogravimetric differential thermal analysis (TG/DTA), and scanning electron microscope (SEM) examinations to determine its nature and constituent compounds.

Specific gravity testing for BBA, cement and sand was conducted as per IS 2720 (3): 1980. The particle size distribution of the BBA was determined as per IS 2720 (4): 1985. The soundness test was performed by the autoclave expansion method for the BBA samples (IS 3812 (1): 2003). An X-ray fluorescence spectrometer (XRF, Philips, PW 1840) was used for chemical characterization. The X-ray diffraction pattern was recorded on a model XRD-Philips X'Pert Pro with a scan rate of 2°/min. XRD patterns were scanned in steps of 0.0170 in a diffraction angle range from 10° to 100° of 2θ using copper (Cu) as an X-ray source. The microstructural analysis of the BBA sample was analyzed using a JSM-6380A scanning electron microscope. The thermogravimetric differential thermal analysis was conducted using Mettler, TA 4000 apparatus to verify the thermal stability of the material.

2.2. Brick development

The automated brick plant was used to make building bricks of dimensions 230 × 100 × 85 mm^3. Mixes of bio-briquette ash, sand and cement with various compositions were prepared. The BBA share in the composition mix varied from 5 to 55% (Table 1). The sand (S) share in the composition mix varied from 85 to 35%. The cement (OPC 53 grade) percentage in the composition mix was kept constant at 10% by weight. Twenty samples for each composition (BBA: S: C) were prepared. First, BBA, sand and cement were mixed for approximately 30 s in a mixing unit of an automated plant. To obtain more homogenous mixes, water (0.20 water to mix ratio) was added into the cement slurry while the mixer was

Fig. 1. Pictorial appearance of bio-briquette ash.

Please cite this article in press as: Sakhare, V.V., Ralegaonkar, R.V., Use of bio-briquette ash for the development of bricks, Journal of Cleaner Production (2015), http://dx.doi.org/10.1016/j.jclepro.2015.07.088