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Fabrication of geopolymer bricks using ceramic dust waste

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HIGHLIGHTS

- Geopolymber bricks were prepared using fine cyclone waste from wall tile industry.
- Compressive strength increased with degree of polymerization.
- Water absorption of bricks generally increase with both curing time and temperature.
- A mix of dust with 10% $Ca(OH)_2$, 1% NaOH resulted in compressive strength of about 9 MPa.

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ABSTRACT

The fine dust waste from the cyclones connected to the spray dryer in ceramic tiles manufacture was used in the preparation of geopolymer bricks. Dust was characterized after firing using XRD, XRF, PSD, and its bulk density was determined. Caustic soda was used at 1% NaOH level together with slaked lime at $Ca(OH)_2$ percentage ranging from 6 to 10%. These were mixed with the fine dust waste and molded to form geopolymer bricks. The properties of produced bricks were studied after 28 days. Results indicated that the 28 days compressive strength increased with the degree of geopolymerization. It was found that the results abide by the Standard ASTM C 62/2013 for a recipe consisting of 1% NaOH, 10% $Ca(OH)_2$ and 38% water. The results were confirmed by SEM imaging.

The use of waste raw materials (except for caustic soda) resulted in a substantial reduction in the estimated production cost of the bricks.

1. Introduction

Conventional solid waste management by dumping or landfilling has a negative impact on the surrounding environment leading to many types of pollution in addition to the cost needed to get rid of these wastes. But if waste is properly managed, it can be used as a raw material in many industries. Many researchers and investigators have aimed at utilizing all types of wastes in environmentally friendly and economic ways as materials in the construction industry such as fly ash, blast furnace slag, recycled aggregates, red mud, etc. [1–3].

Geopolymers are classified as a type of inorganic material with ceramic-like properties which can be produced at ambient or slightly higher temperatures [4]. However, they follow a totally different reaction path than the ordinary pozzolanic cements. While the gain in strength for pozzolanic cements depends mainly on the presence of calcium to form calcium-silicate-hydrates (CSHs) that of geopolymers depends on the poly-condensation of a pozzolanic material normally containing silica and alumina in presence of an alkaline solution [5].

Typical pozzolanic raw materials for geopolymers are metakaolin [6,7], bagasse [8], fly ash from coal combustion [9,10], granular bottom resulting from incineration of municipal solid waste [11], slag waste from metallurgical industries [12–14], glass wastes [15–17], etc. On the other hand, greenhouse emissions resulting from the production of geopolymer concrete are markedly lower than those released from the manufacture of ordinary Portland cement concrete [18,19].

The nature of raw materials and the preparation conditions of geopolymer systems have a direct impact on the properties of the final product. In this respect, Hardijito [20] found that increasing the curing temperature from 30 to 90 °C while using fly ash leads to an increase in the compressive strength from 35 to 65 MPa. Curing time [21,22], calcination temperature [23], type

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Fig. 1. Geopolymer bricks.

Table 1
Chemical analysis of meta-kaolin used.

Constituents	Wt(%)	Constituents	Wt(%)
SiO_2	54.55	NiO	0.011
Al_2O_3	15.88	CuO	0.006
$Fe_2O_3^{tot.}$	4.29	Ga_2O_3	0.002
TiO_2	0.87	Nb_2O_5	0.003
MgO	0.56	Rb_2O	0.013
CaO	12.86	SrO	0.025
Na_2O	2.71	Y_2O_3	0.006
K_2O	2.65	CeO_2	0.037
P_2O_5	0.16	Co_2O_4	0.007
SO_3	0.38	PbO	0.004
Cr_2O_3	0.014	Cl	0.12
MnO	0.07	L.O.I	4.69
ZrO_2	0.046	Total	99.998
ZnO	0.034		

and concentration of activators used [4,5,24–26] also affect the final properties of the prepared geopolymer.

The traditional route for the preparation of geopolymers involves mixing meta-kaolin with strong caustic solution. In the present paper, most of the caustic soda component was substituted by the much less costly slaked lime. Also, the use of ceramic waste fine dust helps eliminating the grinding cost of kaolin although it still have to be fired to 800 °C to produce meta-kaolin. The utilization of these wastes also reduces the negative effects of their disposal. In this paper a priceless waste is utilized that also helps minimizing pollution therefore offering an economic and environmentally friendly solution for producing geopolymer bricks.

2. Experimental procedures

2.1. Raw materials for bricks

The raw materials used consist of ceramic wall fine dust waste and alkali activators. Ceramic dust waste consists of kaolin clay, quartz, limestone, potash feldspar and bentonite; this is the product from cyclones following the spray drying step during wall tile body mix preparation in ceramic tiles industry. The alkaline activators used were calcium hydroxide and sodium hydroxide.

Ceramic fine dust was analyzed by X-ray fluorescence (XRF) and wavelength Dispersive (WD-XRF) Sequential Spectrometer for chemical composition. X-ray diffraction (XRD) was performed to determine the mineralogical composition of the dust.

DTA data were recorded using simultaneous Thermogravimetry – Differential Scanning Calorimetry (STA/TG-DSC). The sample was ground to −200 mesh (74 μm) and alumina was used as a reference inert material. Runs were made at a constant heating rate of 10 °C/min, and their temperatures recorded using two thermocouples. The particle size distribution (PSD) of the as received waste was investigated through Laser Particle Size Analyzer [27].

The powder densities of clay and waste were measured using the standard Pycnometer method (Density flask) [28].

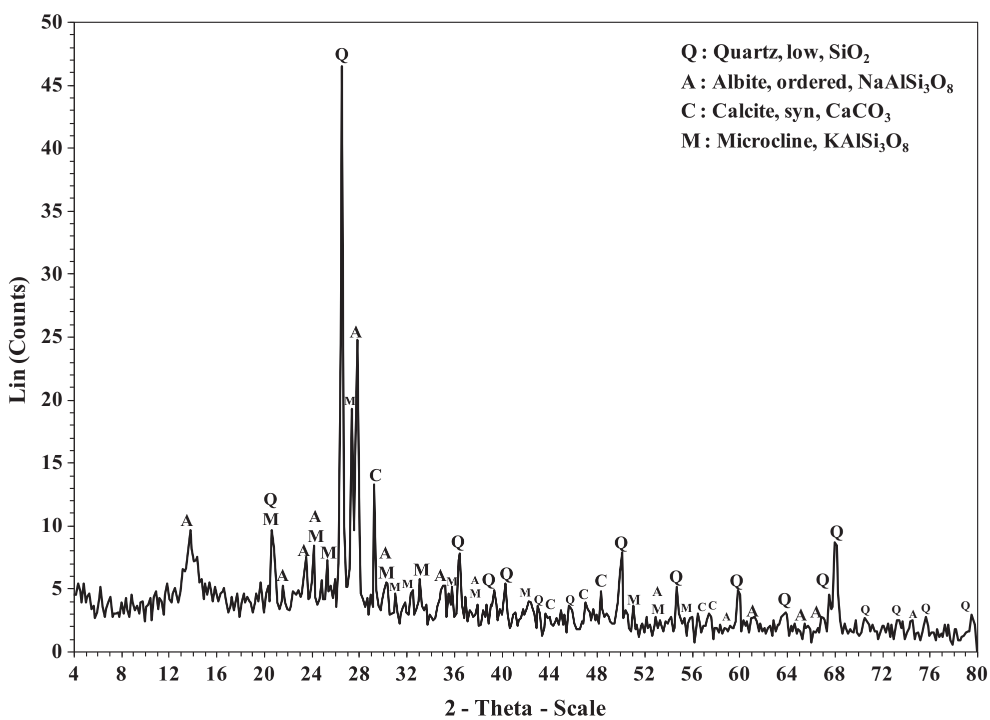

Fig. 2. XRD pattern of meta-kaolin.