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Practicable activated aluminosilicates mortar

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Abstract

Alkali-activated aluminosilicates mortars were produced from recycled bricks, water glass, and commercial grade caustic soda flakes. The solid part of the mortar was a mixture of recycled bricks and caustic soda powders. The liquid part consisted of diluted water glass. Explicitly, the liquid part did not contain the chemically aggressive high molarity sodium hydroxide. Six compositions are devised with different caustic soda and water glass contents. Setting times for the mix pastes were measured; also, the pastes were cured under ambient conditions for 1, 7, 14, 21, and 28 days. Compressive strengths were measured for the cured pastes as function of the curing times. It is found that setting times and the speed of the compressive strength development depends on the ratio of the caustic soda to the water glass content; in addition, the setting time and compressive strength were optimum at a given optimum value of this ratio. The cured pastes were characterized via X-ray diffraction, FTIR, and optical microscopy. It is shown that the produced pastes were quartz and mullite composite in gel matrix, and the peak gel build up was occurred at the optimum value of the caustic soda to the water glass ratio.

Keywords: C. Mechanical properties; Alkali activation; Recycled materials

1. Introduction

The utilization of the recycled materials and decrease in energy consumption in the production processes is a universal concern of the current research activities. Thus, the alkali-activated cementitious aluminosilicates receive increasing attention as a green alternative to Portland cements in view of the great reduction in CO_2 emissions and the potential of incorporating recycled materials as precursors [1–3]. The dominant aluminosilicate precursor for the alkali activated cement pastes is the metakaolin, prepared by calcination of kaolin at around 700 °C [4]. Nevertheless, various aluminosilicate material resources were investigated for it performance as cementitious materials, e.g. volcanic ash and fly ashes from different resources [5–8].

The preparation parameters such as the curing conditions and the SiO_2/Al_2O_3 molar ratio influence the degree of the reaction, the integrity of the microstructure, and the final mechanical properties [9–11]. Moreover, adding up of silica delays the pozzolanic reaction; consequently, an optimum value for Na_2O/SiO_2 should be attained [12].The mechanical and thermal properties were enhanced with the additions of the nano silica. The preparation of the nano silica from burned pods of ‘Delonix Regia’ and burned rice husk are among the various methods of synthesis of the nano silica. [13–14].

Recycling of waste materials is one of the valuable contributions of the alkali-activated cementitious aluminosilicates. Recycled porcelain stoneware scraps were bonded via utilization of alkali-activated metakaolin to make ceramic composites. The scraps act as partially reactive filler, but the surface reactivity were varied for various scraps, which leave the door open for further investigations [15].

The activated aluminosilicates were also suggested resolving the problem of the growing construction waste. Crushed and ground waste brick and concrete were used as starting aluminosilicate's materials. The utilized aluminosilicates were activated using industrial grade sodium silicate and sodium hydroxide. A 28-day compressive strength of 40 MPa were obtained for a certain mix [16]. The metakaolin and waste

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concrete sludge mix was also used as a source of the aluminosilicates and found that the addition of silica fume (SF) can improve both the bending and compressive strengths [17].

A serious environmental problem is the accumulation of the fly ashes from municipal solid waste (MSW) incinerators. These fly ashes are contained toxic materials such as heavy metals; thus they are potentially harmful to the environment. Two different kinds of the incinerator fly ashes (IFA) were included as 20 wt% in the starting materials of the alkali-activated metakaolin and the results show that the pollutant mobility was reduced via physical and chemical bonding [18]. Higher percentages (50–70 wt%) of the ash were included successfully in another study [19]. It is shown that both amorphous and crystalline fractions with a different degree of reactivity are present in the fly ashes, which should be considered in the formulation of the cementitious material. Alkali-activation of metakaolin with (60 and 70 wt%) of ladle slag and incinerator fly ashes were prepared and characterized [20]. One of the outcomes of this study was that the morphology of the prepared pastes was very close to that of the pure metakaolin pastes, but the presence of calcium in the case of ladle slag promotes the formation of calcium–aluminate–silicate–hydrate phase.

Extraction and mineral processing industries results in industrial solid wastes that accompanied with the risk of environmental pollution. The reuse of such materials in the synthesis of cementitious paste is value-added approach in the field of construction materials. The flotation tailings resulted from the mixed sulfide ores processing are solid wastes than can cause the generation of acid mine drainage. Mixtures of flotation tailings and fired-coal fly ash were alkali activated to produce environmental friendly materials that efficiently immobilize of the heavy metals contained in the flotation tailings [21]. Another common industrial waste is the red mud that produced by the Bayer process in Alumina industry. The red mud is highly alkaline, and its accumulation can cause serious environmental problems. Alkali-activated cementitious pastes were synthesized after partials substitution of the metakaolin by the red mud and found that the final microstructure and mechanical properties depend on the red mud contents and the curing times [22]. The red mud and rice husk ash were used produce alkali activated cementitious materials without incorporating metakaolin [23]. The compressive strengths depend on the rice husk ash to the red mud ratio with an optimum value of 20.46 MPa at the ratio of 0.5. Finally, a further progress in this area is the use of Bayer process liquors as a primary source of caustic sodium aluminate in replace of diluted sodium hydroxide [24]. The fly ash is utilized as a source of reactive silica and additional alumina and the silica fume as an additional source of reactive silica. High compressive strength of 43 MPa was accomplished. The use of plant Bayer liquor to produce cementitious paste may represent an impurity removal process for the Bayer process.

The brick fragments and the rice husks are very abundant waste in Iraq, which accumulated yearly with no serious attempts to reuse these materials. In this study, the recycled brick powder is shown as a substitute for the metakaolin and the burned 'Iraqi Anber' rice husks as source of the nano silica that can be utilized in syntheses of alkali-activated cementitious pastes. The usual utilization of high concentrations of NaOH represents a difficulty in handling alkali-activated cementitious materials and may limit its acceptance. The aim of this work is to employ alternative compositions and procedure that makes the solid part contains the aluminosilicates and solid NaOH. The liquid part consists of just diluted water glass, which makes handling of such mortars safe and easy. Finally, the correlation between the compositions related setting times of the cementitious pastes with the final compressive strengths is illuminated in this study.

2. Materials and methods

The starting materials include recycled brick fragments, which were originated from fired local clay, sodium silicates (water glass), and commercial sodium hydroxide as caustic soda flakes (NaOH 96% min). Table 1 shows the chemical composition of the used recycled bricks. The water glass was brought from Al-Taji glass-manufacturing site of the ministry of industry located at Baghdad-Iraq. Table 2 shows the specifications of the used water glass. The recycled brick fragments and the caustic soda flakes were grinded and milled via a rotary blade mill, and the final particle size was 10–53 μm in the two cases. The solid part of the mortar was prepared by dry mixing of the recycled bricks with the caustic soda powders in rotating alumina jar for two hours. The

Table 1
Chemical analysis of the recycled bricks powder and the prepared nano-silica.

	Recycled bricks	Nano Silica
SiO_2	55.25	99.1
Al_2O_3	35.98	0.35
Fe_2O_3	1.26	0.05
Na_2O	0.44	–
K_2O	0.42	–
CaO	0.24	0.25
MgO	0.44	0.25
TiO_2	1.1	–
L.O.I	4.87	–

Table 2
Specifications of the utilized sodium silicate.

Specification	Value as received	Values after adding 5 wt% Silica
Na_2O (wt%)	19.20	18.24
SiO_2 (wt%)	30.70	34.17
SiO_2/Na_2O	1.60	1.87
Density* (g/cm^3)	1.64	
PH	13.5	
Viscosity* poise	20	
Appearance	Clear liquid	

*values at 25 °C.