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The properties of cement-based mortar using different particle size of grinding waste insulator powder

Hong-seok Jang [a], Seung-young So [b,*]

[a] Department of Architectural Engineering, Chonbuk National University, Jeonju 561-756, Republic of Korea
[b] Research Center of Industrial Technology, Department of Architectural Engineering, Chonbuk National University, Jeonju 561-756, Republic of Korea

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ABSTRACT

Insulators used for high-voltage power transmission are made from ceramic, glass, porcelain or composite polymer materials. Ceramic and porcelain goods are produced from natural materials containing a high proportion of clay minerals. And waste insulator can be used as an active additive thanks to their pozzolanic properties, or as recycled aggregate in the manufacture of mortars and concrete. This research studied the effect of different particle size of grinding waste insulator proportions on binder in cement mortar. Experiments were conducted to determine the optimal replacement content and particle type to ensure that the quality of concrete products is maintained. The results indicate that the use of grinding insulator powder as an admixture for cement mortar was efficient in increasing compressive strength, workability and in reducing alkali silica reaction expansion due to the increased amount of calcium silicate hydrates created by pozzolanic reaction. And it was apparent that the properties of mortar were different with particle size of grinding insulator powder.

1. Introduction

Green is the new buzz word, and every facet of today's industry is attempting to reduce their carbon footprint. Builders today are under constant pressure to become more "earth friendly" and are constantly looking for more ways to incorporate recycled materials into their products [1]. Recycling industrial waste not only brings, huge economic benefits but also greatly helps the distribution of resources in the country [2].

Large amounts of natural resources such as gravel, sand, water and cement are used in concrete production. Also, 3 billion tons of raw materials are used each year for cement production in the world [3,4] and, cement manufacturing is responsible for about 2.5% of total worldwide CO_2 emissions from industrial sources [5,6].

The world's cement demand is anticipated to increase by about 2.5–5.8% every year until the first half of the 21st century [7]. To meet the increase of cement demand and simultaneously comply with the Kyoto Protocol, cement that gives less CO_2 discharge should be urgently developed. If cement can be manufactured with industrial byproducts, such as ground granulated blast furnace slag (GBFS), Fly ash and waste ceramic instead of clinker as its counterproposal, there would be many advantages, including maximum use of these industrial byproducts for high added-value resources, conservation of natural resources and save energy by omitting the use of clinker, minimized environmental pollution problems caused by CO_2 discharge, and reduction of the production cost.

High consumption of natural sources, high amount of production of industrial wastes and environmental pollution require obtaining new solutions for a sustainable development. One of the most effective ways to minimize the environmental effect is to use mineral admixtures as a partial cement replacement. The use of mineral admixtures in concrete production improves the compressive strength, pore structure, and permeability of the mortars and concretes [8], because of the pozzolanic reaction [9]. This approach has the potential to reduce costs, save energy, and minimize waste [10] and the lower cement requirement also leads to a reduction of CO_2 generated by the production of cement [11–15].

Generally, insulators used for high-voltage power transmission are made from ceramic, glass, porcelain. But recent rapid developments in synthetic resin technology have led to considerable demand polymer insulator. Since 2005, the demand for such polymer insulator is estimated to be approximately 160 million

* Correspondence to: Chonbuk National University Engineering 1, 125 ho, Department of Architectural: 567 Baekje-daero, deokjin-gu, jeonju-si, jeollabuk-do 561-756 Republic of Korea. Fax: +82 63 2702285.
E-mail address: archiso@jbnu.ac.kr (S.-y. So).

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Table 1
Chemical composition and physical properties of raw materials.

Sample	Chemical composition (%)								Specific gravity
	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	SO_3	B_2O_3	LOI	
OPC	21.74	61.06	5.86	3.22	3.99	2.43	–	0.78	3.15
Insulator powder	65.24	2.85	19.10	5.66	0.44	1.04	–	0.12	2.80

(output for insulator is estimated to be approximately 200 million units each year): As output rises, manufacturing processes produce increased amounts of existing products waste material. The issue of proper insulator disposal is thus a very important issue in Korea Electric Power Corporation (KEPCO).

Being amorphous and containing relatively large quantities of ceramic, glass, porcelain and calcium is – in theory – pozzolanic or even cementitious in nature when it is finely ground [16].

In this study, the replacement of cement with grinding insulator powder in a concrete was studied in detail with the aim of achieving an economic and quality product. Parameters such as compressive strength, workability, microstructure and alkali–silica reaction (ASR) expansion of mortar were considered in order to determine the optimal replacement content and thus ensure a quality of concrete product in line with the prevailing standards.

2. Experimental methods

2.1. Materials

Ordinary Portland Cement (OPC) complying with the requirements of Korean standard KS L 5201 was used. Its chemical composition and physical properties are shown in Table 1. The grinding waste insulator powder was obtained from KEPCO, Korea. To achieve a uniform particle size, the waste insulator was crushed and ground passed through 9 μm, 16 μm sieves and dried for further applications using a planetary mill (see Fig 1).

2.2. Mixing of specimens and curing

An experiment was conducted to investigate the influence of the size and content of grinding insulator powder. The mix proportions are shown in Table 2. The water/binder ratio (w/b) of all the mortars was 0.5 and the proportion of binder to sand was 1:2.45. All specimens were cast into a mould of dimensions $50 \times 50 \times 50$ mm^3 to measure the physical properties of the mortars. The specimens were left in a constant temperature and humidity chamber (20 ± 2 °C, 60 ± 10%).

2.3. Test method

2.3.1. Examination of insulator particle morphology with a scanning electron microscope (SEM)

The morphology of the insulator particles was examined using

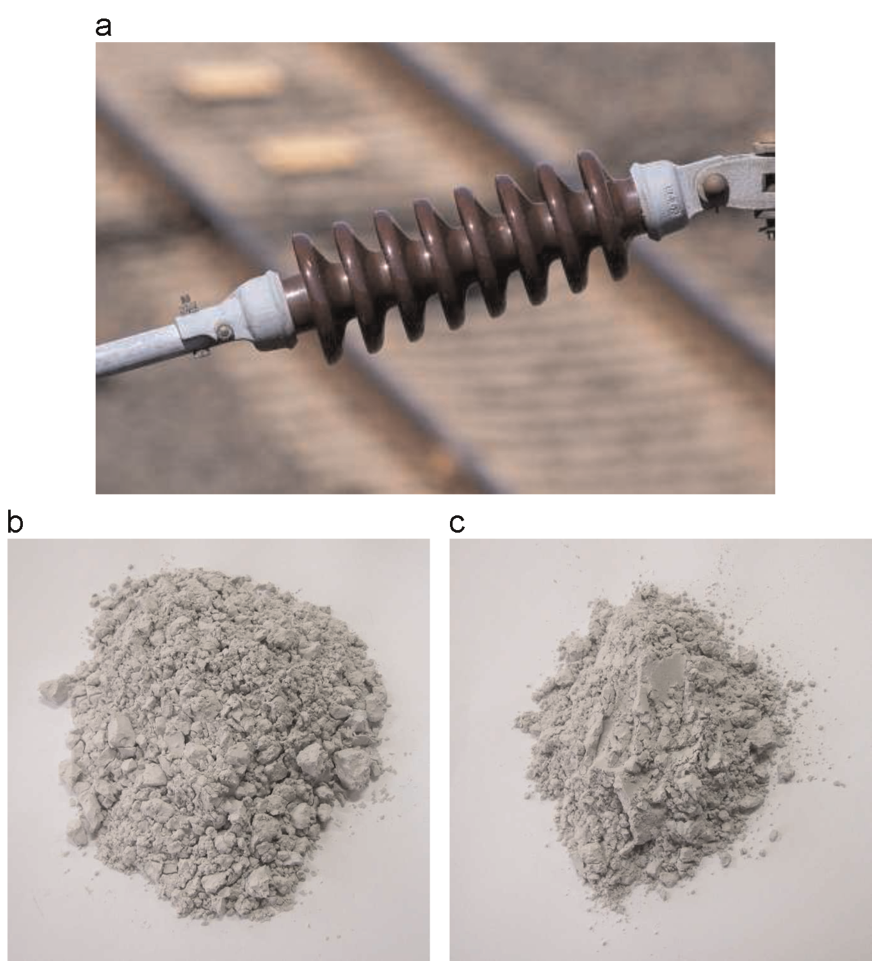

Fig. 1. Insulator and grinding insulator powder. (a) Insulator (Wikimedia commons). (b) Grinding insulator powder passing through 16 μm (A Type). (c) Grinding insulator powder passing through 9 μm (B Type).