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CO_2 emission reduction by reuse of building material waste in the Japanese cement industry

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ABSTRACT

CO_2 emitted from calcination processes in kilns comprises 60% of all emissions from cement production. The chemical components of building materials, demolished inorganic building materials (DIBMs), and waste concrete powder (WCP) are similar to those of cement minerals. Therefore, if DIBMs are used as a cement substitute material along with limestone, the quantity of disposed waste and the use of limestone will likely be reduced, as will CO_2 emissions during cement production. This study proposes a recycling method for recycled cement, using DIBMs and WCP as cement substitute materials, and the properties of trial recycled cement were evaluated. The mortar specimen using recycled cement showed a high compressive strength, as did the ordinary Portland cement mortar. According to the proposed composition, the producible recycled cement was derived from 0.5% to 9.1% of annual cement production (about 57.6 million tons) in Japan. Additionally, the CO_2 reduction by usage of recycled cement ranged from 0.06 million tons to 0.72 million tons from the total annual CO_2 emissions from cement production (about 29.4 million tons), using natural resources in Japan.

Contents

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1. Introduction

1.1. CO_2 emissions in the cement industry

The industrial sector is responsible for 30–70% [1–9] of the total global energy consumption and CO_2 emissions; the countries with the highest CO_2 emissions are shown in Fig. 1 [1]. The cement industry is one of the major contributors to greenhouse gas emissions, specifically that of CO_2, and consumes about 12–15% of total industrial energy usage [3]. Therefore, the cement industry contributes about 7% of the total worldwide CO_2 emissions as a result of fossil fuel burning (about 1.8 Gt of CO_2 emissions annually) [4]. This is due to the calcination of raw materials for the production of cement and the burning of fuels needed to maintain high temperatures in a kiln [5]. The world demand for cement was 2283 million tons (Mt) in 2005, and China accounted for about 47% of the total demand. It is predicted that the demand will increase to about 2836 Mt in the year 2010 [6]. It was also reported that China, India, the United States, and Japan produce the largest quantities of cement, globally (Table 1) [6–8].

Therefore, CO_2 emission reduction in the cement industry is of importance. Focusing on cement materials and energies, some alternative techniques that can reduce CO_2 emissions in cement manufacturing are outlined below [5,9–15]

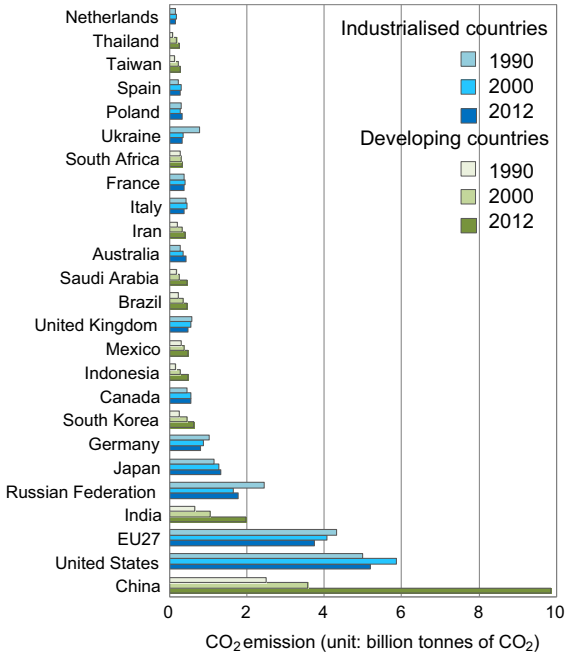

Fig. 1. Largest CO_2-emitting countries [2].

- use of waste heat as an alternative source of energy;
- use of blended cement by reducing the clinker/cement ratio;
- preparation of the raw mixture with non-carbonated calcium;
- use of alternative raw materials that contain carbonates (e.g., fly ash, blast furnace slag, and inorganic building materials).

1.2. Reducing CO_2 emissions by reusing waste building materials

The existing research is focused mainly on the technical, economic, and environmental effects of the use of industrial solid waste as alternative energies, fuels, and raw materials in the cement industry [9–17]. Among the various CO_2 reduction techniques, this study focuses on the use of alternative raw materials that contain carbonates (waste concrete powder and inorganic building material wastes) as a cement substitute material. HuXing [18] and Puertas [19] confirmed the technical viability of utilizing certain types of sludge and waste building materials as raw materials in the mixes used to manufacture Portland cement clinker.

Considering the fact that the chemical components of demolished inorganic building materials (DIBMs) and waste concrete powder (WCP) are very similar to the chemical composition of cement materials, both types could be used as raw materials in the manufacture of Portland cement clinker. The amount of waste discharged from the construction industry constitutes approximately 20% of all industrial wastes in Japan, and the space allotted

Table 1
Annual global cement production statistics (million tons) [1,6,8].

Country	2003	2005	2007	2009	2011	2012
China	865.2	1079.6	1377.8	1637.1	2100.0	2150.0
India	126.7	146.8	172.9	193.1	240.0	250.0
United states	92.9	99.4	95.5	71.9	68.6	74.0
Japan	73.8	72.7	71.4	59.6	51.3	52.0
Turkey	38.1	45.6	50.8	57.6	63.4	60.0
Iran	30.5	32.6	40.0	56.3	61.0	65.0
South Korea	59.7	49.1	54.4	52.2	48.3	49.0
Brazil	35.3	39.2	47.2	52.3	64.1	70.0
Vietnam	24.1	30.8	35.7	48.0	59.0	65.0
Egypt	32.7	38.9	40.1	46.9	44.0	44.0
Russian Federation	41.4	49.5	59.9	47.2	55.6	60.0
Indonesia	34.9	36.1	39.9	39.7	30.0	31.0
Saudi Arabia	24.1	26.1	30.3	37.8	48.4	43.0
Thailand	35.6	37.9	43.2	37.7	36.7	33.0
Mexico	31.8	36.7	39.9	37.1	35.4	36.0
Italy	43.5	46.4	47.5	36.2	33.1	32.0
Spain	44.8	50.3	54.7	30.6	22.2	20.0
Germany	33.6	31.9	33.4	30.4	33.5	34.0
Pakistan	11.3	15.8	26.3	30.9	32.0	32.0
Other countries (rounded)	–	–	–	–	470.0	500.0
World total (rounded)	–	–	–	–	3600.0	3700.0