Available online at www.sciencedirect.com
ScienceDirect
Waste Management 28 (2008) 2048–2053
waste management
www.elsevier.com/locate/wasman

Reuse of waste iron as a partial replacement of sand in concrete

Zainab Z. Ismail *, Enas A. AL-Hashmi

Department of Environmental Engineering, College of Engineering, University of Baghdad, Iraq

Accepted 1 July 2007
Available online 24 October 2007

Abstract

One of the major environmental issues in Iraq is the large quantity of waste iron resulting from the industrial sector which is deposited in domestic waste and in landfills. A series of 109 experiments and 586 tests were carried out in this study to examine the feasibility of reusing this waste iron in concrete. Overall, 130 kg of waste iron were reused to partially replace sand at 10%, 15%, and 20% in a total of 1703 kg concrete mixtures. The tests performed to evaluate waste-iron concrete quality included slump, fresh density, dry density, compressive strength, and flexural strength tests: 115 cubes of concrete were molded for the compressive strength and dry density tests, and 87 prisms were cast for the flexural strength tests. This work applied 3, 7, 14, and 28 days curing ages for the concrete mixes. The results confirm that reuse of solid waste material offers an approach to solving the pollution problems that arise from an accumulation of waste in a production site; in the meantime modified properties are added to the concrete. The results show that the concrete mixes made with waste iron had higher compressive strengths and flexural strengths than the plain concrete mixes.

1. Introduction

One of the main goals of sustainable waste management is to maximize recycling and reuse. Recycling is a logical option for materials not suitable for composting. Metals, plastics and glass are the most common of these materials (Hawken, 1994). Recycling provides opportunities for long-term diversion of major volumes of market-limited waste from landfills and for the development of lower-cost and energy-efficient products (Soroushian et al., 1995). The reuse of waste is important from multiple points of view: it helps to save and sustain natural resources which cannot be replenished, it decreases the pollution of the environment and it helps to save and recycle energy in production processes (Hassani et al., 2005). With increasing environmental pressure to reduce waste and pollution and to recycle as much as possible, the concrete industry has begun adopting a number of methods to achieve these goals (Sear, 2005). Sustainable construction requires a critical review of prevailing practices, techniques and sources of raw materials. In recent years, focus has been turning to natural and industrial wastes and byproducts that have previously received little or no attention (Bai et al., 2005).

Reuse of industrial solid waste as a partial replacement of aggregate in construction activities not only saves landfill space but also reduces the demand for extraction of natural raw materials. Preserving natural aggregates is a matter of sustainable development to ensure sufficient resources for future generations (Rakshvir and Barai, 2006).

Since approximately three-quarters of the volume of concrete is occupied by aggregate, it is not surprising that aggregate quality is of considerable importance. Not only can the aggregate limit the strength of concrete, but the aggregate properties also greatly affect the durability and structural performance of the concrete. Aggregate was originally viewed as an inert, inexpensive material. In fact, aggregate is not truly inert because its physical and sometimes chemical properties influence the performance of the concrete (Neville and Brooks, 1990).

* Corresponding author. Present address: Georgia Institute of Technology, School of Civil & Environmental Engineering, Ford Environmental Science and Technology Building, 311 Ferst Drive Atlanta, GA 30332-0512, United States. Tel.: +1 404 385 4653; fax: +1 404 894 8266.
E-mail addresses: zismail3@mail.gatech.edu, dr_zainab24@yahoo.com (Z.Z. Ismail).

0956-053X/$ - see front matter
doi:10.1016/j.wasman.2007.07.009

Akinmusuru (1991) investigated the use of steel slag as an aggregate for concrete mixes; based on the short-term results and the crushing strengths, ‘‘slagcrete’’ appeared to have potential in the construction industry. Rai et al. (2002) explored the possibility of using metallurgic slags (granulated and air-cooled) in making blended slag cement with ordinary Portland cement. The results, which indicated that slag could be used with slight modifications as non-structural concrete, provided a direction for profitable plans for making blended slag cements.

Tay et al. (2003) examined the potential for using an industrial sludge and marine clay to produce aggregates for the replacement of regular coarse aggregate in concrete. The experimental study indicated that conversion of the sludge and clay into aggregates could offer a feasible technical solution for waste management. Ghailan (2005) utilized an industrial solid waste produced from the iron and steel industry. It was physically treated, fully inspected and incorporated into concrete coarse aggregate. The results confirmed that concrete mixes made with the waste material gave a higher modulus of rigidity, higher rebound number and higher chemical resistance towards the exposure to acids/salts solutions as compared with conventional concrete mixes. Demirboga and Gül (2006) used blast furnace slag aggregate (BFSA) to produce high-strength concretes (HSC). Their results showed that the compressive strength of BFSA concretes was approximately 60–80% higher than that of traditional concretes. These concretes also had low absorption and high splitting tensile strength values. Udoeyo et al. (2006) used wood waste ash (WWA) of pretreated timber as a supplement to concrete. The compressive and flexural strengths of WWA concrete were between 62% and 91% and 65% and 98%, respectively, of the controls.

Iron represents one of the major constituents of industrial solid waste in Iraq. The principal sources of this type of solid waste are likely to include iron and steel manufacturing plants, as well as small- and medium-sized workshops. Although there are no reliable data on the quantities of these wastes generated in Iraq, there are clear signs of a sharp increase in their accumulated quantities as discarded solid wastes due to the absence or poor functioning of systems for the collection, treatment and disposal of these wastes. The main goals of this study were to investigate the following:

– The feasibility of reusing waste iron in concrete mixes as a partial replacement of aggregate in order to reduce the environmental impact resulting from waste iron disposal.
– The impact of waste iron on the properties of concrete as determined by an extensive series of tests.

2. Materials and methods

All of the materials utilized in this study are locally available. Type I Portland cement was used in this investigation. Chemical analysis of the cement was carried out according to ASTM C114-85. The chemical composition and physical properties of the cement are presented in Tables 1 and 2, respectively. The fine aggregate was natural sand of desert origin with a maximum size of 4.75 mm. Its grading conformed to ASTM C136-84. The properties and gradation of the sand are shown in Tables 3 and 4, respectively. Natural crushed stone aggregate with a maximum size of 20 mm and bulk density of 1545 kg/m^3 was used in this study.

Waste iron samples were obtained from the industrial workshops located in the Al-Sheik Omar area of center-city Baghdad. This type of waste iron is normally generated in tremendous quantities from the ironsmith processes in these workshops. A sample of the waste iron utilized in this study is shown in Fig. 1. The maximum size of the waste-iron particles was 4.75 mm, and the gradation

Table 1
Chemical composition of cement

	% (by weight)
Compounds	
Lime	64.43
Silica	21.14
Alumina	5.78
Iron oxide	3.59
Sulfite	2.35
Magnesia	1.52
Loss of ignition	0.89
Lime saturation factor	0.92
Insoluble residue	0.34
Main compounds (Bogue's equation) % by weight	
Name of compounds	
Tricalcium silicate	50.83
Dicalcium silicate	22.30
Tricalcium aluminate	9.25
Tetra calcium aluminoferrite	10.90

Table 2
Physical properties of cement

Properties	Limit	Test method
Fineness (m^2/kg)	269.50	ASTM C204-92
Initial setting time (min)	3:20	ASTM C191-82
Final setting time (h)	4:15	ASTM C191-82
Soundness	0.19	ASTM C151-84
3 days age compressive strength (MPa)	24.96	ASTM C109-92
7 days age compressive strength (MPa)	30.80	ASTM C109-92

Table 3
Properties of sand

Properties	Limit
Sulfate (%)	0.80
Fineness modulus	2.37
Absorption (%)	2.71
Maximum size (mm)	4.75
Density (kg/m^3)	1688
Specific gravity	2.57