Cement and Concrete Research 41 (2011) 533–541

Contents lists available at ScienceDirect

Cement and Concrete Research

journal homepage: http://ees.elsevier.com/CEMCON/default.asp

Post-fire residual mechanical properties of concrete made with recycled concrete coarse aggregates

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ARTICLE INFO

Article history:
Received 1 October 2010
Accepted 1 February 2011

Keywords:
Temperature (A)
Mechanical Properties (C)
Cement Paste (D)
Concrete (E)
Waste Management (E)

ABSTRACT

This paper presents results of an experimental study on the residual mechanical performance of concrete produced with recycled coarse aggregates, after being subjected to high temperatures. Four different concrete compositions were prepared: a reference concrete made with natural coarse aggregates and three concrete mixes with replacement rates of 20%, 50% and 100% of natural coarse aggregates by recycled concrete coarse aggregates. Specimens were exposed for a period of 1 h to temperatures of 400 °C, 600 °C and 800 °C, after being heated in accordance with ISO 834 time–temperature curve. After cooling down to ambient temperature, the following basic mechanical properties were then evaluated and compared with reference values obtained prior to thermal exposure: (i) compressive strength; (ii) tensile splitting strength; and (iii) elasticity modulus. Results obtained show that there are no significant differences in the thermal response and post-fire mechanical behaviour of concrete made with recycled coarse aggregates, when compared to conventional concrete.

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1. Introduction

Construction industry in general and concrete industry in particular are facing considerable pressure in order to reduce their environmental impact. With this in mind, an effort has been made in order to reduce the consumption of natural resources extracted and, in addition, to establish sustainable alternatives for the management of construction and demolition wastes [1,2].

In this context, extensive research has been carried out over the past two decades on the viability of using recycled aggregates in the production of structural concrete. The main effects of incorporating ceramic [3,4] or concrete [5–9] recycled aggregates, or a combination thereof [10], on the mechanical (short-term) and durability performance of concrete are now reasonably well-known. Accordingly, the European Standard EN 12620 [11] already specifies the requirements that recycled aggregates must comply with in order to be used in the production of structural concrete. In addition, several countries have already released national regulations that define the conditions under which those aggregates can be used [12–15]. Nonetheless, in order to allow for the widespread use of this alternative in the construction industry, there are still some issues that need to be addressed, among which the behaviour of concrete with recycled aggregates when subjected to extreme conditions, namely when exposed to fire.

The present study was developed in order to investigate the residual mechanical performance of concrete made with recycled concrete coarse aggregates (CRCCA) after exposure to high temperatures. The research focused on evaluating the residual mechanical properties of CRCCA, namely the assessment of compressive and splitting tensile strengths and elasticity modulus after fire [16]. For this purpose, four different concrete compositions were produced: a conventional reference concrete (RC) and three concrete mixes with replacement rates of 20%, 50% and 100% of natural coarse aggregates (NCA) by recycled concrete coarse aggregates (RCCA). In addition to the reference temperature (20 °C), those compositions were exposed, for 1 h, to temperatures of 400 °C, 600 °C and 800 °C, after being heated in accordance with the standard curve ISO 834.

2. Literature review and research significance

The behaviour of normal strength conventional concrete under fire, which started to be investigated in the 1920s and has been the object of several studies since then, is now reasonably well understood [17–19]. The deterioration of the mechanical properties of concrete subjected to very high temperature stems from the considerable modifications undergone by its components, namely the physicochemical changes in the cement paste and in the aggregates, coupled with the thermal incompatibility between them [19].

At temperatures of 70–80 °C ettringite dissociates and at about 100 °C the water physically bound in both the aggregates and the cement matrix starts to evaporate, increasing capillary porosity and microcracking — at these relatively low temperatures, concrete may only experience a minor loss of strength. At temperatures ranging from 250 to 300 °C the loss of bound water in the cement matrix

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doi:10.1016/j.cemconres.2011.02.002