Cement and Concrete Research 41 (2011) 392–402

Contents lists available at ScienceDirect

Cement and Concrete Research

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

Influence of the nature of aggregates on the behaviour of concrete subjected to elevated temperature

Zhi Xing [a], Anne-Lise Beaucour [a,*], Ronan Hebert [b], Albert Noumowe [a], Béatrice Ledesert [b]

[a] Université de Cergy-Pontoise, L2MGC, EA 4114, F-95000 Cergy-Pontoise, France
[b] Université de Cergy-Pontoise, Géosciences et Environnement Cergy, EA 4506, F-95000 Cergy-Pontoise, France

ARTICLE INFO

Article history:
Received 14 May 2010
Accepted 11 January 2011

Keywords:
Aggregate (D)
Concrete (E)
Mechanical properties (C)
Temperature (A)
Thermal treatment (A)

ABSTRACT

An experimental study is carried out on concretes composed of three different types of aggregates: semi crushed silico-calcareous, crushed calcareous and rolled siliceous. For each aggregate type, two water/cement ratios (W/C), 0.6 and 0.3 are studied. Aggregates and concrete specimens were subjected to 300, 600 and 750 °C heating–cooling cycles. We analyse the evolution of thermal, physical and mechanical properties of concrete in terms of behaviour and physical characteristic evolutions of aggregates with temperature. The study of thermal behaviour of aggregates showed the importance of initial moisture state for the flints. The crystallisation and microstructure of quartz play an important role in the thermal stability of siliceous aggregates. The residual mechanical behaviour of concrete varies depending on the aggregate and the influence of aggregates is also dependent on paste composition. This study allowed to better understand the influence of chemical and mineralogical characteristics of aggregates on the thermomechanical behaviour of concrete.

1. Introduction

The high temperature concrete behaviour is strongly linked to the properties of the cement paste. Indeed, it is within the cement paste that occur the main phenomena of dehydration and expulsion of moisture that lead to concrete deterioration. For about fifteen years, several studies have improved the understanding of the physico-chemical and microstructural evolution of the binding phase [1–4]. But does it mean that aggregates only play a negligible role? Aggregates represent a considerable proportion of volume in the concrete and the thermal conductivity of concrete must be considerably influenced by the thermal conductivity of aggregates. In addition, according to their mineralogical composition and their internal microstructure, it is very likely that aggregates have very different values of thermal conductivities. Moreover, this conductivity evolves differently with temperature depending on the type of aggregates. On the other hand, because of bleeding and a wall effect, there is an accumulation of water at the paste–aggregate interface. This greater water quantity creates a more porous zone in which cracking will be initiated. The aggregate-matrix interface can therefore be considered as the “weak link” of ordinary concrete and is often causing the concrete deterioration. The quality of the paste–aggregate bond is highly dependent on the geometry of the aggregates and on their mineralogical nature (reactive or not with the paste) [5,6].

Then it appears necessary to complete the existing studies about the influence of aggregates on the thermomechanical behaviour of concrete. Few studies have been published until now [7–11]. Several studies showed that a concrete made of siliceous aggregate has worse behaviour than a calcareous aggregate concrete [8,10,12]. The decrease in compressive strength of calcareous aggregate concretes occurs at higher temperatures compared to siliceous aggregate concretes [13]. This is generally attributed to the higher thermal expansion of siliceous aggregates and to the volume increase due to the phase transition (at 573 °C) from α-quartz to β-quartz [14,15]. Some authors also explain that the specific heat of calcareous aggregates is higher than that of siliceous aggregates and that the specific heat of calcareous aggregates is approximately ten times the heat needed to produce the same temperature rise in siliceous aggregates over 600 °C[16]. So carbonate aggregates may increase the fire endurance of concrete compared to that of siliceous aggregates [16,17]. Nevertheless, [11] showed that concretes prepared with some siliceous aggregates can have better mechanical residual behaviour than those with calcareous aggregates. The results of this study disagree with the Eurocode 2-1-2 predictions [12]. Moreover, the carbonates, which have broken down releasing carbon dioxide during heating, re-hydrate during cooling. This re-hydration reaction (44% increases in volume) is believed to cause “post-cooling spalling” in calcareous concretes [18]. These information show that previous studies need to be completed by experimental data on the thermomechanical behaviour of concretes prepared with different natures of aggregates in order to provide a better understanding of the influence of the chemical composition and mineralogy of aggregates.

The objective of this study is to analyse the influence of aggregates on the high temperature behaviour of normal and high performance concretes. Three different types of aggregates are studied (see below for details). Aggregates were subjected to 5 individual heating–cooling cycles

* Corresponding author. Tel.: +33 1 34 25 69 75; fax: +33 1 34 25 69 41.
E-mail address: Anne-Lise.Beaucour@u-cergy.fr (A.-L. Beaucour).

0008-8846/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cemconres.2011.01.005