Cement and Concrete Research 41 (2011) 380–391

Contents lists available at ScienceDirect

Cement and Concrete Research

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

Impact of time-dependant thermal expansion coefficient on the early-age volume changes in cement pastes

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ARTICLE INFO

Article history:
Received 8 September 2010
Accepted 11 January 2011

Keywords:
Fresh concrete
Shrinkage (C)
Cement paste
Granulated blast-furnace slag
Thermal expansion coefficient

ABSTRACT

Volume changes and time-dependent thermal expansion coefficient were determined at early stages and the measured total strain was separated into thermal strain and autogenous strain. Cement paste specimens were subjected to temperature histories that imitated hydration-induced temperature rise of the mass concrete. It was shown that the thermal expansion coefficient increased significantly with the development of hydration and became more conspicuous when the ground granulated blast furnace slag was added. The time-dependant increase of thermal expansion coefficient, due to self-desiccation, could result in considerable shrinkage strain at the end of the temperature history. The impact of the time-dependant increase of thermal expansion coefficient might be taken into account as one of the necessary factors in the crack control design from now and cannot even be neglected within the range of the water to binder ratio of this study, because the shrinkage originated in that effect sometimes exceed the autogenous shrinkage.

1. Introduction

When ground granulated blast furnace slag, GGBFS, is admixed with concrete, thermal expansion coefficient [1] and autogenous shrinkage [2] increase compared with those of normal concrete. The increase in the autogenous shrinkage is more significant when subjected to high temperature histories due to the hydration reactions. The Japanese guideline for the crack control of mass concrete specified that the ground granulated blastfurnace slag cement concrete should presume its thermal expansion coefficient 20% larger than that of the normal concrete and the designed autogenous shrinkage should be larger than that with the ordinary Portland cement—OPC [3]. The aim of this study includes the discussion on the volume change mechanism of the GGBFS-added concrete.

The autogenous shrinkage is generally determined by subtracting thermal dilatation out of the measured total strain with an assumption that the thermal expansion coefficient is constant throughout the measurement [4,5]. As far as the thermal crack risk is discussed in terms of the total strain, this may not invite significant problems while there still is a possibility of confusing the effects of thermal strain and autogenous shrinkage. In fact, countermeasures for the thermal cracking would become significantly different whether the emphasis is laid on the reduction of the autogenous shrinkage or control of the thermal dilatation.

In this study, careful examination of the factors affecting the thermal cracking was attempted and measurements of total strain and thermal expansion coefficient of early-age cement pastes were conducted followed by the separation of the thermal strain and the autogenous strain out of the total strain (hereafter we use 'autogenous strain' on behalf of 'autogenous shrinkage' because sometimes strain of cement paste or concrete due to self-desiccation by hydration shows expansion). During the measurement, specimens were subjected to high temperature histories imitating the hydration heat and to instantaneous thermal pulses to determine the thermal expansion coefficients at each age of the specimen.

Determination of the thermal expansion coefficient of early-age concrete, mortar or cement paste has been performed mostly by length change measurement during changes in temperature. The employed sensors included contact displacement gauge [6–8], laser displacement meter [9], vibrating wire extensiometer [10] and fiber-optic deformation sensor [11]. A dilatometer was also used when measurement begins immediately after mixing [12,13].

As Loser [13] pointed out, contact type gauges may not be appropriate if applied to specimens in a plastic state at very early stages because the contact pressure may pose some effects on the volume change of the specimen. The contact-free laser displacement meter may similarly be inappropriate when the specimen is not elastic enough to give changes in the gauge marks. However, as the existing studies have shown [6,7,9,10,12] that the thermal expansion coefficient decreases immediately after mixing and shows a minimum around the set point in accordance with the development of stiffness of the specimen, use of the reliable laser displacement meter to measure the post-setting thermal deformations may be allowed when

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0008-8846/$ – see front matter
doi:10.1016/j.cemconres.2011.01.003