Cement and Concrete Research 41 (2011) 981–986

Contents lists available at ScienceDirect

Cement and Concrete Research

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

Revisiting the protected paste volume concept for internal curing of high-strength concretes

Semion Zhutovsky *, Konstantin Kovler, Arnon Bentur

National Building Research Institute, Faculty of Civil and Environmental Engineering, Technion — Israel Institute of Technology, Haifa 32000, Israel

ARTICLE INFO

Article history:
Received 22 January 2011
Accepted 17 May 2011

Keywords:
High-strength concrete (E)
Internal curing (A)
Autogenous shrinkage (C)
Porosity (B)

ABSTRACT

Internal curing of high-strength concrete has been the subject of extensive research for the last decade. The concept of protected paste volume has been one of the most significant theoretical approaches to internal curing. In this paper, the applicability of the protected paste volume concept to internal curing is re-evaluated in view of recent experimental evidence. It is shown, that the concept of protected paste volume and recommendation to limit the spacing factor to approximately 200 μm, cannot be extended to internal curing of high-strength concrete, since the distance of penetration of the internal curing water into the surrounding matrix depends mainly on the availability of internal curing water to the surrounding cementitious matrix. The pore structure of LWA and the size of SAP particles seem to have a marked influence on the availability of internal curing water and thus are factors of greater importance than the spacing factor.

1. Introduction

The popularity of high-strength concrete (HSC) is growing steadily due to its outstanding mechanical and durability characteristics. However, the high early-age cracking sensitivity of HSC limits its application [1–3]. Non-structural cracking of HSC is induced by self-desiccation and autogenous shrinkage [4]. Conventional curing methods are not effective for HSC, since curing water cannot penetrate into low permeability concrete. For this reason, internal curing was proposed [5–7], which implies distributing internal curing water reservoirs inside the concrete. Water-saturated lightweight aggregate (LWA) [8,9], superabsorbent polymers (SAP) [10,11] and other porous materials [12,13] can serve as internal curing water reservoirs. These porous materials used for internal curing are referred to as internal curing agents.

Poor mechanical properties of the porous internal curing agents can have detrimental effect on the mechanical properties of HSC [8,9]. Therefore it was suggested to optimize the size and amount of internal curing agent in accordance with the protected paste volume concept [9]. This concept suggests minimizing the size of internal curing agent particles, so that all the cement paste will lie within a sufficiently small distance from the internal curing agent particle surface, to which the internal curing water could penetrate. In this case the cement paste would be "protected" from self-desiccation. According to this concept "spatial proximity" of internal curing water reservoir to the cement paste matrix is the most important parameter. Implied however is that the reservoir holds sufficient water for curing the paste in the perimeter of its proximity and that all of this water is readily available to penetrate into the surrounding paste.

Recent experimental data demonstrated some discrepancy between the theory and behavior of internally cured HSC. In this paper the results of relevant experimental studies on internal curing are reviewed and the applicability of protected paste volume concept to internal curing is revised. Various engineering parameters for the description of internal curing processes and their suitability as design criteria are discussed.

2. Internal curing

The use of HSC has been expanding due to its superior mechanical and durability properties [14,15]. HSC has its economical benefits, significantly reducing maintenance costs and enhancing service life [16]. Enhanced durability of HSC makes its use very attractive in the environments where ordinary concrete would not suffice. The HSC has had a continuous growing number of applications: marine structures, high-rise buildings, bridge decks and piers, thin-wall shells, airport pavements and many others. However, HSC advancement is hindered by its early-age cracking sensitivity.

HSC made with extremely low w/c ratios is prone to self-desiccation that results in autogenous shrinkage [3,17]. Autogenous shrinkage is restrained internally by aggregates and externally by neighboring structural members, and thus induces tensile stresses which lead to cracking and even fracture [18,19]. Obviously, cracking leads to reduced mechanical properties and impaired durability. In order to reduce autogenous shrinkage of HSC and to prevent its early-age cracking it was suggested to introduce into the HSC mix pre-

* Corresponding author. Tel.: +972 507150769.
E-mail address: semionz@yahoo.com (S. Zhutovsky).

0008-8846/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cemconres.2011.05.007