Cement and Concrete Research 41 (2011) 1150–1156

Contents lists available at ScienceDirect

Cement and Concrete Research

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

Pore pressure development in hybrid fibre-reinforced high strength concrete at elevated temperatures

Mugume Rodgers Bangi *, Takashi Horiguchi

Hokkaido University, Graduate School of Engineering, Laboratory of Environmental Material Engineering, N13-W8, Sapporo 060-8628, Hokkaido, Japan

ARTICLE INFO

Article history:
Received 10 February 2011
Accepted 6 July 2011

Keywords:
Temperature (A)
High performance concrete (E)
Fibre reinforcement (E)
Mechanical properties (C)
Spalling

ABSTRACT

The present experimental work investigates the build-up of pore pressure at different depths of High Strength Concrete (HSC) and Hybrid-Fibre-Reinforced High Strength Concrete (HFRHSC) when exposed to different heating rates. First, the effect of the measurement technique on maximum pore pressures measured was evaluated. The pressure measurement technique which utilised a sintered metal and silicon oil was found to be the most effective technique for pore pressure measurement. Pore pressure measurements carried out showed that addition of polypropylene fibres is very effective in mitigation of spalling and build-up of pore pressure inside heated HSC. Addition of steel fibres plays some role in pore pressure reduction at relatively higher pressures in deeper regions of concrete during fast heating. Pore pressure development is highly influenced by the rate of heating with fast heating leading to higher pore pressures in the deeper regions of concrete compared to slow heating.

1. Introduction

High strength concrete (HSC) has been increasingly utilised in construction of many civil engineering structures worldwide such as bridges, high-rise buildings and tunnels because of its superior performance compared to normal strength concrete due to its low permeability and improved durability. However fire accidents which have occurred involving infrastructures and various studies have shown that high strength concrete performance is highly susceptible to high temperature condition [1–5] because of its low permeability. Thermal instability in form of spalling has been observed which leads to breaking off of layers or pieces of concrete from the thermally exposed surface and this significantly compromises the structural integrity of the concrete structures [2,5,6].

However, studies by different researchers on the factors influencing the occurrence of explosive spalling are inconsistent and not in agreement with each other. Studies on HSC [7,8] which used a similar slow heating rate but different pressure measurement techniques observed quite different maximum pore pressures whilst other studies [9–13] using fast heating rates measured significantly different maximum pore pressures. Also some findings [8,9,14] are not in agreement with classical theoretical considerations of the effect of heating rate on pore pressure development in concrete where by an increase in heating rate should lead to an increase in maximum pore pressures. Due to its superior performance and increased usage, it is very important to clearly understand factors influencing the occurrence of explosive spalling in HSC when exposed to elevated temperatures.

The purpose of this experimental study is to evaluate the effect of the measurement technique on the maximum pore pressures measured since it has already been observed that researchers have recorded varying maximum pore pressures. Also measurement of the build-up of pore pressure at different depths inside concrete was done as well as evaluating the effect of heating rate on pore pressure development. Furthermore, the effect of hybrid (HY) fibre reinforcement (a combination of polypropylene and steel fibres) on the mitigation of spalling and pore pressure development inside HSC exposed to elevated temperatures has been studied. It has been observed in previous studies [4,15–17] that hybrid fibre reinforced concrete showed better performance of the mechanical properties during and after exposure to elevated temperatures compared to Plain and polypropylene (PP) mixtures hence, there is a need to ascertain whether a hybrid system contributes towards spalling mitigation.

The present study involves the analysis of the thermal–hydral process of different series of concretes at 10, 30 and 50 mm depths using three heating rates of slow, moderate and relatively fast heating. Also, pore pressure measurement using three different measurement techniques was conducted in order to determine the most appropriate pore pressure measurement technique.

2. Experimental procedure

2.1. Materials and mix proportions

Six series of concretes were prepared using OPC (Ordinary Portland Cement) and crushed stone with the maximum nominal

* Corresponding author. Tel.: +81 11 706 6180; fax: +81 11 706 6179.
E-mail addresses: mugume_2rb@eng.hokudai.ac.jp (M.R. Bangi), horiguti@eng.hokudai.ac.jp (T. Horiguchi).

0008-8846/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cemconres.2011.07.001