Cement and Concrete Research 41 (2011) 56–63

Contents lists available at ScienceDirect

Cement and Concrete Research

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

A thermal active restrained shrinkage ring test to study the early age concrete behaviour of massive structures

M. Briffaut [a,b], F. Benboudjema [a], J.M. Torrenti [c,*], G. Nahas [a,b]

[a] LMT/ENS Cachan/CNRS UMR8535/UPMC/PRES UniverSud Paris, Cachan, France
[b] Institut de radioprotection et de sûreté nucléaire, Fontenay-aux-Roses, France
[c] Université Paris Est, Laboratoire central des ponts et chaussées, Paris, France

ARTICLE INFO

Article history:
Received 8 March 2010
Accepted 9 September 2010

Keywords:
Early age
Massive structures
Thermal shrinkage
Autogenous shrinkage
Ring test

ABSTRACT

In massive concrete structures, cracking may occur during hardening, especially if autogenous and thermal strains are restrained. The concrete permeability due to this cracking may rise significantly and thus increase leakage (in tank, nuclear containment…) and reduce the durability.

The restrained shrinkage ring test is used to study the early age concrete behaviour (delayed strains evolution and cracking). This test shows, at 20 °C and without drying, for a concrete mix which is representative of a French nuclear power plant containment vessel (w/c ratio equal to 0.57), that the amplitude of autogenous shrinkage (about 40 µm/m for the studied concrete mix) is not high enough to cause cracking. Indeed, in this configuration, thermal shrinkage is not significant, whereas this is a major concern for massive structures.

Therefore, an active test has been developed to study cracking due to restrained thermal shrinkage. This test is an evolution of the classical restrained shrinkage ring test. It allows to take into account both autogenous and thermal shrinkages. Its principle is to create the thermal strain effects by increasing the temperature of the brass ring (by a fluid circulation) in order to expand it. With this test, the early age cracking due to restrained shrinkage, the influence of reinforcement and construction joints have been experimentally studied. It shows that, as expected, reinforcement leads to an increase of the number of cracks but a decrease of crack widths. Moreover, cracking occurs preferentially at the construction joint.

1. Introduction

At early age in massive concrete structures, cracking may occur during hardening. Indeed, hydration is an exothermic chemical reaction (temperature in concrete may overcome 60 °C [1–3]). Therefore, if autogenous and thermal strains are restrained (self restraint, construction joints), compressive stresses and then tensile stresses rise, which may reach the concrete strength and induce cracking in a real structure. For instance, Ithuralde [1] observed several crossing cracks (opening up to 0.5 mm) in a 1.2 m width concrete wall (representative of French nuclear power plant containment), cast on a concrete slab. For structures like tanks or nuclear containment vessels, this cracking may significantly increase concrete permeability and reduce tightness. For other massive structures (bridges, tunnels…), the serviceability may be reduced due to the penetration of aggressive species (such as carbon dioxide, sulfate and chloride ions).

The restrained shrinkage ring test is used to determine the concrete behaviour (creep strain and cracking) due to autogenous and drying shrinkages. In this study, a concrete mix, which is representative of a French nuclear power plant containment vessel, is tested. This test shows that, at 20 °C with this concrete and without drying (for nuclear power plant containment the formwork remains during about 2 weeks after casting, which prevents drying and thus subsequent cracking due to drying shrinkage at early age) the amplitude of autogenous shrinkage is not sufficient to cause cracking. Indeed, in this configuration (classical restrained shrinkage ring test), thermal shrinkage does not occur whereas in massive structures thermal strains restraint (due to internal restraint, i.e. temperature gradients or due to construction joints) is the main phenomena involved in cracking [4,5]). Therefore, a device, which is an evolution of the classical restrained shrinkage ring test (devoted to be representative of a massive structure), has been developed to study the cracking due to restrained thermal shrinkage in laboratory conditions. Effectively, to the authors' knowledge, only few experimental devices exist in literature to study cracking due to the restraint of thermal shrinkage [6,7] and requires a complex load system or are limited to mortar samples.

Cracking highly depends on creep (essentially basic and thermal creep in massive structures). However, the question whether creep strains are the same in compression (such tests are “classical”) and

* Corresponding author. Tel.: +33 1 40 43 54 40.
E-mail address: jean-michel.torrenti@lcpc.fr (J.M. Torrenti).

0008-8846/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cemconres.2010.09.006