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ScienceDirect

Procedia Engineering 161 (2016) 583 – 588

Procedia Engineering

www.elsevier.com/locate/procedia

World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium 2016, WMCAUS 2016

Experimental Investigation of the Variation of Concrete Pores under the Action of Freeze-Thaw Cycles

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Abstract

The variation of concrete pores under the action of freeze-thaw cycles was investigated experimentally by using the X-ray tomography (X-ray CT). Firstly, the statistical characteristics of concrete pores of testing specimens were obtained by the X-ray image analysis. Secondly, the variations of porosity and pore volume of concrete were analyzed and discussed through the comparison with the above characteristics. Thirdly, the failure process of the concrete specimens under the freeze-thaw cycles was investigated by scanning the interior structure of concrete specimens. The results showed that there was no big variation of both the amounts and volume of concrete pores that were located at the interval [0.5mm^3, 20mm^3], while a huge change was observed during the process of the experiment for the pores in other intervals. The severity of damages caused by the repeated freezing and thawing actions gradually ranged from surface spalling to a completed disintegration of the interior concrete specimens after 30 freeze-thaw cycles.

Peer-review under responsibility of the organizing committee of WMCAUS 2016

Keywords: concrete; pore; freeze-thaw cycles; X-ray CT;

1. Introduction

Improvement of the durability of concrete material is a significant and scientific issue for the design of civil structures [1]. In cold climate regions, the durability of concrete structures decreases owing to the effect of some

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Peer-review under responsibility of the organizing committee of WMCAUS 2016
doi:10.1016/j.proeng.2016.08.696

environmental factors, especially one of which is well known as the freeze-thaw cycles [2]. Under the repeated action of freeze-thaw, the frost damage is a major concern for the design and maintenance of concrete structures [3]. Therefore, it is necessary to thoroughly investigate and reasonably evaluate the deterioration of concrete structures in order to improve the durability and safety of concrete structures [4].

For the effective maintenance of concrete structures under freeze-thaw condition, the focus was not on the damage of structures themselves but on the failure mechanism of concrete material [5]. Considering this point, the X-ray micro-tomography (X-ray CT), which is a powerful tool for non-destructively investigating the three-dimensional microstructure of a material, was applied to investigate the failure process of concrete material under the action of freeze-thaw cycles in this study [6].

2. Materials and Experiments

2.1. Materials and mix proportions

The local materials were utilized in order to implement this study. A Chinese Standard (GB175-2007) 42.5 Ordinary Portland cement was applied for the cementitious material during the experiment. The fine aggregate was natural river sand with the fineness modulus of 2.9, and the coarse aggregate was single-grading crushed stone with diameter from 5 mm to 10 mm. The water reducer was the polycarboxylate superplasticizer, and the designed mix proportions of concrete for experiment are listed in Table 1.

Table 1. Mix proportions of concrete used for experiment

	Amount of concrete per cubic meter (kg/m^3)				Water-cement ratio	Sand (%)	28-day compressive strength (MPa)
	Cement	Water	Sand	Stone			
A	380	190	659	1121	0.5	37	35.5
B	430	172	664	1084	0.4	38	46.4
C	477	138	622	1262	0.29	33	60.5

2.2. Apparatus and testing specimens

A desktop micro-focus CT system was applied to obtain the slice images of each specimen. The set-up of this experimental system consists of a micro-focus X-ray emitter, a five-axis rotary worktop, an image intensifier detector and a software sub-system. Some photos of this experimental system are shown in the following figure.

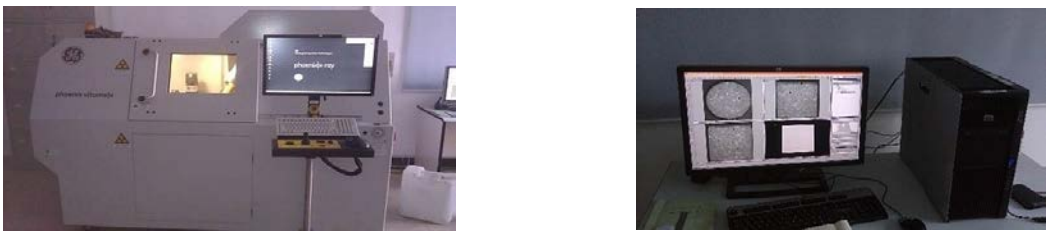

Fig. 1. Photo of X-ray CT system (Mode: Phoenix v|tome|xs).

To investigate the distribution of the concrete pore, each specimen is divided into four parts. The rule for this partition is described as follows. As shown in Fig. 2, the diameter of the specimen is deemed as four circles: ø75mm, ø60mm, ø40mm, ø20mm, respectively.