Physics and Chemistry of the Earth 128 (2022) 103253

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Compressive properties and microscopic analysis of engineered cementitious composites after salt freezing

Jialing Che [a,*], Mengying Gong [a], Xue An [a], Haifeng Liu [a], Shu Ing Doh [b]

[a] *School of Civil and Hydraulic Engineering, Ningxia University, Yinchuan, 750021, China*
[b] *Faculty of Civil Engineering Technology, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300, Gambang Kuantan, Pahang, Malaysia*

ARTICLE INFO

Keywords:
Engineered cementitious composites
Freezing–thawing cycles
Compressive performance
Stress–strain curve
Microstructure

ABSTRACT

In order to study the compressive properties of Engineered Cementitious Composites (ECC) after salt freezing, the failure, compressive strength, and deformation capacity of cubic concrete specimens subjected to single-side freezing–thawing cycles considering the number of cycles, aggregate type Maowusu or Tengger Desert sands (MDS and TDS, respectively) and river sand (RS), and salt medium (NaCl or NaCl + Na_2SO_4). The results showed, In the presence of salt, the compression failure modes of all samples involved the formation of vertical cracks in the stress direction, but MDSECC and TDSECC showed better integrity than C30 concrete. With increasing freeze–thaw cycles, the strengths, slopes of the stress–strain curves, peak stress, and curve area of the desert sand specimens decreased, but the residual stress and ductility increased. Through regression analysis of the strength loss rate, the ECC lifetime was predicted, and using X-ray diffractometry and scanning electron microscopy, the effects of salt freezing on the mechanical properties of ECC were revealed.

1. Introduction

Li et al. proposed the basic design concept of engineered cementitious composites (ECC) based on micromechanical and fracture mechanics principles (Li and Leung, 1992). Owing to the excellent mechanical properties of ECC, it can be used to improve the durability of components and reduce concrete brittleness (Maalej and Li, 1995). Research has shown that component durability can be improved by using ECC instead of ordinary concrete in steel–concrete joints, for building repair, and in bridge decks and pavements (Xu and Li, 2008). Because of the increasing use of ECC, the study of its mechanical properties after salt freezing is crucial to ensure structural safety and improve its durability (Luo et al., 2020) and service life. On the basis of material durability research, the durability at the structural (Ma et al., 2021; Liu et al., 2021) level can be further studied.

In addition, because of the high cost of silica sand, the complexity of manufacturing sand, the shortage of river sand, and the need for more green and sustainable engineering methods, the use of local desert sand as construction sand has drawn attention. In fact, studies have found that desert sand can replace fine aggregate to produce concrete that meets the functional requirements (Wang et al., 2014; Liu et al., 2016; Ren et al., 2018; Yan et al., 2019; Zhang et al., 2019), and the use of desert sand to replace construction sand completely for the preparation of high-toughness cement-based composites has been proposed. Practically, the particle size and type of fine aggregate affect the toughness of the ECC matrix (Sahmaran et al., 2009), which also affects the salt freezing performance of ECC. Therefore, it is necessary to study the durability of these materials (Iqbal Khan et al., 2017; Meng et al., 2017; Che et al., 2017; Che et al., 2019; Yang et al., 2021; Che et al., 2022).

Environmental factors such as freeze–thaw cycles and salt erosion are important causes of the degradation of cement-based materials and the shortening of service life. In fact, combined salty and freezing conditions are a key cause of loss of durability (Kosior-Kazberuk and Berkowski, 2017; Zhao et al., 2004). At present, the “quick freezing method” is widely used to study the frost resistance of fiber-reinforced cement matrix composites subjected to freeze–thaw cycles, and these studies mainly focus on the ductility (Yun, 2013; Xu et al., 2009), relative dynamic elastic modulus (Sun et al., 2002; Mu et al., 2002; Xu and Cai, 2010), and flexural toughness (Yun and Rokugo, 2012; Ahmed and Mihashi, 2007) of the material after freeze–thaw cycling. But the destruction of materials under the condition of single-sided salt freezing and thawing can better reflect the actual engineering situation of roads and bridge decks damaged by deicing salt. Therefore, Wang (Wang et al., 2017) studied the effects of fiber content, water-binder ratio, and fly ash

---

* Corresponding author.
E-mail address: che_jialing@nxu.edu.cn (J. Che).

https://doi.org/10.1016/j.pce.2022.103253
Received 9 June 2022; Received in revised form 29 August 2022; Accepted 20 September 2022