Effect of Stress Level on the Frost Resistance and Uniaxial Compressive Properties of Desert Sand Concrete

Yanjie Jiang[1]; Haotian Liu[2]; Haifeng Liu[3]; Jialing Che[4]; Yijiang Liu[5]; Weiwu Yang[6]; and Shu Ing Doh[7]

Abstract: Rapid freeze-thaw (F-T) tests were conducted to study the frost resistance of desert sand concrete (DSC) at different stress levels (SL), desert sand replacement rate (DSRR) and the number of F-T cycles. The impact of the SL, DSRR, and number of F-T cycles on the mass loss rate, ultrasonic wave velocity, and stress-strain curve of DSC was investigated through uniaxial compression tests. Scanning electron microscope (SEM) was used to examine the microstructure of DSC. The constitutive relationship was established considering the influence of the SL and number of F-T cycles. The results indicated that the frost resistance and uniaxial compressive mechanical properties of DSC could be effectively enhanced when desert sand was added at 40%. The peak strain initially decreased and then increased as the DSRR increased. In contrast, the peak stress first increased and reached a maximum value as the DSRR increasing to 40%, followed by a gradual decrease. The F-T cycles gradually deteriorated the macroscopic properties of DSC. The proposed constitutive model of DSC was established by combining the two classical models as the ascending and descending sections, respectively. The model prediction results matched well with the experimental results, which can provide a theoretical basis for the engineering application of DSC under F-T cycles and loading environments. **DOI: 10.1061/JMCEE7.MTENG-18451.**

Author keywords: Desert sand concrete (DSC); Desert sand replacement rate (DSRR); Stress level (SL); Freeze-thaw (F-T) cycles; Uniaxial compressive experiment; Stress-strain curve.

Introduction

Concrete is an indispensable material in the field of construction engineering and sand is considered an important material for the preparation of concrete specimens. A boom in the construction industry has led to a surge in the demand for sand. Approximately 32 to 50 billion tons of sand resources per year are mined and utilized worldwide annually (Zhang et al. 2022). The overexploitation of sand resources has resulted in ecological damage, triggering environmental problems such as declining groundwater levels, vegetation degradation, and landslides, thereby leading to severe harm to the natural environment. Desert sand resources are widely throughout northwest China. To safeguard the ecological environment, conserve natural resources, and utilize local materials, it is important to prepare concrete suitable for engineering applications using desert sand to replace a portion of the medium sand used in concrete. Although desert sand concrete (DSC) is characterized by the low slump, poor flowability and large water requirement of fine aggregate (Al-Harthy et al. 2007; Zhang et al. 2022), several studies (Abu Seif et al. 2016; An et al. 2021; Kaufmann 2020; Liu et al. 2022) have shown that concrete made with desert sand can satisfy basic engineering specifications and provide superior characteristics compared with normal concrete.

In northwest China, there are a significant temperature differences between day and night. Therefore, concrete structures often experienced cyclic temperature changes, which lead to performance deterioration. Pore water experiences alternating positive and negative temperatures inside the concrete specimens during freeze-thaw (F–T) cycles. Its physical form shifts between water and ice, resulting in pore pressure and tension, which are the primary causes of concrete damage (Wang et al. 2022). Meanwhile, these concrete structures are regularly subjected to external loading. Many scholars have studied the frost resistance of concrete under loading (Lei et al. 2018; Shen et al. 2019; Wang et al. 2019), which indicated that a lower stress level (SL) makes the inner structure of concrete more compact, restricts microcrack extension and improves the frost resistance. In contrast, a higher SL results in the nucleation and stretching of more microcracks and microvoids inside concrete specimens and accelerates the F-T cycle process. Several studies have focused on the frost resistance of DSC. Wu and Shen (2017) investigated the performance changes and intrinsic damage mechanisms of DSC in an F-T environment and concluded that frost resistance was directly correlated with the desert sand replacement

[1]Graduate Student, College of Civil and Hydraulic Engineering, Ningxia Univ., Yinchuan, Ningxia 750021, China. ORCID: https://orcid.org/0009-0002-1337-6704. Email: 1097407139@qq.com

[2]Graduate Student, College of Civil and Hydraulic Engineering, Ningxia Univ., Yinchuan, Ningxia 750021, China. Email: 1461994768@qq.com

[3]Professor, College of Civil and Hydraulic Engineering, Ningxia Univ., Yinchuan, Ningxia 750021, China (corresponding author). Email: liuhaifeng1557@163.com

[4]Professor, College of Civil and Hydraulic Engineering, Ningxia Univ., Yinchuan, Ningxia 750021, China. Email: che_jialing@126.com

[5]Graduate Student, College of Civil and Hydraulic Engineering, Ningxia Univ., Yinchuan, Ningxia 750021, China. Email: liuyijiang613@foxmail.com

[6]Professor, College of Civil and Hydraulic Engineering, Ningxia Univ., Yinchuan, Ningxia 750021, China. Email: yangww71@126.com

[7]Professor, College of Engineering, Malaysia Pahang Univ., Gambang, Kuantan 26300, Pahang, Malaysia. ORCID: https://orcid.org/0000-0001-6607-0552. Email: dohsi@ump.edu.my

Note. This manuscript was submitted on January 4, 2024; approved on April 29, 2024; published online on September 23, 2024. Discussion period open until February 23, 2025; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Materials in Civil Engineering***, © ASCE, ISSN 0899-1561.