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Durability of recycled aggregate concrete under coupling mechanical loading and freeze-thaw cycle in salt-solution

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HIGHLIGHTS

- With increases of alternating times and stress level, the cracks under freeze-thaw cycles obviously increased.
- The compressive strength loss increased with the increase of stress level and alternating times.
- The decreasing rate of microhardness value of ITZ for NAC was higher than that of RAC.
- After 50 times freeze-thaw cycles, the resistance of ITZ in RAC to freeze-thaw was better than that of NAC.

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ABSTRACT

In this study, a novel coupling testing protocol with separated repetitive loading and freezing-thaw cycles in salt-solution is designed to simulate coupling mechanical loading and complex environmental effects on durability and deterioration of recycled aggregate concrete (RAC). The Micromechanical properties and porosity of RAC were also characterized by scanning electron microscopy (SEM) and microhardness. The results show that the number and width of cracks of RAC and NAC under freeze-thaw cycles obviously increased with the increase of alternating times of repetitive load and the compressive stress level. The compressive strength losses for both RAC and NAC increase with the increase of compressive stress level and alternative times of repetitive load. However, the compressive strength of natural aggregate concrete (NAC) became lower than that of RAC after freeze-thaw cycles. It was found that the freeze-thaw resistance of RAC seems even better than that of NAC under the same freeze-thaw attacks and cyclic mechanical loading. It indicates that after freeze-thaw cycles in salt-solution, the durability of RAC is better than that of NAC. On the other hand, the microhardness and SEM characterization results indicate that the interface transition zone (ITZ) was a weak part in both RAC and NAC, and the ITZ in NAC obviously deteriorated faster than that of RAC.

1. Introduction

Recycled aggregate concrete (RAC) has obtained worldwide attention as an important part of sustainability. For promoting the practical application, the mechanical properties and failure mechanism of RAC and the micromechanical properties of old and new interfacial transition zones (ITZs) in RAC were also investigated by advanced techniques [1–4]. Meanwhile, a lot of studies have been conducted on the durability of RAC [5–7]. Most of the results showed that the durability of RAC is generally lower than that of natural aggregate concrete (NAC), and it decreases with the increase of recycled coarse aggregate (RCA) replacement ratio [8–10]. This can be attributed to the complex microstructures of RAC that contains attached old cement mortar, and also the presence of unsound particles (e.g. aggregate cracks) and voids, etc. [11,12]. In order to better understand the complex durability of RAC, the effect of the microstructure on the durability performance has been studied [16–19]. And the methods to enhance the durability of RAC have also been proposed [13–15].

Many studies on the freeze-thaw resistance of NAC and RAC were focused on either single deterioration process or several separated deteriorating processes [20–23]. It was found that the obtained results on RAC durability using different testing methods

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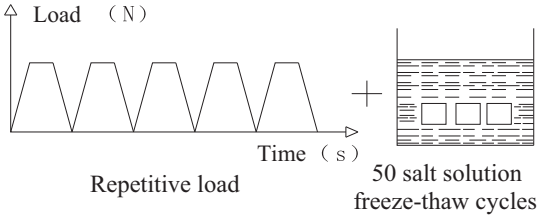
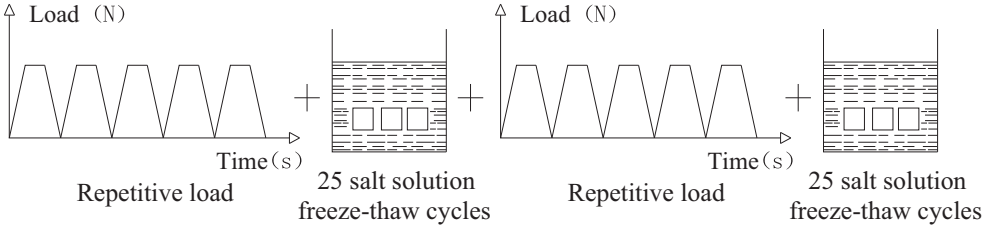
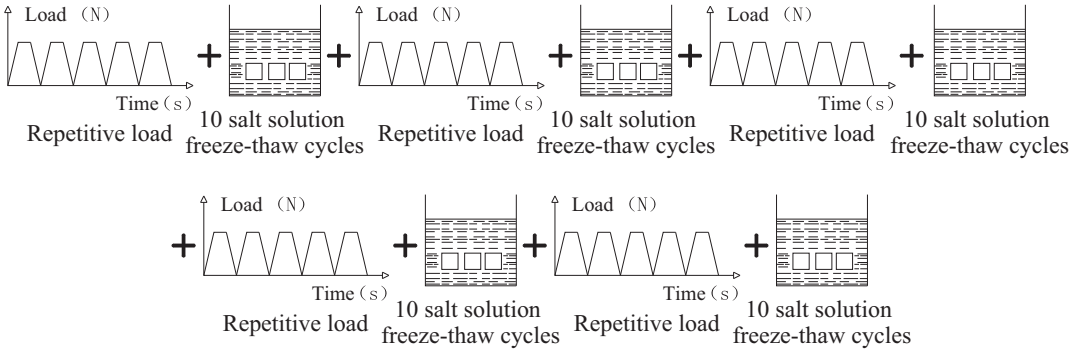


(a) One alternative time of repetitive load and n freeze-thaw cycles (Protocol 1)



(b) Two alternative times of repetitive load and freeze-thaw cycles (Protocol 2)



(c) Five alternative times of repetitive load and freeze-thaw cycles (Protocol 3)

Fig. 1. Three methods for coupling experiment of cycling loading and freeze-thaw cycles in salt-solution.

Table 1
Loading methods for different NAC and RAC specimens.

NAC	Alternative times of repetitive load		Compressive stress level (%)	RAC	Alternative times of repetitive load		Compressive stress level (%)
NAC-0-0	0		0	RAC-0-0	0		0
NAC-1-40%	1	Protocol 1	40	RAC-1-40%	1	Protocol 1	40
NAC-1-70%	1		70	RAC-1-70%	1		70
NAC-2-40%	2	Protocol 2	40	RAC-2-40%	2	Protocol 2	40
NAC-2-70%	2		70	RAC-2-70%	2		70
NAC-5-40%	5	Protocol 3	40	RAC-5-40%	5	Protocol 3	40
NAC-5-70%	5		70	RAC-5-70%	5		70

Table 2
Chemical composition of Portland cement.

Percentage	SiO_2	Al_2O_3	CaO	MgO	Fe_2O_3	SO_3	K_2O	TiO_2	Na_2O
%	20.52	7.63	60.14	2.59	2.60	2.53	0.61	0.32	0.23