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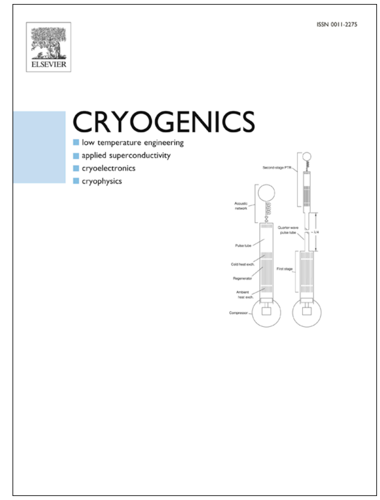

Research paper

Increased strength and related mechanisms for mortars at cryogenic temperatures

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Increased strength and related mechanisms for mortars at cryogenic temperatures

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Abstract

Properties of cement-based materials at cryogenic temperatures are quite different from those at room temperatures. The strength of mortars at cryogenic temperatures was experimentally studied and an empirical model was established. The freezing thermodynamic process of pore water and pore size distribution in mortars were characterized by differential scanning calorimeter (DSC) and thermoporometry (TPM), respectively. The relationship between the increased cryogenic strength and pore ice formation was discussed. The results showed that flexural strength of mortars increased at a higher rate than compressive strength. Water content and initial strength at room temperatures were the main factors influencing the cryogenic strength. Higher water content and higher initial strength resulted in higher cryogenic strength. Ice formation in pores is one of the main reasons for the mortar's cryogenic strength increase. Nearly half of the water remained unfrozen in pores with radius less than 40nm at -40^{o}C. Both ice formed in capillary pores and gel pores contributes to the strength increase observed at cryogenic temperatures.

Keywords: Compressive strength; Freezing; Pore water; Cryogenic temperatures; Thermoporometry

1. Introduction

The demand for natural gas (NG) has increased due to the increased demand for energy and environmental protection requirements. One of the most widely used methods to reserve liquefied natural gas (LNG) is to cool LNG to about -160^{o}C, which saves space (~1/600) and reduces costs [1-4]. The LNG storage tank is usually made of concrete and steel. Once the steel structure inside the tank goes out of service, the concrete outside will make contact with the cryogenic liquids directly. Moreover, the proposed all-concrete tank concept, which uses concrete as the primary container (directly in contact with LNG), requires a more comprehensive and fundamental understanding of the properties of cement-based materials at cryogenic temperatures [2, 3, 5].

Most research papers [6-17] on cryogenic concrete were published more than 35 years ago, at which time the natural gas industry developed quickly after the oil crisis. Concrete is a great cryogenic construction material due to its good mechanical properties. It has been reported that the strength and elastic modulus of concrete increased as temperature decreased, and that both compressive and flexural strengths increased up to two times at cryogenic temperatures [9, 11, 15, 17]. However, the proposed strength developing models at cryogenic temperatures differ from each other. Monfore and Lentz [17, 18] indicated that as temperature decreased,