Experimental Study of Air-entrained Concrete under Biaxial Loads after Freeze-thaw Cycles

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ABSTRACT

The experimental study of the air-entrained concrete specimens subjected to different cycles of freeze-thaw was carried out. The strength of specimens under uniaxial compression, uniaxial tension, biaxial compression and biaxial tension-compression was measured. The crack and failure modes were examined. The experimental results showed that the compressive strength and tensile strength decreased as the freeze-thaw cycles were repeated. The influence of freeze-thaw cycles on the strength was analyzed. A concise mathematic formula of the relationship between concrete strength and number of freeze-thaw cycles was established. It can serve as a reference for the maintenance, design and the life prediction of coastal and offshore engineering structures such as offshore platforms and concrete dock walls in cold regions.

KEY WORDS: concrete; freeze-thaw cycles; biaxial strength; failure criterion.

INTRODUCTION

Concrete has been widely used for concrete dock walls and offshore structures in cold regions. In various cases, freezing and thawing is harmful for a porous, brittle material such as concrete, when concrete is subjected to lower temperatures. It has been a significant scientific and technical problem to improve the durability and to prolong the service life of concrete around the world. The freezing and thawing durability of concrete is of utmost importance in countries having subzero temperature conditions such as the arctic zone, the northern part of Europe, Russia and the northern part of China, etc.. Sun, Zhang, Yan and Wu (1999) investigated damage and damage resistance of high strength concrete under the action of flexural loads and freeze-thaw cycles. Zaharieva, Buyle-Bodin, and Wirquin (2004) reported the frost resistance of concrete containing building waste recycled as aggregates. Persson (2003) outlined laboratory and analytical studies of salt frost scaling and internal frost resistance of self-compacting concrete (SCC) that contained increased amount of filler, different air contents, and dissimilar methods of casting. Cheng, Zhang and Li (2003) investigated the influence of freeze-thaw cycles on the compressive strength, flexural strength and cleavage strength of plain concrete. Qin (2003) investigated the strength and deformation characteristics of plain concrete under uniaxial and multiaxial compression after different cycles of freeze-thaw; the influence of stress ratio and number of freeze-thaw cycles on the strength and strain was analyzed. Gokce, Nagataki, Saeki and Hisada (2004) investigated freezing and thawing resistance when air-entrained or non-air-entrained concrete is used as recycled coarse aggregate into air-entrained concrete.

An air-entraining agent is recommended for nearly all concretes, principally to improve resistance to freeze-thaw cycles when exposed to water in cold regions. However, very little work has been documented on the strength of air-entrained concrete under biaxial stress states after different cycles of freeze-thaw. This paper presents an experimental study of air-entrained concrete after 0, 100, 200, 300, 400 cycles of freeze-thaw according to the Chinese Specification—“Test Method of Long-term and Durability on Ordinary Concrete”(GBJ82-85) . The strength of specimens under uniaxial compression, uniaxial tension, biaxial compression and biaxial tension-compression were measured after 0, 100, 200, 300, 400 freeze-thaw cycles.

EXPERIMENTAL PROCEDURES

Materials and mix proportions

In this investigation, local materials were utilized. A Chinese standard (GB175-92) 425# Portland cement (which has a standard compressive strength of 42.5 MPa at the age of 28 days) was used. Natural river sand with fineness modulus of 2.6 was used. Coarse aggregate was crushed stones with diameters from 5mm-10mm. The mix proportions and the major parameters are listed in Table 1. The mixing was accomplished by putting all the coarse and fine aggregate into the mixer before starting. These ingredients were mixed for about 1 min, and then the water was added in one minute. The mixing continued for about 2 min after all water was added.

Table 1 Mix proportions and major parameters of concrete

<table>
<thead>
<tr>
<th>Cement (kg/m³)</th>
<th>Sand (kg/m³)</th>
<th>Coarse aggregate (kg/m³)</th>
<th>Water (kg/m³)</th>
<th>air-entraining agent (kg/m³)</th>
<th>air content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>412.67</td>
<td>586.83</td>
<td>1186.00</td>
<td>164.30</td>
<td>1.03</td>
<td>5.5-6.5</td>
</tr>
</tbody>
</table>

Specimens and testing programs