Construction and Building Materials 171 (2018) 779–792

Contents lists available at ScienceDirect

Construction and Building Materials

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

Experimental tests on the underwater abrasion of Engineered Cementitious Composites

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HIGHLIGHTS

- Under-water abrasion test was conducted on ECC specimens based on ASTM C1138.
- The investigated variables were the PVA fiber content and the age of the specimens.
- The abrasion of normal concrete topped with ECC layer was also investigated.
- PVA contents of 1.5% and 2.0% increased the abrasion resistance by up to 95%.
- For 1 cm ECC topping layer, gravel particles of NC were abraded at early ages.

ARTICLE INFO

Article history:
Received 30 December 2017
Received in revised form 2 March 2018
Accepted 21 March 2018

Keywords:
Abrasion
Underwater abrasion test
ASTM C1138
ECC
PVA

ABSTRACT

The abrasion of Engineered Cementitious Composites (ECC) due to waterborne materials in hydraulic structures was investigated using the ASTM C1138 abrasion test method. The test specimens were divided into two groups, the first was directed to study the effect of the PVA fiber content, while the second investigated the effect of the ECC covering layer thickness. The tests were conducted at ages of 3, 7 and 28 days. The test results showed that the abrasion resistance increases as PVA content increase. At an age of 28 days, incorporating low PVA contents (0.5% and 1.0%) increased the abrasion resistance by approximately 20%, while the inclusion of high PVA contents (1.5% and 2.0%) improved the abrasion resistance significantly with percentage improvements ranging from 50 to 95%. The percentage abrasion weight losses after 72 testing hours at this age were 7.6, 5.9, 4.7, 3.6 and 2.4% for fiber contents of 0, 0.5, 1.0, 1.5 and 2.0%, respectively. The test results also showed that covering of normal concrete with 1 cm layer of ECC is not effective during the early age of this material, while a layer of 3 cm thickness showed good abrasion resistance at early and mature ages.

1. Introduction

The deterioration of concrete in hydraulic structures due to water motion is recognized as a time-dependent abrasion wear problem in such structures. This action of water is always accompanied by waterborne materials such as sand and gravel, which accelerate the abrasion of the exposed surfaces [1,2]. Two types of abrasive forces where specified as the main causes of concrete abrasion in hydraulic structures, these are the friction and impact forces [3]. The different water and waterborne bed particles motions on concrete surfaces impose shearing stresses that cause the gradual grinding of these surfaces. As a result, the cement paste is weakened between the aggregate particles leading to the deterioration of bond and the dislocation of the aggregate particles. Such progressive grinding action may lead to serious abrasion damages of the surfaces reaching several feet in depth [1]. On the other hand, on other surfaces the water and waterborne particles act normally to that surface producing a direct impact force. The imposed impact force results also in progressive abrasion deterioration, which depends mainly on the impact velocity and angle between water pressure and the surface. Several previous researchers investigated the abrasion of concrete due to impact forces using the water-jet flow method [4–8].

To evaluate the abrasion resistance in hydraulic structures, there are two standard abrasion tests. The first is according to ASTM C1138 underwater abrasion test method [9], while the second is more general and is according to the European standards (Bohme disc method) [10]. Other test methods are also available, but are either nonstandard or not suitable for this purpose.

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https://doi.org/10.1016/j.conbuildmat.2018.03.213
0950-0618/

The abrasion wear imposes maintenance problems and reduces the service life of the hydraulic concrete structures. The improvement of the abrasion resistance needs to modify the concrete properties and increase the compressive strength. Increasing the cement content is a key factor to enhance the mechanical properties of concrete. However, such alternative is associated with higher hydration heat, which would impose other unrequired early age problems [13]. Therefore, the development of new cementitious composites was the focus of researchers for many years. One of the recognized results of extensive research works is the Engineered Cementitious Composites (ECC). This material is identified for its superior durability, superior strain energy absorption and distinguishable high ductility [14]. Such unique properties introduced this material as one of the favorable candidates to improve the abrasion resistance of concrete surfaces in hydraulic structures where abrasion wear is probable.

Several research works that investigate the abrasion of concrete under waterborne materials were reviewed. These works agreed that abrasion may affect the surfaces of some concrete hydraulic structures and hence reduce their service life. The degree of this effect depends on many parameters. It was shown that the increase of compressive strength and the decrease of the w/c ratio increase the abrasion resistance of concrete surfaces [3,4,7,12–13,15–18]. Moreover, the reviewed literature disclosed that the use of the different types of discrete short fibers could enhance the abrasion resistance of concrete [1,7,11–12,18–21]. The review also showed that several test methods were used to evaluate the abrasion resistance of concrete surfaces in hydraulic structures. The most widely used of which is the ASTM C1138 (underwater method). On the other hand, several types of tests using several types of specimens were conducted during the last decade to evaluate the strength, ductility, durability, and other properties of ECC. However, there still some gaps of knowledge in other aspects such as the abrasion resistance in hydraulic structures. According to the best of the author's knowledge, no previous researches were found in the literature on the abrasion resistance of ECC. Therefore, in this work, an experimental study was directed to investigate the abrasion resistance of ECC specimens using the standard ASTM C1138 underwater abrasion test method.

2. Abrasion testing methods

There are many test methods, standard and nonstandard, developed to evaluate the abrasion erosion resistance of concrete specimens. ASTM introduces four standards for this purpose, which are

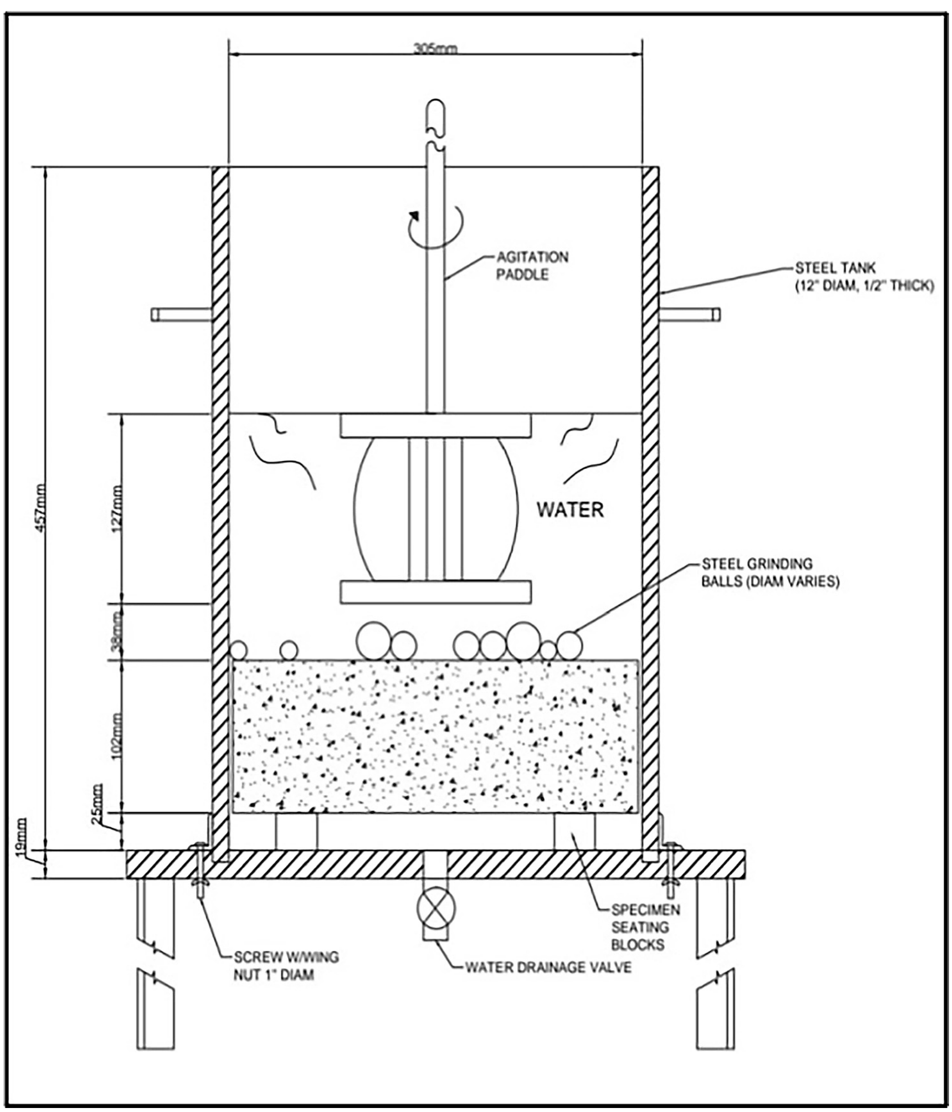

Fig. 1. Abrasion test Device (underwater method) ASTM C1138/97 [9].