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Mechanical properties of steel fiber-reinforced reactive powder concrete at high temperature and after cooling

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Abstract

Reactive powder concrete (RPC) is advanced cement-based material. It is produced through microstructure enhancement technique. Like other types of concretes, RPC has also been affected by severe environmental conditions such as accidental fire. Up to date, very limited research has been carried out to compare the performance of RPC at fire and after cooling. To address this gap in knowledge, the mechanical properties such as compressive strength, split-tensile strength, flexural strength and elastic modulus have been studied at high temperature and after cooling. 72 cubic specimens and 72 prismatic samples were tested. The hot and residual strength results were plotted as a function of temperature. The results indicated a higher residual strength than hot-strength in the temperature range of 20-300℃. Above 300℃, there was no sizable difference between the hot and residual strength of PRC.
A comparison has also been made among the test data with current design codes.

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Keywords: Reactive powder concrete; high temperature; hot behavior; residual behavior, mechanical properties

1. Introduction

Reactive powder concrete (RPC) is advanced cement-based material. It is produced through microstructure enhancement technique.

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Nomenclature

f_{cu}^{H} , f_{cu}^{R}	Hot and residual cubic compressive strength of RPC, respectively.
f_{c}^{H} , f_{c}^{R}	Hot and residual prism compressive strength of RPC, respectively.
f_{t}^{H} , f_{t}^{R}	Hot and residual split-tensile strength of RPC, respectively.
f_{f}^{H} , f_{f}^{R}	Hot and residual flexural strength of RPC, respectively.
E_{c}^{H} , E_{c}^{R}	Hot and residual elastic modulus of RPC, respectively.

The superior mechanical and durability properties of RPC are achieved by reducing water-to-binder ratio less than 0.2, exclusion of coarse particles, optimizing the particles packaging by the addition of silica fume and using special curing regimes [1]. The addition of steel fibers improves the tensile and flexural strength, toughness and durability [2].

The use of RPC is increasing with each passing day. RPC is widely used in the construction of nuclear power projects. However, it is also used for civil, military and marine structures. The special treatment methods encouraged the precast industry more as compared to in situ construction work. The higher cost of RPC can be balanced due to its superior strength, which results in saving of passive steel reinforcement.

The dense microstructure of RPC makes it more vulnerable to high temperature spalling and cracking. However, the addition of steel fibers improves the tensile strength. Which resists the internal vapor pressure at high temperature. This protects RPC from spalling [3].

Like other types of concrete, RPC is also severely affected by high temperature. The degradation trends of normal strength concrete (NSC) and high strength concrete (HSC) is different under and after high temperature [4,5]. Similarly, very limited work has been carried out about the hot and residual mechanical properties of RPC.

The purpose of this article is to compare the performance of RPC at fire (hot-strength) and after cooling (residual strength). The mechanical properties such as compressive strength, split-tensile strength, flexural strength and elastic modulus have been studied at high temperature and after cooling. The test results are compared with design provisions such as Eurocode-2 [6], ACI code [7], ASCE manual [8] and the Finland Association for concrete guidelines [9].

2. Experimental methods

2.1. Specimen preparation and heating regime

The Chinese standard P.O 42.5 N Portland cement have been used. The commercially available silica fume with specific surface area of 20775 m^2/Kg was used. The specific surface area of slag used was 480 m^2/Kg. The quartz sand of fine (0.2 mm) and coarse sizes (0.4 mm) have been used with an equal ratio. A liquid polycarboxylate superplasticizer was used. The steel fibers used were brass coated with a diameter of 0.22 mm and length of 13 mm. the detail mix design is given in Table 1.

An electronic digital balance was used for measurements of materials. Initially, the dry materials were uniformly mixed for about 5 minutes. The water and polycarboxylate water reducer were added together after 5 minutes of mixing. The mix was converted to an even plastic consistency by the end of 5 more minutes of mixing. The steel fibers were then sprinkled in flowable concrete and mixed for total 5 minutes.

A total of 72 cubics and 72 prismatic samples were made. The dimension of cubic samples are 70.7×70.7×70.7 mm and the prismatic samples are 70.7×70.7×210 mm. The vibrating table was used for compaction, and the moulds are filled in 3 layers. The samples were demoulded after 24 hours and put in an accelerated steam curing box