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ScienceDirect

Procedia Engineering 210 (2017) 588–596

Procedia Engineering

www.elsevier.com/locate/procedia

6th International Workshop on Performance, Protection & Strengthening of Structures under Extreme Loading, PROTECT2017, 11-12 December 2017, Guangzhou (Canton), China

Evaluation of residual mechanical properties of steel fiber-reinforced reactive powder concrete after exposure to high temperature using nondestructive testing

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Abstract

Reactive powder concrete (RPC) is classified as ultra-high performance concrete, owing to its superior strength, excellent durability and high fracture energy. However, RPC may also be severely affected by devastating fire exposures. This paper presents the variations in residual mechanical properties of RPC after exposure to high temperature. The strength of RPC after cooling was also assessed by nondestructive tests (NDTs). The ultrasonic pulse velocity (UPV) method and resonance frequency (RF) method were used. The samples were subjected to the target temperature of 120°C, 300°C, 500°C, 700°C and 900°C. The heating was continued for further 3 hours so that steady state condition was achieved. The available equations have been used for determination of dynamic elastic modulus of RPC using UPV and RF measurements. The residual mechanical properties, RF and UPV were plotted as a function of temperature. The result shows that the residual strength increases from room temperature to 300°C. However, above 300°C, it's decreasing gradually. Various comparisons have been made between residual mechanical strength versus UPV and RF measurements. Relationships have been proposed among residual mechanical properties versus NDTs values. These relationships can be employed for post-fire strength assessment of RPC structures.

Peer-review under responsibility of the scientific committee of the 6th International Workshop on Performance, Protection & Strengthening of Structures under Extreme Loading

Keywords: Reactive powder concrete; high temperature; residual mechanical properties; ultrasonic pulse velocity; resonance frequency

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Peer-review under responsibility of the scientific committee of the 6th International Workshop on Performance, Protection & Strengthening of Structures under Extreme Loading.
10.1016/j.proeng.2017.11.118

Nomenclature

f_{cu}	Cubic compressive strength of RPC.
f_t	Split-tensile strength of RPC.
f_f	Flexural strength of RPC.
E_c	Static elastic modulus of RPC.
E_d	Dynamic elastic modulus of RPC.

1. Introduction

Reactive powder concrete (RPC) is the new generation of concrete having ultra-high strength, excellent durability, remarkable flexural strength and high fracture energy. These outstanding properties are achieved by enhancement of microstructure technique. The elimination of coarse particles, reducing water-to-binder ratio, lowering Cao/Sio2 ratio by the addition of silica fume and the addition of steel fibers are the main factors for the ultra-high strength of RPC [1]. Owing to the outstanding mechanical properties, RPC is classified as ultra-high performance concrete [2].

Over the past few years, RPC has been extensively used around the world in infrastructure work of civil, military, marine and nuclear power projects. Its consumption is more for precast and pre-stressed structures. Although the production cost of RPC is higher, however, the superior strength results in saving of steel reinforcement and concrete cover.

RPC is prone to spalling at high temperature, however, the adequate amount of steel fibers (2-3% by volume of concrete) improves the tensile strength and the resistance against vapor pressure and internal stresses [3] (Causes of spalling). Steel fibers also improve the mechanical properties, ductility and resistance against cracking.

The commonly used method for assessment of structural strength is the nondestructive testing (NDTs). Some of the reliable and popular methods among NDTs are ultrasonic pulse velocity (UPV) and resonance frequency (RF) methods. In the former, the stress waves propagate through the fixed length specimen and received at the recorded time, where as in later the resonance peak response is recorded. The most important applicability of UPV and RF tests is the determination of dynamic elastic modulus and quality of concrete [4]. However, very little work has been available up to now about the application of NDTs for evaluation of residual mechanical properties of RPC.

The goal of this article is to find the UPV and RF values of RPC after exposure to high temperature. Furthermore, the residual mechanical properties have been determined with destructive tastings. Moreover, various comparisons have been made between residual mechanical properties (f_{cu}, f_t, f_f, and E_m) versus UPV and RF measurements. Relationships have been proposed among residual mechanical properties versus NDTs values. These relationships can be used for post-fire strength assessment of RPC structures.

2. Experimental methods

2.1. Specimen preparation and heating regime

The cement used was Chinese standard P.O 42.5 N Portland cement with 28 days compressive strength greater than 42.5MPa. The silica fume used having a specific surface area of 20775 m^2/Kg and its SiO_2 percentage were 94.25%. The slag used having a specific surface area of 480 m^2/Kg. The crushed quartz sand of 0.2 mm and 0.4 mm sizes were used with 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.