Density and Spalling behavior of Reactive Powder Concrete after Exposure to Fire Flame

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Keywords: Reactive powder concrete; Density; Spalling.

ABSTRACT − One of the most significant problem that threating the structural safety of buildings is the fire accident. so, it is important to understood the change in the properties of concrete due to exposure to high temperature. Reactive Powder Concrete (RPC) samples were designed, all set and cured for various ages; (3, 7, 28 and 56) days. Density and spalling behavior were determined and evaluated after exposure to real fire flame at (150°C, 300°C, 450°C and 600°C) as well as in (23°C) laboratory temperature. The samples that were not spalled acceptable and classify into two sets based on the cooling treatment. The results showed that there was an increase in the RPC densities for the specimens that were burned at 150 °C compare to laboratory temperature (23°C). A noticeable reduction was also found in the density for samples burned at 300°C and 450°C. At 600°C, about 20 % of the total RPC specimens were partially or completely spalled. In the other hand it was found that the density for samples cooled in water was higher than for others cooled in air.

1. INTRODUCTION

Reactive powder concrete (RPC), a new type of high-strength concrete (HSC) improved in the late 1990s, is characterized by ultra-high strength, notable deformability and outstanding robustness. Since the start of RPC, it has attracted great consideration for both engineering and academic aspects and has been widely used in a variety of engineering presentations, such as pavements, bridges, runways, nuclear containments[1]. 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 [2]. Despite its outstanding room-temperature mechanical performance, RPC experiences severe spalling when exposed to high temperatures. Spalled RPC has been characterized as completely crushed, presenting a powder-like morphology, which differs from the partial surface failure or cracking experienced by conventional HSC at high temperatures. However, RPC spalling has remained a poorly understood phenomenon, and the associated risk is difficult to predict by modelling. Until now, the spalling risk of (HSC) has been commonly explained by three different mechanisms:, thermal cracking, thermal stress and vapor pressure [3]. In this paper, the density and spalling behaviour of RPC after exposure to real fire flame is reported.

2. MATERIALS AND METHODS

Ordinary Portland Cement Type I, micro silica, very fine sand with maximum size 600µm, super plasticizer (sika visco crete- 5930) which is free from chlorides and complies with ASTM C494-99 type G and F, steel fiber (0.25 mm diameter and 13.1 mm length) and water were mix to preparing reactive powder concrete samples. The mix proportions are illustrated in Table 1. According to ASTM C1437-01 RPC workability were conformed using mortar flow table test. Cubic moulds with dimensions (50×50×50 mm) were used for preparing the samples. These specimens were cured in water for different ages (3, 7, 28 and 56 days) before the fire test. After curing, the samples were weighted and the dimensions were measured. The samples are then subjected to fire test that are classified into four groups depending on the fire flame temperatures (150°C, 300°C, 450°C, 600°C) as well as in laboratory temperature (23°C). The temperatures were continuously recorded at different depths by applying infrared ray thermometer from about two meters from the concrete exposed to fire and three digital thermometers. After applying fire test some of these specimens were spalled while others were success. All the successful samples were cooled either by sprinkled by water or by air. The density was calculated for all samples before and after fire by (weight/volume), while the spalling was measured depending on visual assessment. Figure (1) shown the flow chart for experimental.

Table (1): Reactive Powder Concrete Samples' Mix proportions.

w/p	Cement (Kg/m3)	Sand (Kg/m3)	Silica fume (Kg/m3)	Superplasticizer (lit/1000kg cement)	Steel fiber %
0.175	880	970	220	0.5	2

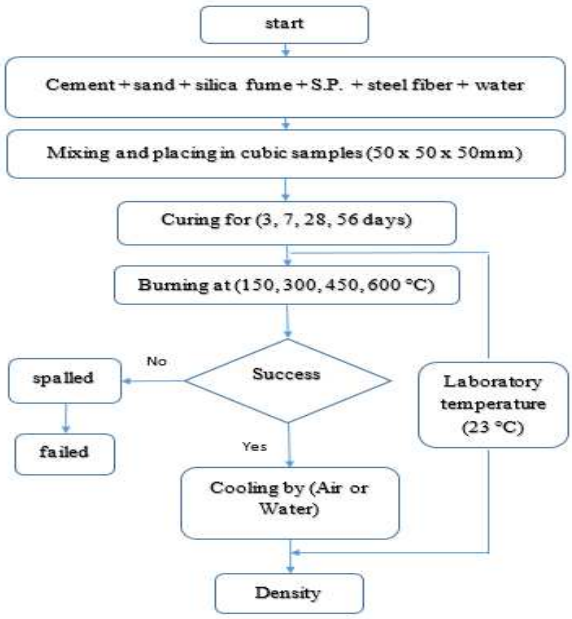

Figure (1): Research steps flow chart

3. RESULTS AND DISCUSSION

Density of RPC - The volume and weight of all cubes were measured at laboratory temperature (23 ºC) and after exposure to fire flame at 150, 300, 450 and 600 ºC, the weight of succeeded cubes were measured and the densities were calculated. The results in laboratory temperature (23 ºC) were compared with the others after burning. Figure (2) describes the relations between the densities after exposure to different fire flame temperatures for both air and water cooled samples. The densities of the samples at 600 ºC are not shown in Figure (2) because the samples at 600 are completely spalled.

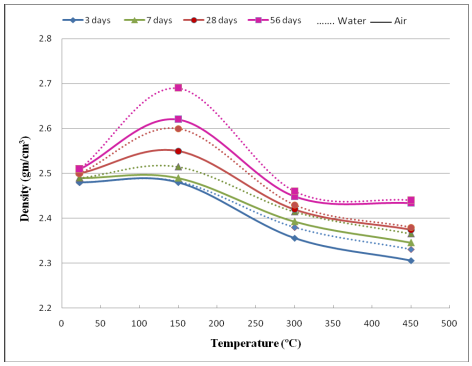

Figure (2): The Density of RPC samples at different Fire Flame.

Spalling - The spalling mechanism is the phenomenon of explosion RPC specimens affected by fire flame at temperature reach 600 ºC. The Spalling may be graded as follows:

Spalling Sequence - After exposure to high temperature reaching (600 ºC); A noticeable sound was recorded for RPC specimens

By analyze the results indicated after spalling, sequence was observed at around (600 ºC) in cases where spalling happen. During the first 3 – 5 minutes, sound of cracks was heard; slight pieces were fallout from the surface layer. Explosive spalling was taking place at around 18 minutes. After spalling, large parts were fall out. Finally, after completing 30 minutes and taking off the fire source, the samples were found with different and irregular shapes as well as with damaged edges.

Suggested Spalling Mechanism - Based on the results and photos of samples that's are affected by the real fire flame; partially or totally splitting and fallout of surface layer from different positions under the core of the specimen were observed. Plate (1) demonstrate the expected mechanism of spalling. This may occur due to internal cracks, thermal stresses and vapor pressure.

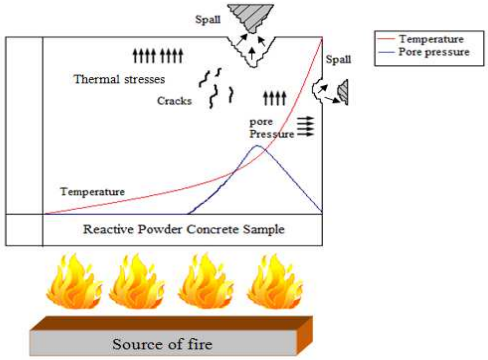

Plate (1): expected mechanism of Spalling behavior of RPC Samples affected by Real Fire Flame.

4. CONCLUSION

In conclusion, the dense structure of RPC is the main cause of spalling under high temperature. Further studies should be taken place to study the microstructure of RPC before and after fire test. Study on the effect of deferent type and percentage of fiber utilized in the RPC preparation is also recommended.

ACKNOWLEDGEMENT

Grant FRGS/1/2014/TK04/FKP/02/F00215 for the financial assistance for participating in this research day.

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