IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 18, Issue 2 Ser. I (Mar. – Apr. 2021), PP 55-63
www.iosrjournals.org

Exposure of Reactive Powder Concrete to High Temperatures

Ahmed Ibrahim Abdel-Fattah
Degree of Ph.D. In Structural Engineering, Faculty of Engineering, Mansoura University, Egypt.

Abstract
Reactive Powder Concrete (RPC) is composed of very fine powders (cement, sand, and silica fume), steel fibers and super plasticizer. A very dense matrix is achieved. The coarse aggregate becomes the weakest link in concrete. In order to increase the compressive strength of concrete even further, the only way is to remove coarse aggregate. RPC is characterized by extremely good physical properties, such as strength and durability. Due to exposed to high temperature, mechanical properties of RPC gradually improves by increasing temperature up to 200° C, but mechanical properties decrease due to higher temperatures than 200° C . The compressive, flexural and tensile strength, decreased at a higher rate of temperatures higher than 300°C. For an exposure temperature of 300°C, results show that the reduction on mechanical properties with respect to the one obtained for room. Using polypropylene fibers in RPC was resisted deterioration, and the amount needed to be more than 2.0 kg/m^3 which are greater than that normally adopted amount in HSC or HPC due high temperatures Using steel fiber and polypropylene fibers together to decrease failure due to high temperatures.
Keywords*: High temperatures, Compressive Strength, , flexural strength, Reactive Powder Concrete, splitting tensile strength*

Date of Submission: 08-03-2021 Date of Acceptance: 22-03-2021

I. Introduction

Concrete is a commonly used structural material in construction around the world. Over the past decade, some research works have been conducted to examine the effects of cementitious materials that can achieve a higher mechanical performance. Reactive Powder Concrete (RPC) is a concrete made of powder materials that are experiencing a second binding reaction, after binding the water with cement.

Reactive powder concrete (RPC) is a high strength ductile material formulated from a special combination of constituent materials. These materials include Portland cement, silica fume, quartz sand, quartz powder, high-range water-reducer, water and steel fiber. RPC is considered as one of the most important products viewed by the construction industry world during the last decades in the field of producing new and improved types of concrete. Due to the higher cement content, the shrinkage deformation of RPC was large. The effect of the steel fibers in RPC mixtures is to reduce the shrinkage by restraining effect offered by the fibers. The mechanical properties are obtained by decreasing the water to cementitious ratio and often using super plasticizers and silica fume. RPC is a family of concretes obtained by using three major principles:

1) Improvement of the material homogeneity by removing all coarse aggregates
2) Increase of the compactness by granular optimization and compaction
3) Possible improvement of the microstructure by heat treatment

Achievement of material ductility by the addition of steel fibers

II. Objectives

The main goal of the research is studying some durability aspects, such as, exposure to high temperatures of RPC.

III. Experimental Work

3.1 Materials

The choice of cement is an important factor because the cement type has a very high effect on the performance of RPC. The ideal cement must have a high C_3S and C_2S (di- & tri-calcium silicate) and low C_3A (tri-calcium aluminate) content. This is understandable because C_3A has little intrinsic value as a binding agent and is primarily included in cement due to its role as a flux during the calcination process. The RPC considered here, is prepared by ordinary Portland cement CEM I 52.5 N EL- ARISH PORTLAND CEMENT Company-BENI-SUEF (El -Askary). Silica Fume (SF), which is an industrial product of the manufacturing and purification of silicon, zirconia and ferro-silicon alloys in submerged-arc electric furnaces, has been used for RPC. It fills micro voids and produces secondary hydrates by pozzolanic reaction. SF was provided from Sika Company. Quartz sands (with maximum particle size of 0.6 mm and 0.3 mm) and quartz powder (with maximum particle size of 0.1 mm) with a density of 2.61 t/m^3 were used for preparing RPC mixtures. The very low water/binder ratios used in RPC would be possible by using high amount of high-quality super plasticizer. Polycarboxylate high-range water-reducing admixture Sika ViscoCrete® -3425was used.

3.2. Sample Preparation

The mix proportions of RPC are shown in Table 1.

Table 1: RPC mix proportions (kg/m^3)

Mix no	Cement content	Silica fume	Quartz powder	Quartz sand	SP	Water	Steel fibers	P.P fibers	***w/c***	***w/b***
F1	900	-	-	1353	27	171	-	-	0.19	0.19
F2	900	-	225	1128	27	171	-	-	0.19	0.19
F3	900	270	225	807	27	171	-	-	0.19	0.15
F4	900	270	225	755	27	171	156	-	0.19	0.15
F5	900	270	225	784	27	171	-	8.19	0.19	0.15
F6	900	270	225	732	27	171	156	8.19	0.19	0.15
W/C *is water to cement ratio*					*P.P fibers is polypropylene fibers*					
W/b *is water to cementitious ratio*					*SP is superplasticizer (**HRWRA**)*					

3.3 Mixing

After selection of all needed constituent materials and amounts to be used (mix designs); all materials are weighed properly. Then mixing with a power-driven tilting revolving drum mixer started to ensure that all particles are surrounded with cement paste and silica fume and all the materials and steel fibers should be distributed homogeneously in the concrete mass. Mixing was performed in a high speed-mixer to overcome the high viscosity and cohesiveness of the mixtures associated with the extremely low w/c, and to facilitate the dispersion of water and super plasticizer. Capacity of mixer is 60 liter.

Figure 1: RPC mix after dry mixing

Figure 2: RPC mixer

3.4 Preparation of the specimens

When RPC mixes were ready, it was poured into the required molds (table 2, and figure 3) which were sprayed with mold oil to reduce the friction at the interface between the molds and RPC mix. The molds were filled with the RPC mixture, the mixture pastes were evenly compacted using an electric vibrating table during approximately 1 minute on . After casting, all molds were covered with a wet cloth for 24 hours to minimize the loss of moisture.

Table 2: Shape and size of specimens

Name of test	Size of Specimen
Compression strength test	Cubes 50 × 50 × 50 mm
Split tensile strength test	Cylinders 50 mm diameter × 100 mm height
Flexural strength test	Prism40 × 40 × 160 mm

(a) Molds of compressive strength

b): Molds of tensile strength

c): Molds of flexural strength

Figure 3: Molds of tests (a,b,c)

4.1 Experimental procedure

In this research the influence of high temperatures on mechanical properties of reactive powder concrete was investigated. Mixes F1, F2, F3, and F4 were used for examination.

Fifth temperatures used in this study (200 °C, 300 °C, 400 °C, 500 °C,) and 25 °C (no heated) as the control group.

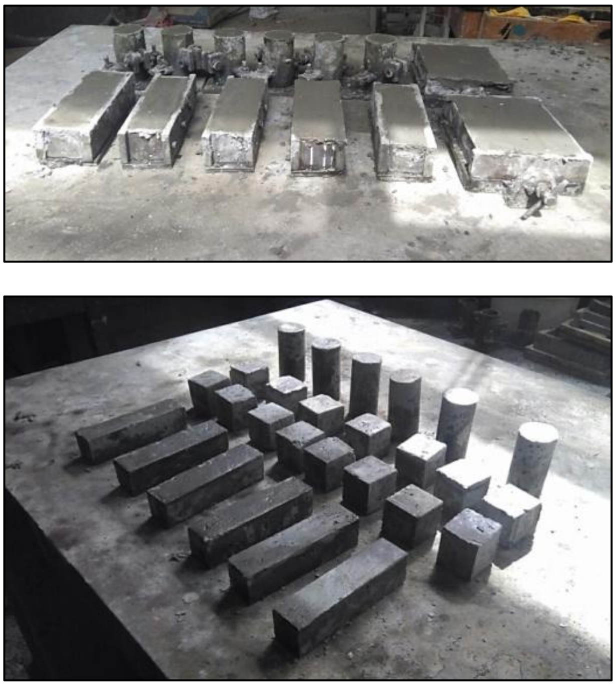

Figure 4: Concrete specimens for each mixture

4. 2 Heating regime

Electric furnace used in this study is with internal space dimensions (width ×height × depth) of 16 × 16 × 37 cm with a maximum temperature of 1200 ºC , and maximum heating speed of 10°C per minute was used .
Figure 4.44 shows an electric furnace used in heating regime.

Figure 5: An electric furnace used in heating regime

IV. Results And Discussion

5.1 Exposed to high temperatures results

In this study, the properties of strength and explosive spalling behavior of RPC before and after the fire tests are investigated. The influences of hybrid fiber (P.P and steel fiber), cement, and silica fume contents as the factors that control explosive spalling of RPC are also investigated.

RPC were made using polypropylene fibers, steel fibers, and mixed of the two kinds of fibers. Using steel and polypropylene fibers together were used to overcome failure and increase the remaining mechanical properties of RPC exposed to high temperatures.

It can be seen that all mixtures which contain silica fume and exposed to 200 °C exhibited gain of its compressive strength by about (3.6% to 6.5 %). This was because of the improvement of the hydration of hydrated cementitious materials by evaporation the free water inside the specimens.

The use of steel and polypropylene fibers has shown to mitigate the problem of spalling at high temperatures. Heating causes different changes in its properties and in particular, changes in microstructure accompanied by the loss of mechanical strength. Polypropylene fibers have a melting point at about 170 °C. When concrete heats up past this point, the fibers themselves melt and disperse into the surrounding matrix. This leaves artificial pores space roughly the size of fiber. This newly introduced void space helps reduce the vapor pressure from evaporating water and dehydration of concrete. This reduces the tendency of dense concretes to spall when heated quickly.

The addition of polypropylene fiber was effective in decreasing failure of the RPC specimens in the fire tests, and that more than 2.0 kg/m3 was required. RPC specimens were more prevent to failure as the cement percent, and silica fume contents increased.

Figures 6, 7, and 8 illustrate the results of RPC exposed to high temperature tests.

5.2 Effect of high temperatures on strength

As represented in Figure 6.9, Figure 6.10, and Figure 6.11 there is an increasing in strength until temperature 200 °C by about 12 %. After that there is degradation of strength. There is a reduction in strength by about 20% - 30%, 30% -50%, and 84% - 100% were recorded for specimen's exposure to 300°C, 400 °C and 500°C respectively.

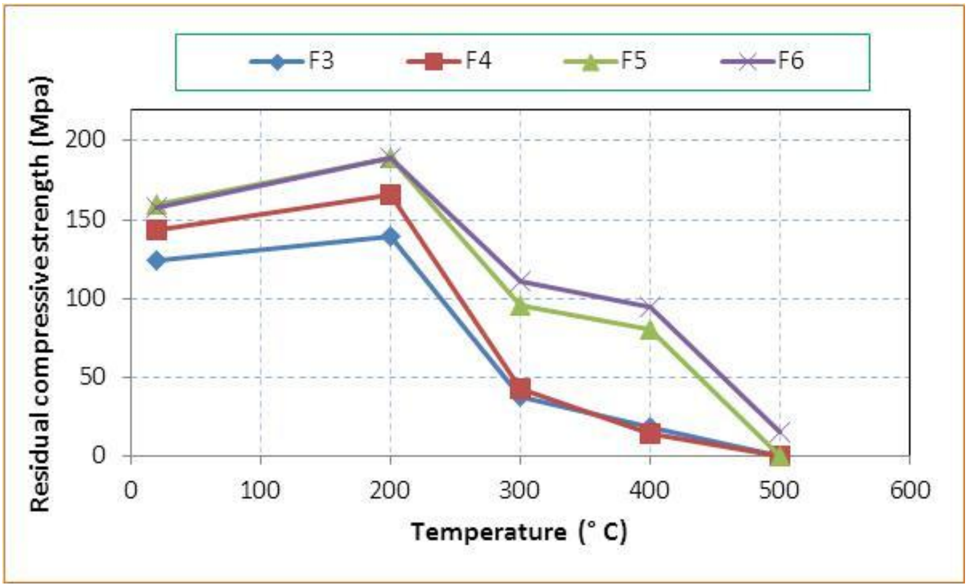

Figure 6: Effect of temperatures on compressive strength

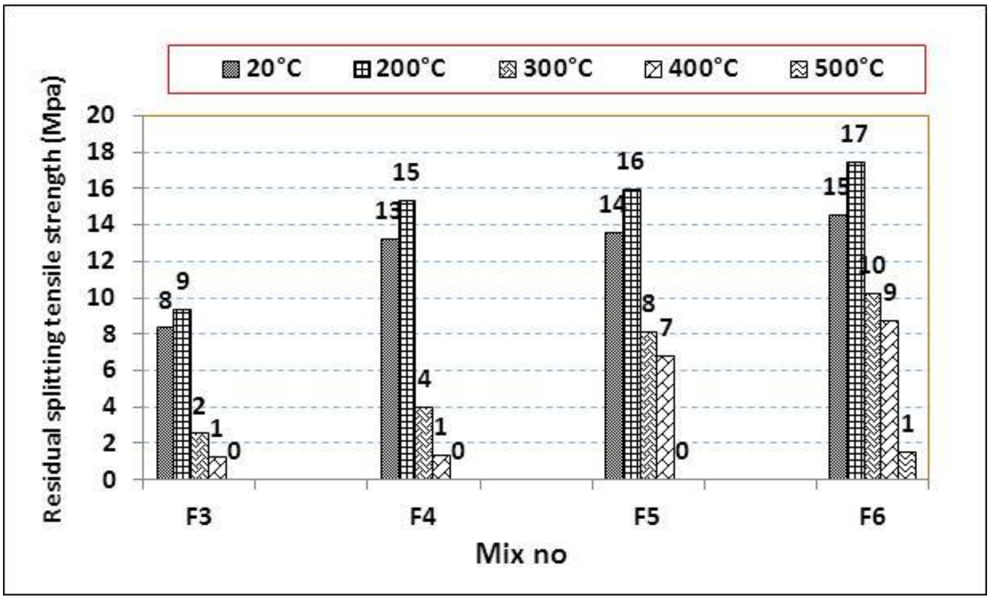

Figure 7: Effect of temperatures on residual strength

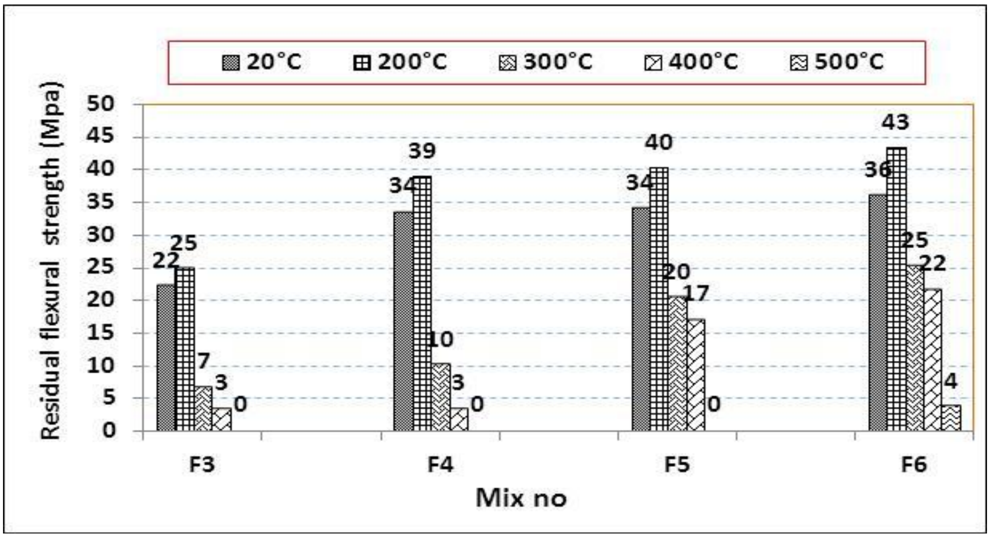

Figure 8: Effect of temperatures on flexural strength

5.3 Appearance and color change

The relative residual strength of RPC after the fire test increased with increasing P.P fiber content. Figure 10 shows the appearance and color change of RPC specimens due to high temperatures exposure.

The weight loss ratios of RPC specimens within the temperature range of 25°C to 500°C increased with increasing cement content, especially with increasing Ca(OH)2 hydrates in the RPC specimens.

(a) (b)

Figure 9: Effect of high temperatures (a) Partially spalled, (b) Fully failure and broke into large parts.

Cylinders remained Intact (no failure)

Cubes without any failure

Cylinders remained Intact (no spalling)

Cubes remained Intact (no change)

Cubes with minimum spalling

A prism without spalling

A prism partially spalling

A cube and cylinder with minor failure.

A cube partially failure.

Cubes fully spalling and became large pieces

Cubes fully spalled and became small parts

Figure 10: Appearance and color change of RPC specimens due to high temperatures exposure

V. Conclusions

1) Due to exposed to high temperature, mechanical properties of RPC gradually improves by increasing temperature to 200° C, but mechanical properties decrease due to higher temperatures than 200° C .
2) The compressive, flexural and tensile strength, decreased at a higher rate for temperatures higher than 300 ° C. For an exposure temperature of 300 ° C, results show that the reduction on mechanical properties with respect to the one obtained for room.
3) RPC has well to excellent water absorption resistance.
4) Using polypropylene fibers in RPC was resisted deterioration, and the amount needed to be more than 2.0 kg/m3 which are greater than that normally adopted amount in HSC or HPC due high temperatures.
5) Using steel fiber and polypropylene fibers together to decrease failure due to high temperatures.

References

[1]. Yang Ju, Li Wang, Hongbin Liu, and Guowei Ma "Experimental Investigation into Mechanical Properties of Polypropylene Reactive Powder Concrete", ACI Materials 2018: 21-32.
[2]. Yang, J., Hong Bin, L., Jian, C., YuDan, J., and PeiHuo, P., (2009), "Toughness and Characterization of Reactive Powder Concrete with Ultra-High Strength", Sci. China Ser E-Tech Sci. 52(4): 1009-1018.
[3]. Yazici, H. (2007). "The effect of curing conditions on compressive strength of ultra-high strength concrete with high volume mineral admixtures", Building and Environment, 42(5): 2083-2089.
[4]. Yazici, H., Yardımcı, H.Y., Aydın, S. and Karabulut, A., (2009), "Mechanical Properties of Reactive Powder Concrete Containing Mineral Admixtures under Different Curing Regimes", Construction and Building Materials, 23(3): 1223-1231.
[5]. Yuh-Shiou Taia,∗ , Huang-Hsing Panb, Ying-Nien Kungb "Mechanical properties of steel fiber reinforced reactive powder concrete following exposure to high temperature reaching 800 ◦C", Nuclear Engineering and Design 241 (2011): 2416–2424.
[6]. Zanni, H., Cheyrezy, M., Maret, V., Philippot, S., and Nieto, P., (1996), "Investigation of Hydration and Pozzolanic reaction in Reactive Powder Concrete (RPC) using 29Si NMR", Cement and Concrete Research, 26(1): 93-100.
[7]. Serdar Aydın and Bülent Baradan , "High Temperature Resistance of Alkali-Activated Slag- and Portland Cement-Based Reactive Powder Concrete" ,ACI Materials : 463-470.
[8]. Shaheen, E. and Shrive, N.G. (2006). "Optimization of Mechanical Properties and Durability of Reactive Powder Concrete". ACI Materials Journal, 103(6): 444-451.

Ahmed Ibrahim Abdel-Fattah. "Exposure of Reactive Powder Concrete to High Temperatures." *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE),* 18(2), 2021, pp. 55-63.