Research Article

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Punching shear of reinforced concrete slabs bonded with reactive powder after exposure to fire

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Abstract: Reactive powder concrete (RPC) is one of the most recent and significant advancements in the world of building. Due to its higher concrete characteristics, it has a common excessive benevolence happening in the globe at the moment, excessive ductility, shrinkage resistance, and corrosion and abrasion resistance. Investigated is the method for amending the RPC experimentally in punching shear slab action and the properties of construction material to investigate properties of volumetric ratios of steel fiber, and silicas fume, tensile steel ratio, the most important component for construction is reinforced concrete, which works well with other materials to create structures in any shape that is needed. In the present research, investigational work of RC slab with (1,000 × 1,000 × 60) mm dimensions was tested. This study aims to see how the relative volume of steel fibers (Vf) and silica fume content (Sf) affect the actions of RC slabs after being exposed to fire. It originated that a concrete mix containing 2% steel fibers improved the RPC slab's cracking and final punching shear. The existence of reactive powder increases fire resistance. This study's experiment aimed to see how reactive powder and Slab's ultimate punching shear strength were affected by replacement ratio. Whenever a fire is present. After fire exposure, the initial and subsequent stiffness of reinforced concrete slabs reduced considerably the temperature grew from 25 to 750°C.

Keywords: reinforced concrete slabs, reactive powder, fire

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1 Introduction

To the knowledgeable, reactive powder concrete (RPC) is distinctive. And because of its greater mechanical qualities, concrete equipment has seen the most dramatic advances [1,2]. In 2018, Abdulraheem [3] studied the aims too see how RPC columns are RPC. After being subjected to fire, perform. This study's objective is to offer a detailed take into account the consequences of Fire on the stiffness, ductility, and energy absorption capability of twelve RPC columns measuring 100 by 100 by 900 mm imperiled to Inverse force, as well as to examine lateral ties' influence and increased concrete cover on refining post-fire behavior of columns. The findings revealed that determining the power of absorbing energy is preferable to utilizing the ductility index of displacement to estimate the ductility of specimens afterward presence visible to fire. In addition, RPC columns showed a significant decrease in the first and subsequent stiffness after fire exposure, with the reduction percentages increasing as the fire temperature increased from 400 to 600°C. In addition to various important RPC mechanical properties being examined, this study gives an experimental modification of the below fundamental static load impact, punching shear the RPC's actions of slabs. The influence of steel fiber volumetric ratio (Vf) and silica fume volumetric ratio (SF) was tested in this study on four slabs; after being exposed to fire, the temperature rose from 25 to 750°C.

2. Works in progress

Normal cement (type I) industrial from the Kufa factory was sent to the lab to be prepared for the casting of specimens and joints. The parameters of the used cement are shown in Tables 1 and 2; the cement was kept in airtight containers [4].

Sand, a fine aggregate, was provided and sourced from the nearby Al-Akhaider quarry. After screening the sand, all elements bigger than 600 m also lesser than 150 m in

Table 1: Cement chemical characteristics

Composition of oxides	% by weight	Limit of Iraqi specification no. 5/1984 [4]
SiO_2	20.60	—
CaO	63.19	—
MgO	4.10	5.0 (max.)
Fe_2O_3	4.20	—
Al_2O_3	4.10	—
SO_3	1.88	2.5 (max.)
Start-up loss	2.45	4.0 (max.)
Leftovers that are insoluble	1.31	1.5 (max.)
Time exhaustion	0.91	0.66–1.02
Constituents		
C_3S	50.02	—
C_2S	26.23	—
C_3A	4.40	—
C_4AF	13.62	—

Table 2: Cement's physical attributes*

Physical characteristics	Trial product	Limit of Iraqi specification No. 5/1984 [4]
Region of specific surface (Blaine method), m^2/kg	332.9	230 (min.)
Time setting (Yicale's technique)		
The starting point, h:min	2:0	00:45 (min.)
Last situation, h:min	4:1	10:00 (max.)
Strength in compression (MPa)		
3-Day period	21.20	15.00 (min.)
7-Day period	30.10	23.00 (min.)

*Analysis performed in the engineering faculty labs at Kufa University in Iraq.

diameter were unconcerned. Residual sand ranged in scope from 150 to 600 m was then cleaned with faucet water, emptied, settled a sieve 150 m in diameter, and left to trough for 2 min. Lastly, 48 h were spent drying the sand at 110°C. Before being cast off, Table 3 provides information regarding the sand's grain size distribution [5]. Table 4 displays its physical attributes.

Only clean drinking water is used for mixing, forming, and curing. The Sika Company provided grey densified silica fume, which was added to the concrete mixture to prepare the RPC samples as a substitute material. Table 5 [6] lists the chemical components of the substance. In this work, mild carbon steel and steel fibers with hooked ends were utilized. The steel fiber's properties are listed in Table 6 [7]. Glenium 51 is used commercially and adhering to ASTM C494 type a [8], an agent with a broad water

Table 3: Sand particle size distribution

By weight, passing (%)		
Sieve degree (mm)	**Sample**	**(IOS 45/1984) boundaries for sector no. 3 [5]**
4.75	96	90–100
2.36	87	85–100
1.18	76	75–100
0.60	60	60–70
0.30	14	12–40
0.15	4	0–10

Table 4: Fine aggregate property

Physical assets	Assessment product	Iraqi specifications have a limit. No.45/1984 [5]
Particular gravity	2.60	–
Sulfate concentration	0.061%	0.5% (max.)
Absorption	0.75%	–

Table 5: Silica fume's chemical composition*

Oxide configuration	Contraction	Oxide gratified (%)	description (ASTM C 1240-04) [6]
Silica	SiO_2	94.87	85.0 (min.)
Alumina	Al_2O_3	1.18	—
Iron oxide	Fe_2O_3	0.09	—
Lime	CaO	0.23	—
Magnesia	MgO	0.02	—
Sulfate	SO_3	0.25	—
Potassium oxide	K_2O	0.48	—
Ignition loss	L.O.I.	2.88	6.0 (max.)
Moisture level	—	0.48	3.0 (max.)

*Implementing the tests at the quality control lab of the engineering faculty at the University of Kufa in Iraq yielded the test.

Table 6: Steel fiber's properties*

Formation	Property	Description
	Statute	Hooked
	Dimension	30 mm
	Diameter	0.375 mm
	Density	7,800 kg/m^3
	Strength in tension	1,800 MPa
	The degree of flexibility	200 GPa
	Lf/Df characteristic ratio	80

*As supplied by the producer.

Table 7: Glenium 51 superplasticizer characteristics*

Procedure	Slick liquid
Name of the business	Glenium 51
Chemical	Naphthalene formaldehyde and sulfonated melamine
Composition	**Condensates**
Possessions of a subsidiary	An improvement in compression strength both early and late
Method	Viscous liquid
Colour	Light brown
Density	1.1 g/cm^3 at 20°C
pH	6.6
Viscosity	128 ± 30 cps at 20°C
Passage	Not considered to be dangerous
Classification	Hazard labels are not necessary.
Chloride satisfied	None

*As stated by the producer.

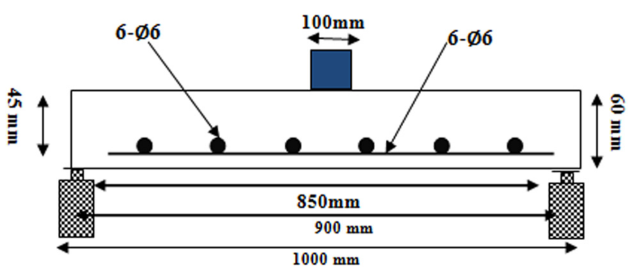

Figure 1: Cross-section of laboratory specimens.

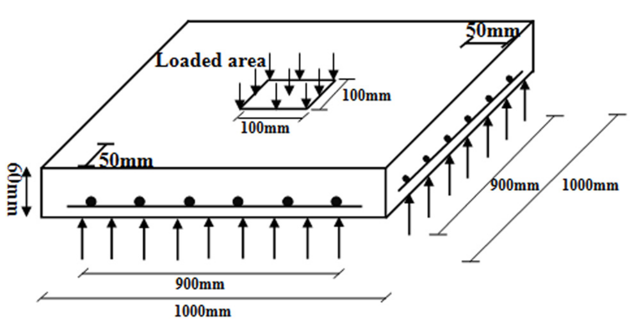

Figure 2: Geometry of laboratory specimens.

reduction range was supplementary to the mixture as a superplasticizer. Table 7 shows this sort of superplasticizer. As longitudinal reinforcement, steel reinforcing deformed bars were castoff, and as closed stirrups of diameter (φ = 6 mm) (square mesh from BRC type), reinforcement is with No. 6 bars spaced at 15 cm in x- and y-directions shown in Figures 1 and 2. Table 8 lists test values for every bar size [9].

2 Mixture of concrete

This study used two types of concrete mixtures.

2.1 Typical concrete mix

Casting normal (NC) using materials used were cement, fine aggregate, coarse aggregate, and water to create a conventional concrete composition. This mixture also yielded a regulator sample in the form of a cylinder test.

2.2 Concrete mixes using reactive powders

In this revision, five RPC mixes were discarded. Table 9 shows the number of supplies of all blends.

2.3 Setup for the test and how the loading is applied to the slabs

In the past, substantial research was conducted into slab punching shear in ambient settings. However, in the case of slabs in fire, punching shear has received insufficient attention, and only two references can be cited: The first is regarding small circular slabs' residual behavior, and the first is based on fire experiments on two-way slabs at full scale, while the second is based on formulae frequently

Table 8: Reinforcing steel properties*

Dim. (mm)	Area (mm^2)	Perimeter (mm)	Weight (g/m)	Yield strength (MPa)	Yield strain	Ultimate strength (MPa)	Ultimate strain
6	28.286	18.857	228	545	0.0028	760	0.051

*The engineering faculty laboratory at the University of Kufa in Iraq conducted the tests.

Table 9: Various forms of RPC mixes have different properties

Mix♣	Cement (kg/m³)	Sand (kg/m³)	Silica fume* (%)	Silica fume (kg/m³)	w/cementitious	SP** (%)	Steel fiber*** (%)	Steel fiber (kg/m³)
M0,25	1,000	1,000	25	250	0.2	1.7	0	0
M1,25	1,000	1,000	25	250	0.2	1.7	1	78
M2,25	1,000	1,000	25	250	0.2	1.7	2	156
M2,20	1,000	1,000	20	200	0.2	1.7	2	156
M2,15	1,000	1,000	15	150	0.2	1.7	2	156

♣The first value indicates (Vf), while the second indicates (SF). *Percentage of cement's weight. **Superplasticizer, as a percentage. ***% of total mix volume.

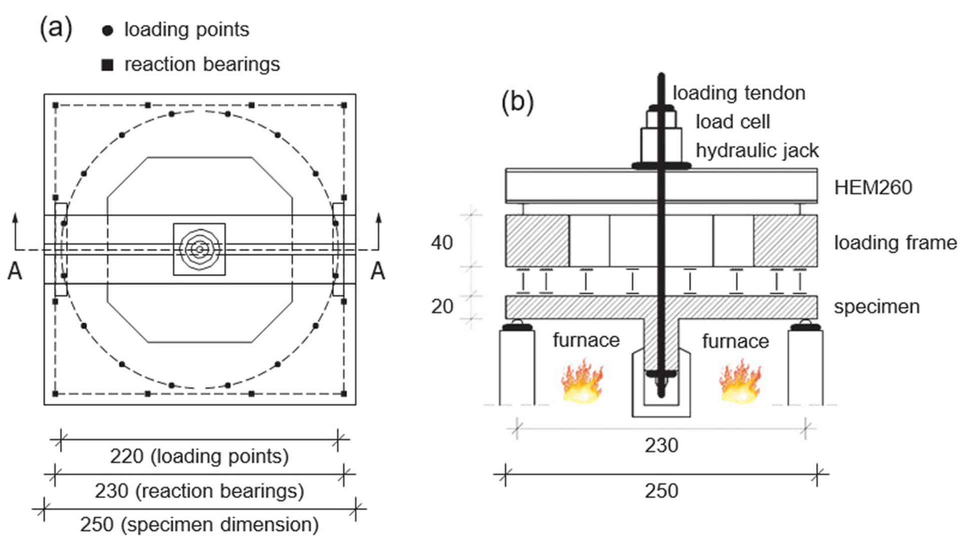

Figure 3: Setup for a test [13]: (a) top view and (b) A–A portion was cut.

expanded to accommodate the condition of high-temperature exposure when operated at ambient temperature [10].

The specimens that survived after the conclusion of the heating procedure, constant load phase without collapse, were loaded to failure protocol for applying loading to slabs depicted in Figure 3.

3 Discussion of experiment results

3.1 RPC's mechanical characteristics

Table 10 shown the results of hardened concrete test mechanical properties.

Table 10: Results of hardened concrete test mechanical properties

No. of mix	Combination of types	Steel fiber V_f (%)	Silica fume SF (%)	f_c' (MPa) [11]	f_t (MPa) [12]	f_r (MPa) [13]	E_c (MPa) [14]	Specimens
1	M0,25	0	25	91.87	6.64	6.27	37,481	RPC-S1
2	M1,25	1	25	111.93	11.78	14.64	42,342	RPC-S2
3	M2,25	2	25	122.78	16.18	18.89	45,324	RPC-S3
4	M2,20	2	20	121.22	15.31	17.97	44,663	RPC-S4
5	M2,15	2	15	113.98	14.69	17.12	44,467	RPC-S5
6	M_{normal}	—	—	26.98	2.79	3.28	25,354	NC-S6

3.2 Load-mid-span deflection owing to concrete type

Four specimens were recognized mid-span deflection of typical and RPC specimens are shown in Figure 4.

3.3 Patterns of crack

Figure 5 depicts the ultimate crack patterns of all slab specimens analyzed.

4 Conclusions

1. Increased steel fiber effects quantitative ratio on the last deflection demonstrates that growing the volumetric proportion of steel fibers to 2% permits RPC slabs to be more capable of ductility of considerable deflections earlier attainment of the resonant potential of final load, percentage (0, 1, and 2%) display that the deflection reductions at all loading phases due to an upsurge in stiffness.
2. Growth for steel fiber RPC slab in the first fracture load and final load through an enhanced ratio is owing to the

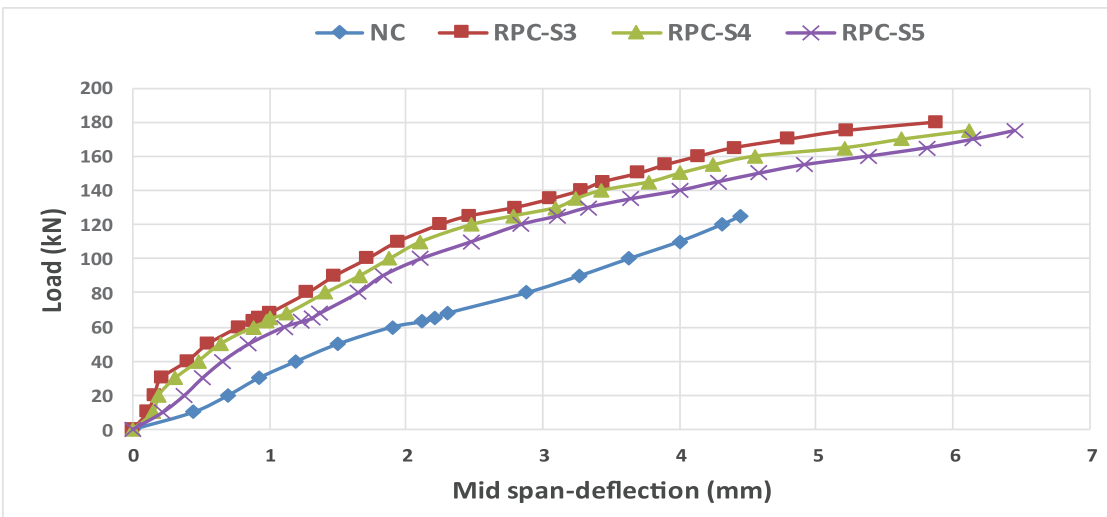

Figure 4: Bond between load and deflection for specimens at 750°C.

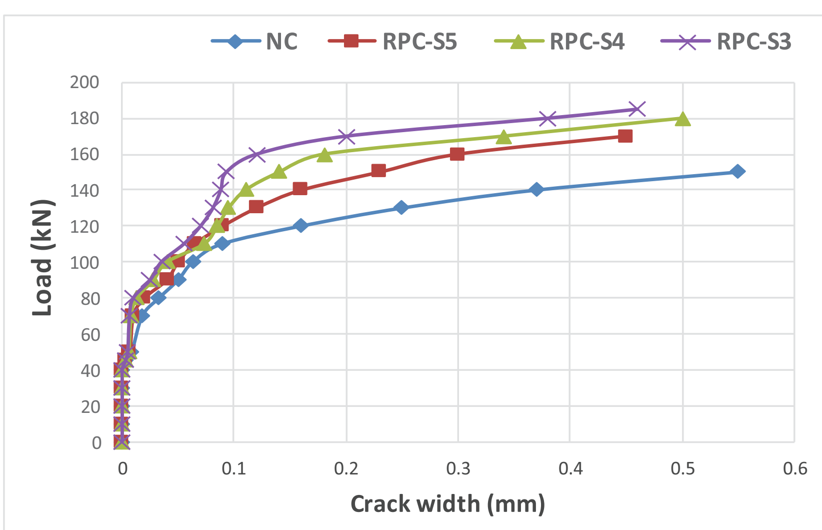

Figure 5: Comparison of load–crack width curves for specimens.

element that fibers boundary expansion and allowance cracks concluded the primary cracks.
3. Silica fume in concentrations ranging from 15 to 25% has minimal effect on RPC slabs' major fracture capacity, ultimate punching shear, or mid-span deflection. The mid-major span's crack load, maximum strength, and ultimate deflection all upsurge by 15–25%.
4. With proportions, the deflection increases through 30% of the total for RPC-S3, 22% for RPC-S4, and 16% for RPC-S5 as related to ordinary concrete slab confirmation upsurge.
5. Adding steel fibers in RPC improves the material's compressive strength. Increasing compressive strength improved as the volume portion grew from 0 to 1 and 2% of 20 and 33%, respectively.
6. As the percentage of steel fiber growth beginning splitting strength of 0 to 1% and 2% increases through 75 and 139%, respectively, silica fume has a minimal effect on increasing tensile splitting capability, with increases ranging from 15 to 20 to 25% rising through 2.32% toward 8.77%, separately.

Conflict of interest: The authors state no conflict of interest.

Data availability statement: Most datasets generated and analyzed in this study are comprised in this submitted manuscript. The other datasets are available on reasonable request from the corresponding author with the attached information.

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