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A Study on Responsive Powder Concrete: A Ultra High Strength Concrete

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Abstract - High-strength, next-generation concrete, Reactive Powder Concrete (RPC) is made from an innovative blend of powdered ingredients. Cement (often Portland cement), fine sand, silica fume, quartz powder, and high tensile steel fibers make up the other components of reactive powder concrete. Very high performance concrete includes reactive powder concrete. The use of steel pellets can increase the compressive strength of this concrete from its already impressive 200 MPa to a maximum of 800 MPa. With a flexural strength between 25 and 40 MPa, this new kind of concrete has an enhanced ductile behavior. The goal of this study is to determine whether or not prefabricated constructions, and in particular angle sections, can benefit from using Reactive Powder Concrete. In order to have a handle on how to proceed with this project, it is necessary to first define the properties of RPC blend.

Keywords - Responsive Powder Concrete, Ultra, High Strength, Concrete.

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INTRODUCTION

High-strength, next-generation concrete, Reactive Powder Concrete (RPC) is made from an innovative blend of powdered ingredients. Cement (often Portland cement), fine sand, silica fume, quartz powder, and high tensile steel fibers make up the other components of reactive powder concrete. Very high performance concrete includes reactive powder concrete. The mechanical and long-term stability of this concrete is greatly improved. Steel pellets may be used to increase the compressive strength of this concrete from its already impressive 200 MPa to as much as 800 MPa (Kim, 2017). With a flexural strength between 25 and 40 MPa, this new kind of concrete has an enhanced ductile behavior. These results can be attributed to the extremely discontinuous pore structure and enhanced microstructure characteristics. In comparison to regular confined concrete, this stuff has a high hardness index (Marvila, 2021).

Carbonation, chloride ion penetration, and sulfate attack are all nearly null. Moreover, the abrasion resistance is comparable to that of rock. The end result is a highly disconnected pore structure and maximal compactness (Naaman, 2018). The lack of shrinkage and creep makes the material ideal for use in prefabricated and prestressed buildings. Prefabricated structural applications benefit from the material's high strength and ease of production using standard industrial equipment via casting, injection, and extrusion (Wang, 2018).

RESEARCH METHODOLOGY

specifics of RPC's history of development and testing procedures. The goal of the research is to determine the most important factors that impacted the ratios used to create Reactive Powder Concrete and the most effective ways to cure the material. The viability of employing RPC as structural components, such as angle sections, is further investigated by studying its varied mechanical characteristics. These are the numerous programs that have been put through their paces in testing.

Experimental Schedule

With commonplace ingredients (such as cement, fine aggregate, silica fume, quartz powder, and micro fiber) and the right heat curing cycles, ready-mix concrete (RPC) with a goal compressive strength of around 200 MPa may be manufactured.

Mechanical Properties of RPC

- As part of the process of determining the optimal limits for fiber content, the impact of fiber addition on compressive and flexural strengths was also investigated.
- Research on RPC's potential usefulness in a given context.
- Compressive strength goals between 150 and 200 MPa, designed RPC blends

- Research on RPC's potential usage in a variety of applications
- Direct stress on bolted RPC plates.

Materials Used

For the experiment, researchers utilized regular Portland cement that met the requirements of IS: 12269. The Blain's fineness of the silica fume employed in this research was 20m2/g. Along with quartz powder, silicon dioxide made up the bulk of the silica fume's 94%. cement powders' chemical make-up and particle size distribution. Reactive powder concrete was made using standard sand meeting IS: 650 specifications (RPC). Aggregates in RPC may be no bigger than 2.36 mm in diameter, and that's both the maximum and nominal size. Micro steel fibres of two different lengths (6mm and 13mm) were utilized to create aggregates of different sizes (for RPC). Third-generation polycarboxylic-based superplasticizers were eventually used in sufficient amounts to provide workability control.

Formulation and Properties of RPC

The behavior of cylinders with varying combinations of fibre content is studied, and a Reactive Powder Concrete formulation developed at the Structural Engineering Research Center, Chennai, on the basis of thorough research was employed for fabrication of RPC. The next paragraphs detailed the numerous experimental procedures used in this investigation.

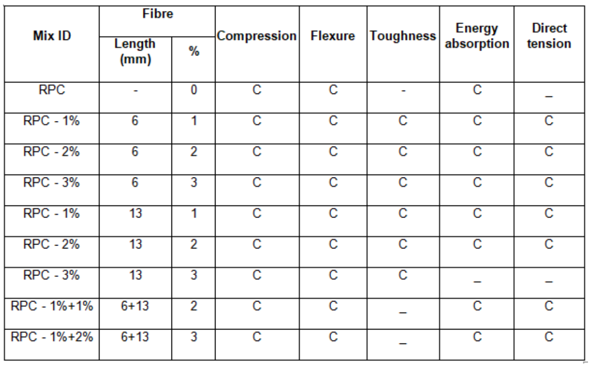
The following items were utilized in this investigation:

- Ordinary Portland cement of Grade 53 conforming to IS: 12269 : 1987
- Silica Fume
- Quartz powder
- Standard Ennore Sand conforming to IS: 383 : 1970
- Quartz sand
- Poly-acrylic ester type Super plasticizer
- Steel fibre of diameter 0.16mm and length 13mm & 6mm having tensile strength of 2000MPa.

Tests for Mechanical Properties

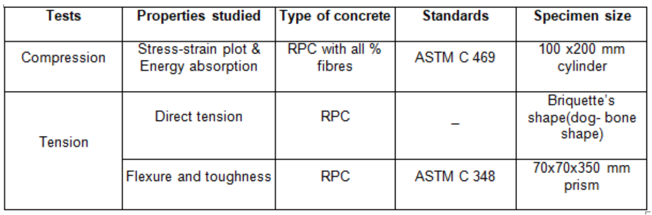
Compression, direct tension, and flexure tests are used to analyze the mechanical characteristics of RPC. The investigation's testing schedule is shown in Table 1. You can see the size of the specimens and the standard operating procedure for the mechanical testing in Table 2. Compression testing with 100 mm x 200 mm cylinders was used to calculate the static modulus of elasticity for RPC in accordance with the ASTM C 469 standard. Once each cycle of cure had lasted 28 days, the tests were run. Area under the flexural strength vs deflection curve was used to derive the concretes' toughness characteristics. According to ASTM C 1108, the toughness index was determined at levels of distortion of I5, I10, and I20. RPC concretes' energy absorption characteristic was determined by first charting the stress-strain curve in compression and then calculating the area under the stress-strain plot.

Table 1: Experimental program



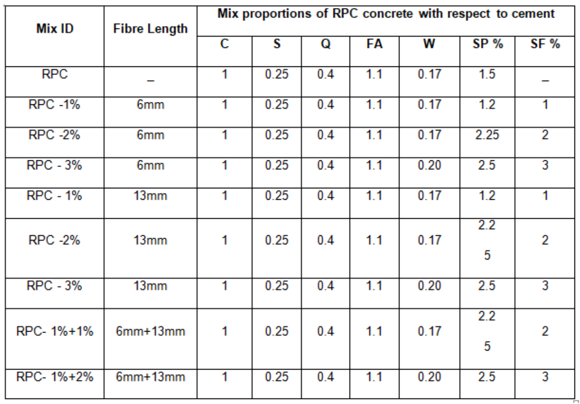
Mix ID	Fibre		Compression	Flexure	Toughness	Energy absorption	Direct tension
	Length (mm)	%					
RPC	-	0	C	C	-	C	_
RPC - 1%	6	1	C	C	C	C	C
RPC - 2%	6	2	C	C	C	C	C
RPC - 3%	6	3	C	C	C	C	C
RPC - 1%	13	1	C	C	C	C	C
RPC - 2%	13	2	C	C	C	C	C
RPC - 3%	13	3	C	C	C	_	_
RPC - 1%+1%	6+13	2	C	C	_	C	C
RPC - 1%+2%	6+13	3	C	C	_	C	C

Table 2: Tests conducted to study the Mechanical Properties of RPC



Tests	Properties studied	Type of concrete	Standards	Specimen size
Compression	Stress-strain plot & Energy absorption	RPC with all % fibres	ASTM C 469	100 x200 mm cylinder
Tension	Direct tension	RPC	_	Briquette's shape(dog- bone shape)
	Flexure and toughness	RPC	ASTM C 348	70x70x350 mm prism

Table 3: Mixture proportions

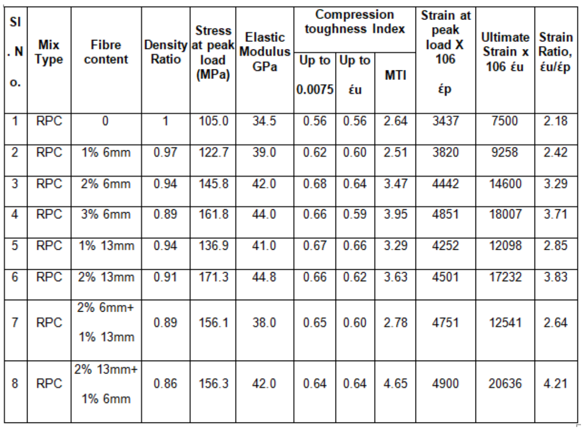


Mix ID	Fibre Length	Mix proportions of RPC concrete with respect to cement						
		C	S	Q	FA	W	SP %	SF %
RPC	_	1	0.25	0.4	1.1	0.17	1.5	_
RPC -1%	6mm	1	0.25	0.4	1.1	0.17	1.2	1
RPC -2%	6mm	1	0.25	0.4	1.1	0.17	2.25	2
RPC - 3%	6mm	1	0.25	0.4	1.1	0.20	2.5	3
RPC - 1%	13mm	1	0.25	0.4	1.1	0.17	1.2	1
RPC -2%	13mm	1	0.25	0.4	1.1	0.17	2.2 5	2
RPC - 3%	13mm	1	0.25	0.4	1.1	0.20	2.5	3
RPC- 1%+1%	6mm+13mm	1	0.25	0.4	1.1	0.17	2.2 5	2
RPC- 1%+2%	6mm+13mm	1	0.25	0.4	1.1	0.20	2.5	3

RESULTS

The elastic modulus, ultimate strain, and toughness indices, as well as the peak stress and associated strain, for a variety of mixtures, are displayed in Table 4. Table 4 demonstrates that when compared to regular concrete, the RPC mixtures have a compressive strength that is anywhere from 112.6 percent to 246.8 percent greater. The compressive strength of RPC mixes including both 6mm fibers and 13mm fibers rose when the fiber concentration was increased. The compressive strength of 2% 13 mm fibers was measured at 171.3 MPa, making it the highest of any fibre size tested. Compressive strength was lowest when a mix of 6mm and 13mm fiber was employed, compared to the best compressive strength achieved by using fibers of a single size. Table 4 shows density ratios that suggest the decreased workability and lower compaction density may be to blame. The findings of the current investigation suggest that the optimal fibre contents are 3% for 6mm and 2% for 13mm.

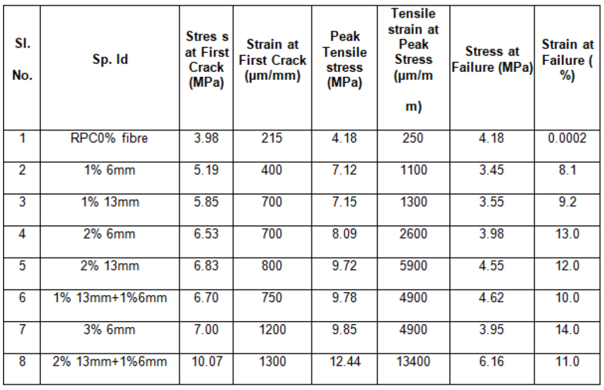
Table 4: Compressive strengths compared across RPC concentrations



Sl. No.	Mix Type	Fibre content	Density Ratio	Stress at peak load (MPa)	Elastic Modulus GPa	Compression toughness Index			Strain at peak load X 106 έp	Ultimate Strain x 106 έu	Strain Ratio, έu/έp
						Up to 0.0075	Up to έu	MTI			
1	RPC	0	1	105.0	34.5	0.56	0.56	2.64	3437	7500	2.18
2	RPC	1% 6mm	0.97	122.7	39.0	0.62	0.60	2.51	3820	9258	2.42
3	RPC	2% 6mm	0.94	145.8	42.0	0.68	0.64	3.47	4442	14600	3.29
4	RPC	3% 6mm	0.89	161.8	44.0	0.66	0.59	3.95	4851	18007	3.71
5	RPC	1% 13mm	0.94	136.9	41.0	0.67	0.66	3.29	4252	12098	2.85
6	RPC	2% 13mm	0.91	171.3	44.8	0.66	0.62	3.63	4501	17232	3.83
7	RPC	2% 6mm+ 1% 13mm	0.89	156.1	38.0	0.65	0.60	2.78	4751	12541	2.64
8	RPC	2% 13mm+ 1% 6mm	0.86	156.3	42.0	0.64	0.64	4.65	4900	20636	4.21

Table 5 displays the tensile parameters of the various blends, including the tensile strength at first visible fracture, peak stress, and failure stress and strain. what happens to the stress-strain behavior when you switch up the fiber type and/or the percentage of volume devoted to fibres. According to Jungwirth and Muttoni [2004] 44, all the samples originally exhibited linear elastic behavior with Young's modulus values around 42 GPa. The first visible break emerged at a stress level of around 70%-90%, depending on the kind and volume fraction of fibre. This resulted in brittle failure for plain RPC, whereas fibred RPC exhibits quasi-strain hardening, with stress increases of up to 10-30% depending on fibre type and volume percentage. There is a noticeable shift in the tensile stress-strain curve after cracking, but this is because of the high fiber-to-matrix ratio; that is, the fibers that span the fracture are stronger than the cement matrix as a whole. Nevertheless, quasi strain hardening is largely insignificant for low fibre volume fractions. Similar to traditional reinforced concrete, the quasi strain hardening action is characterized by an increase in capacity following cracking. Several fissures form at this point.

Table 5: Comparison of RPC Samples for Tensile Strength



Sl. No.	Sp. Id	Stres s at First Crack (MPa)	Strain at First Crack (μm/mm)	Peak Tensile stress (MPa)	Tensile strain at Peak Stress (μm/m m)	Stress at Failure (MPa)	Strain at Failure (%)
1	RPC0% fibre	3.98	215	4.18	250	4.18	0.0002
2	1% 6mm	5.19	400	7.12	1100	3.45	8.1
3	1% 13mm	5.85	700	7.15	1300	3.55	9.2
4	2% 6mm	6.53	700	8.09	2600	3.98	13.0
5	2% 13mm	6.83	800	9.72	5900	4.55	12.0
6	1% 13mm+1%6mm	6.70	750	9.78	4900	4.62	10.0
7	3% 6mm	7.00	1200	9.85	4900	3.95	14.0
8	2% 13mm+1%6mm	10.07	1300	12.44	13400	6.16	11.0

This multi-cracking effect is uniformly dispersed down the whole length of the specimen, thus it may be treated as spread. The micro-crack hole is large enough to activate the fibers and transmit the stresses from the matrix to the fibers. The binding strength of the fibers across the fracture is attained in one of the cracks at a strain of around 1500-3000 microstrains. When the fracture widens, it becomes a macro-crack that spreads throughout the full width, localizing the deformation there.

Fracture energy:

The following equation can be used to determine the fracture energy.

GF=W/Alig

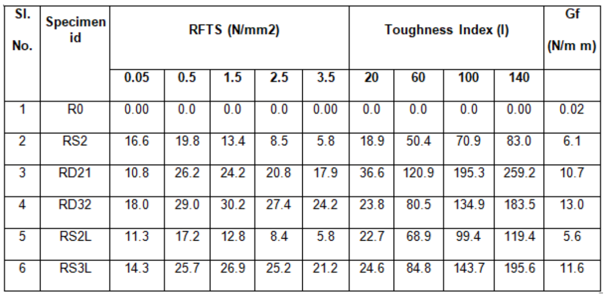
Where,

GF = fracture energy (N/mm2)

W = range from the bottom of the CMOD curve to the point where the specimen breaks (N-mm)

Alig = area of broken ligament (b*h) (mm2)

Table 6: Types of RPC Beams with Respect to Their Residual Flexural Strength, Fracture Energy, and Toughness Indices



Sl. No.	Specimen id	RFTS (N/mm2)					Toughness Index (I)				Gf (N/m m)
		0.05	0.5	1.5	2.5	3.5	20	60	100	140	
1	R0	0.00	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.00	0.02
2	RS2	16.6	19.8	13.4	8.5	5.8	18.9	50.4	70.9	83.0	6.1
3	RD21	10.8	26.2	24.2	20.8	17.9	36.6	120.9	195.3	259.2	10.7
4	RD32	18.0	29.0	30.2	27.4	24.2	23.8	80.5	134.9	183.5	13.0
5	RS2L	11.3	17.2	12.8	8.4	5.8	22.7	68.9	99.4	119.4	5.6
6	RS3L	14.3	25.7	26.9	25.2	21.2	24.6	84.8	143.7	195.6	11.6

The failure mode of the RPC samples subjected to Double Shear testing. Table 7 displays a tabulation of the shear stress for a range of fiber doses. With a mixed fiber ratio (3% 6mm + 2% 13mm), the maximum shear stress is 83.33MPa. In contrast, shear stress increases dramatically for 2% 13mm fibers (53.09 MPa). A high of 80.43 MPa was recorded with even 3%13mm fibers. When the percentage of fibers rises, so does the shear stress. Other mechanical testing have found the same thing. Therefore, the RPC beam devoid of any fiber has the lowest shear stress (13.33 MPa). This exemplifies the results obtained by incorporating RPC concrete with high tensile fibers. plots of shear stress against deformation for RPC with varying amounts of fiber. According to the findings, the optimal dose of fiber in RPC concrete is 2%, and the fiber size should be 13 mm.

Table 7: Shear Properties of RPC Beam Specimens

Sl.No.	Fibre content %		Peak Load(kN)	Corresponding Shear Stress(MPa)	Corresponding Elongation(mm)
	6mm	13mm			
R0	0	0	89.25	13.33	2.36
RS2	2	0	238.2	27.18	2.13
RD21	2	1	274.0	46.57	2.46
RD32	3	2	420.0	83.33	4.08
RS2L	0	2	275.0	53.09	2.81
RS3L	0	3	389.15	80.43	2.83

CONCLUSION

There is a new kind of Ultra High Performance Concrete called reactive powder concrete (RPC) that has improved attributes such strength, durability, ductility, and long-term stability. This research aimed to examine the mechanical characteristics of an RPC formulation made using local materials under compression, tension, shear, and flexure, and to look into its potential usage in certain common structural components, such as those found in building frames and space constructions. Small-scale structural models of various structural components, such as angle sections and infilled tubes, were tested to determine their performance. More than 205 MPa (Cubic Compressive Strength) of RPC may be made utilizing locally sourced components and straightforward manufacturing processes. In comparison to regular concrete and even high performance concrete, RPC has vastly improved material qualities. RPC can be used as a replacement for conventional concrete and HPC in engineering applications. The highest improvement in material characteristics was found to be attained with a fiber dose of 2% 13mm, without negatively impacting the workability of concrete.

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