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Mechanical and durability properties of reactive powder concrete

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Abstract
Reactive Powder Concrete (RPC) is composed of very finesteel fibres and superplasticizer. This Cohesive matrix gives ultra-high strength and durability properties. A comparison of the physical, mechanical and durability properties of RPC and high performance concrete (HPC) shows that RPC possesses better results compared to HPC. In order to increase the compressive strength of concrete even further than HPC, the only way is to remove coarse aggregate. This philosophy has been employed in what today known as Reactive powder concrete. The principal objective of this study is to prepare RPC120. In the present study, performance of reactive powder concrete without quartz powder and containing silicafume as a replacement for cement at the varying percentage of 0%, 5%, 10%, 15% and 20% by each is investigated. To compare the results of cement replaced mixture, specimens without cement replacement are also casted. Performance of the various mixes is tested by the Compressive strength, Flexure strength and Tensile strength. The results show improvement in compressive strength, flexural strength and Tensile strength in cement replaced mixes in Reactive powder concrete.

Keywords: Reactive powder concrete, RPC, steel fibers, silicafume

1. Introduction

1.1 General

Concrete is a versatile and critical material for the construction of infrastructure facilities throughout the world composed mainly of water, aggregate, and cement. Often, additives and reinforcements are included in the mixture to achieve the desired physical properties of the finished material. This is the most widely used material in construction field. Adding or replacing these constituent materials of concrete new type of concretes can be generated.. A new developing materials known as Reactive powder concrete (RPC) is available that differs significantly from traditional concrete. RPC has no large aggregates and contains small steel fibers that provide additional strength and in some cases can replace traditional steel reinforcement. Reactive powders concrete (RPC) will allow the concrete industry to optimize material use, generates economical benefits and built structures that are strong and durable.

1.2 Objectives of the Study

- The principal objective of this study is to prepare Reactive powder concrete (RPC 120) by adding steel fiber and silica fume in different volume proportions (0%, 5%, 10%, 15%, 20%).
- To investigate the durability properties such as Acid-Alkali attack by measuring % loss of weight for reactive powder concrete.

2. Experimental Program

2.1 Materials Used

The different materials used in this investigation are:

- Cement
- Aggregates
- Steel fibers
- Mineral admixtures
- Chemical admixture - Super plasticizer
- Water

2.1.1 Cement: Cement is a binding material, which is the combination of two raw materials called calcareous and argillaceous materials. Zuari-53 grade ordinary Portland cement conforming to IS: 12269 was used.
The physical properties of the cement are listed in Table

Table 1: Properties of Ordinary Portland cement.

S. No	Properties	Results	IS : 12269-1987
1.	Specific gravity	3.15	--
2.	Normal consistency	32%	--
3.	Initial setting time	35	Minimum of 30min
4.	Final setting time	600	Maximum of 600min
5.	Compressive strength A. 3 days strength B. 7 days strength C. 28days strength	 29.4Mpa 42.5Mpa 56.1Mpa	 Minimum of 27Mpa Minimum of 40Mpa Minimum of 53Mpa

2.1.2 Fine Aggregates
The standard sand used in this investigation was obtained from pennar river, Nellore. The standard sand shall be of quartz, light grey or whitish variety and shall be free from silt. The sand grains shall be angular, the shape of the grains approximating to the spherical form elongated and flattened grains being present only in very small or negligible quantities. The standard sand shall (100 percent) pass through 2-mm IS sieve and shall be (100 percent) retained on 90-micron IS Sieve and the sieves shall conform to IS 460 (Part: 1): 1985.
The physical properties of sand is given by

Table. 2 Properties of Fine aggregate

Colour	Grayish White
Specific gravity	2.64
Shape of grains	Angular

2.1.3 Coarse Aggregates
According to IS 383: 1970, coarse aggregate may be described as crushed gravel or stone when it results from crushing of gravel or hard stone. The coarse aggregate procured from quarry was sieved through the sieved of sizes 20 mm and 10 mm respectively. The aggregate passing through 20 mm IS sieve and retained on 10 mm IS sieve was taken.
The physical properties of gravel is given by

Table 3: Properties of Coarse aggregate

Colour	Grayish White
Specific gravity	2.60
Absorption in24 hours	0.80%
Shape of grains	Sub angular

2.1.4 Steel Fibers
Stainless steel fibers are manufactured fibers composed of stainless steel. Composition may include carbon (C), silicon (Si), manganese (Mn), phosphorus (P), sulfur (S), and other elements. To enhance the RPC ductility, some mixes were produced with micro-fibers of straight carbon steel wire, 13 mm in length and 0.2 mm in diameter, with a minimum on-the-wire tensile strength of 2,000 MPa. These were supplied by ''ASTRRA CEMICALS IN CHENNAI''

Fig 1: Steel fibers of Hooked type.

The properties of steel fibers used in this investigation are given in following table.

Table 4: Properties of Steel fibers

Colour	Grey
Specific gravity	>1450Mpa
Shape of grains	Hooked

2.1.5 Mineral Admixture
2.1.5.1 Silica Fume
A highly reactive silica pozzolan is an essential component of reactive powder concrete
The general properties of the silica fume used in this study are contributed by ''ASTRRA CEMICALS IN CHENNAI'' its properties are mentioned below.

- Micro silica is initially produced as an ultra-fine dandified powder.
- At least 98%SIO2 content.
- Minimum specific surface area is 15,000 m2\kg.
- Spherical particle shape.

2.1.6 Chemical Admixture
2.1.6.1 Super Plasticizer
Super plasticizer is essential for the creation of SCC. The job of SP is to impart a high degree of flow ability and deformability, however the high dosages generally associate with SCC can lead to a high degree of segregation. "VARAPLAST SP 123" is utilized in this project, which is a product of AKARSH SPECIALITIES Company.

2.1.7 Water
Portable water was used in the experimental work for both preparing and curing. The pH value of water taken is not less than 6.

3. Mix Design for Present Investigation
3.1 RPC120 mix design (parts by mass)

1. Considerable numbers of trial mixtures were prepared to obtain good RPC and HPC mixture proportions.
2. Particle size optimization software, LISA[developed by Elkem ASA Materials] was used for the preparation of RPC trial mixtures.
3. Various mixture proportions obtained from the available literature were also studied.
4. The selection of best mixture proportions was on the basis of good workability and ideal mixing time.
5. Finalized mixture proportions of RPC is shown in below Table.

Table 5: Mix proportion for RPC 120

Components	Low temperature curing	High temperature Curing
Cement	1.00	1.00
Sand	1.10	1.10
Silica fume *or* pozzolan	0.25	0.23
Powdered quartz flour	NIL	0.39
Steel fibres [optional]	0.175	0.175
w/b ratio [as required for workability]	0.11-0.26	0.17-0.23
Super-plasticiser [% solids on cement]	0.6-16	1.9-2.5

Moulds Used For Casting

Standard cubes moulds of 150 x 150 x 150mm for HPC and 100 x 100x 100mm for RPC made of cast iron were used for testing of compressive strength.

Cylindrical moulds of 150 mm in diameter and 300 mm height for HPC and 100 mm in diameter and 200 mm height for RPC were used for concrete specimens for testing of Split tensile strength.

Prism moulds of dimension 500 x 100 x 100mm were used for both RPC and HPC for the testing of flexural strength.

4. Results and Discussions

4.1 Workabilty Test Results

Table 6 Slump values for RPC 120 and HPC M60 grade varying % of silica fume.

% added	Slump in ‘’mm’’
	RPC 120
	Silica fume added
0%	65
5%	68
10%	75
15%	82
20%	85

The above values shows the different slump values at different percentages. The high workability is obtained at 20% of silica fumes in cement content for the Reactive Powder Concrete.

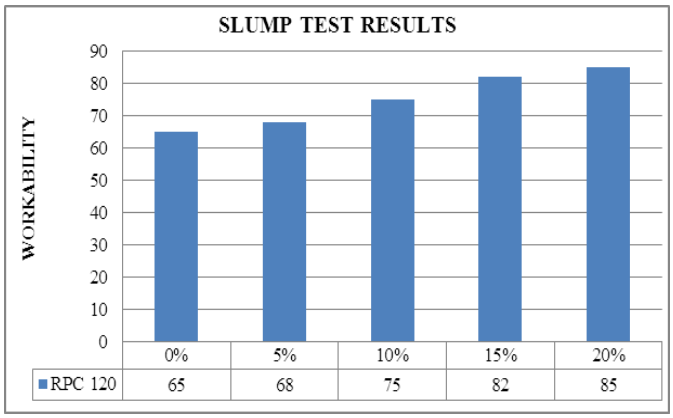

Fig 2: Slump values for RPC 120 grade varying % of silica fume.

4.2 Compressive Strength Test

Table 7: Compressive strength test values for RPC 120 varying % of steel fibers and silicafume.

Compressive strength in N/mm^2			
% of Silica fume added	RPC 120		% of Silica fume added
	7 days	28 days	
0%	65	107	0%
5%	67	112	5%
10%	70	115	10%
15%	72	120	15%
20%	74	123	20%

From above table we can notice that the average compressive strength of Reactive Powder Concrete is attain more than target strength at 20% of Silica fumes replacement with cement quantity.

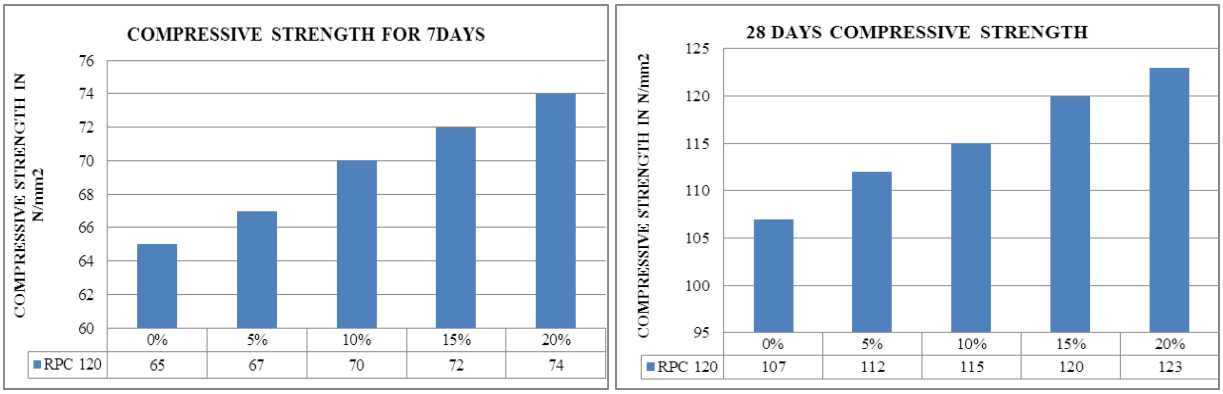

Fig 3: Compressive strength test values of RPC 120 varying % of steel fibers and silicafume 7& 28 days curing.

4.3 Tensile Strength Test

Table 8: Tensile strength test values for RPC 120 varying % of silicafume.

Tensile strength in N/mm^2			
% of Silica fume added	RPC 120		% of Silica fume added
	7 days	28 days	
0%	3.9	6.4	0%
5%	4.1	6.9	5%
10%	4.3	7.2	10%
15%	4.6	7.6	15%
20%	5.1	8.4	20%

From above table we can notice that the average tensile strength of Reactive Powder Concrete are attain more than target strength at 20% of Silica fumes replacement with cement quantity.

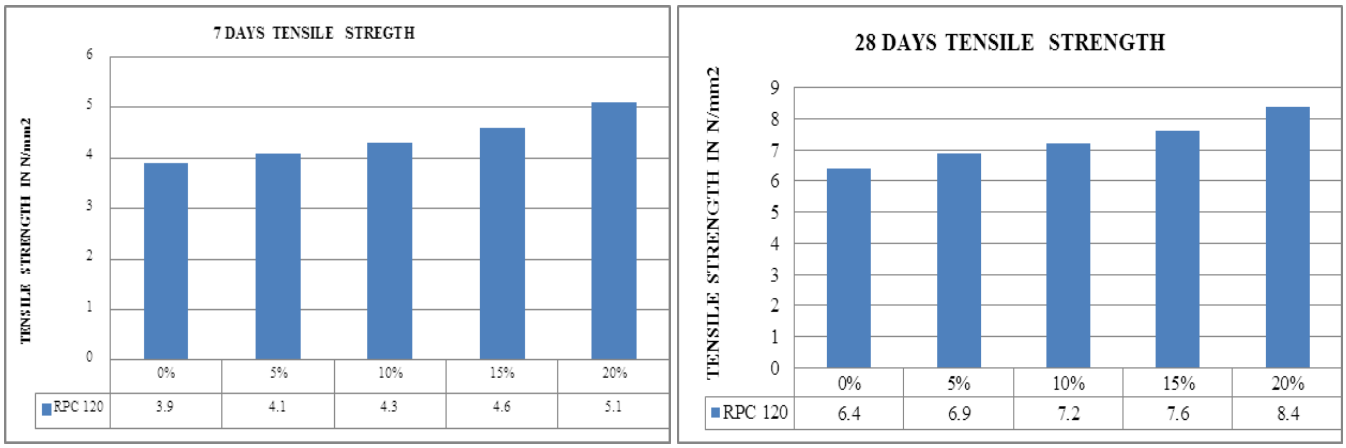

Fig 4: Tensile strength test values of RPC 120 varying % of steel fibers and silicafume 7& 28 days curing.

4.4 Flexural Strength Test Results

Table 9: Flexural strength test values for RPC 120 varying % of silicafume.

Flexural strength in N/mm^2			
% of Silica fume added	RPC 120		% of Silica fume added
	7 days	28 days	
0%	3.7	6.1	0%
5%	3.9	6.5	5%
10%	4.1	6.8	10%
15%	4.3	7.1	15%
20%	4.8	7.6	20%

The average Flexural strength of Reactive Powder Concrete attain more than target strength at 20% of Silica fumes replacement with cement quantity.

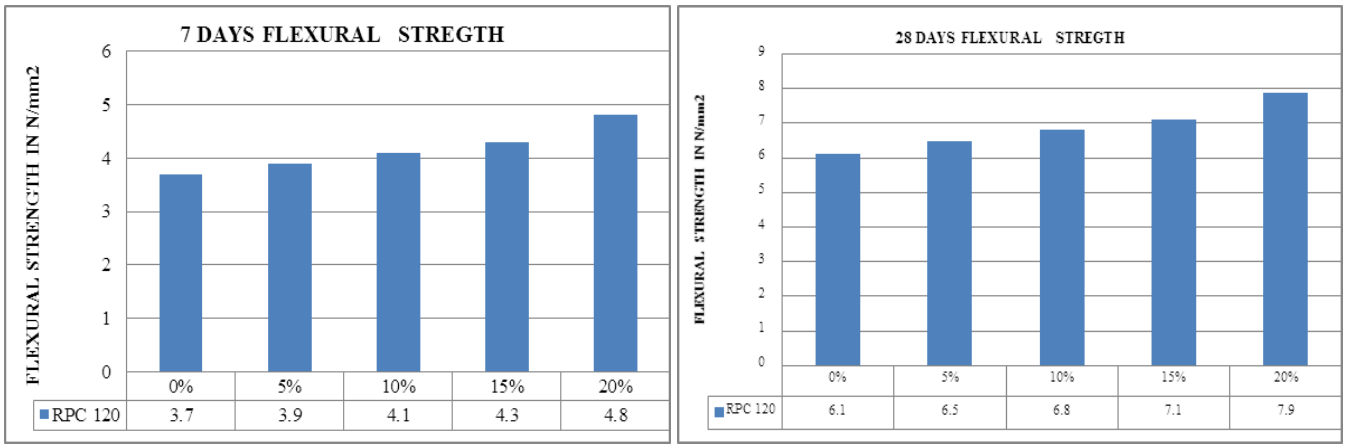

Fig 5: Flexural strength test values of RPC 120 varying % of steel fibers and silicafume 7& 28 days curing.

4.5 Acid Attack Test Results

4.5.1% Loss of Weight Reduction of Cubes after 28 Days Acid Curing

Table 10: % loss of weight reduction of cubes in acid curing after 28 days

% added	% loss of weight reduction		
	RPC 120		
	Silica fume added		
	Initial weight	Final weight	% loss in weight
0%	2.40	2.22	7.5
5%	2.55	2.48	2.70
10%	2.72	2.65	2.57
15%	2.80	2.73	2.50
20%	2.85	2.78	2.45

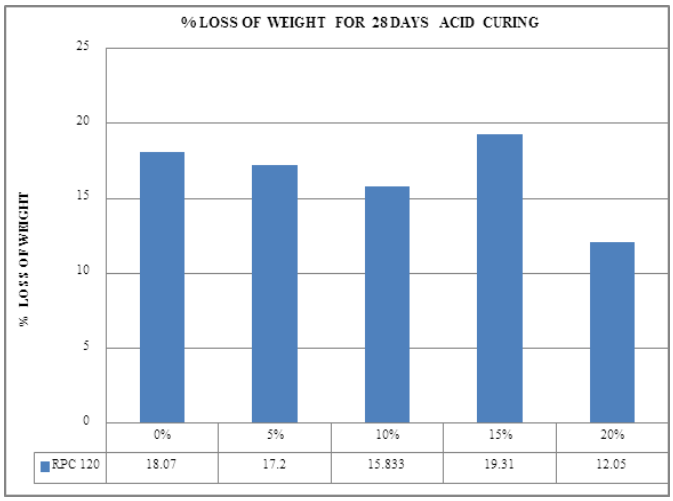

Fig 6: % loss of weight reduction of cubes in acid curing after 28 days

4.6 Alkali Attack Test Results

4.6.1 % Loss of Weight Reduction of Cubes after 28 Days Alkali Curing

Table 11: % loss of weight reduction of cubes in alkali curing after 28 days

% added	% loss of weight reduction		
	RPC 120		
	Silica fume added		
	Initial weight	Final weight	% loss in weight
0%	2.40	2.22	7.5
5%	2.57	2.48	3.50
10%	2.70	2.62	2.96
15%	2.80	2.72	2.86
20%	2.86	2.78	2.79

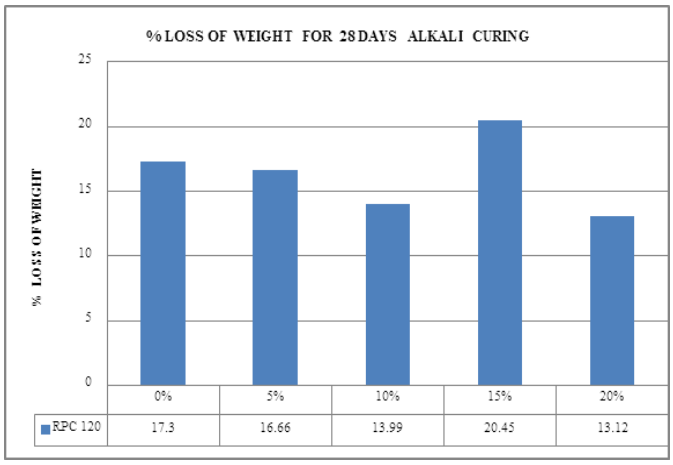

Fig 7: % loss of weight reduction of cubes in alkali curing after 28 days

5. Conclusions

- The addition of Steel Fibres in Reactive Powder Concrete will give more strength than High Performance Concrete
- For dealing with Steel Fibres in Reactive Powder Concrete there is a necessity of suitable super plasticiser to achieve workability.
- The average workability increases in slump of concrete with increase in silica fume percentages from 0% to 20% in Reactive Powder Concrete.
- The use of Reactive Powder Concrete as conventional concrete gives more strength with less Thickness.
- It has more weight and less amount of Reinforcement is required for casting.
- Reactive Powder Concrete is suitable where the thickness is fixed and strength required more.
- It reduces the requirement of Reinforcement than convention concrete, which is Economical than conventional concrete.
- It allows for design of extremely subtle and light structural elements, which brings savings in costs of other load bearing parts of the structure, transport and the assembly itself.
- It is resistant against aggressive environmental conditions and extreme climatic conditions.

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