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Study on Properties of Modified Reactive Powder Concrete

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Abstract:- Reactive Powder Concrete (RPC) is an ultra-high strength and high ductility composite material with advanced mechanical properties. It is developed in 1990's by the French Company Bouygues. It is a special concrete wherein the microstructure is optimized by precise gradation of all particles in the mix to yield maximum density.

RPC extensively uses the pozzolanic properties of highly refined silica fume and optimization of the Portland cement chemistry to produce the highest strength hydrates. It represents a new class of Portland – cement based material with compressive strengths of range 150Mpa. The material exhibits high ductility with values of energy absorption approaching those that are reserved for only metals.
The RPC concept is based on the principle that a material with a minimum of defects such as micro-cracks and voids will be able to achieve a greater load – carrying capacity and greater durability.
And finally, the purpose of this investigation is to attribute to the refinements in RPC with an introduction of graded aggregate (3-8mm) and also do the without of coarse aggregate is to be done by the Ordinary Reactive Powder Concrete (ORPC). So as to make this RPC more economical and feasible without much reduction in its mechanical properties. This modification makes the traditional RPC as an innovative MRPC (Modified Reactive Powder Concrete).

Keywords: Compressive Strength, Flexural Strength, Curing Regime, Steel Fibres, MRPC.

I. INTRODUCTION

Reactive powder concrete is an ultra high strength and high ductility composite material with advanced mechanical properties which is developed in 1990's by French company Bouygues. It is a special concrete wherein the microstructure is optimized by precise gradation of all particles in the mix to yield maximum density. Reactive Powder Concrete (RPC) consists of fibre - reinforced, super plasticizers, silica fume-cement mixture with very low water-cement ratio (w/c) and very fine quartz sand (0.15-0.40 mm) instead of ordinary aggregate. In fact, it is not a concrete because there is no coarse aggregate in the cement mixture. The absence of coarse aggregate was considered by the inventors to be a key aspect for the microstructure and the performance of the RPC in order to reduce the heterogeneity between the cement based matrix and the aggregate. RPC represents a new class of Portland cement based material with compressive strength in excess of 150mpa. By introducing fine steel fibres, RPC can achieve remarkable flexural strength up to 30-40mpa. The material exhibits high ductility with typical values for energy absorption approaching those reserved for metals. The main purpose of the present study was to modify RPC by replacing a fraction of quartz sand by graded natural aggregate (max size 8 mm) and to study the influence of the graded aggregate on the properties of cement mixtures in terms of required water-cement ratio, compressive and flexural strength. Though RPC is economical compared to steel structures by itself and is replacement in such cases, it can be made still economical and feasible by modifying it by replacing Quartz powder by natural graded aggregate.

A. MATERIALS

Cement used in the investigation was 53 Grade Ordinary Portland cement confirming to IS: 12269. The specific gravity of cement was 3.15. The initial setting time of cement is 40 min and final setting time is 560 min. The fine aggregate was conforming to Zone-4 according to IS: 383. The fine aggregate used was obtained from a nearby river source. The specific gravity was 2.61, while the bulk density of sand was 1400 kg/m3. Quartz sand is used by the replacing of natural river sand. The specific gravity of Quartz sand is 2.7, while the bulk density of sand was 1450 kg/m3. Crushed granite was used as coarse aggregate. The coarse aggregate was obtained from a local crushing unit having 3-8 mm nominal size, well graded aggregate according to IS: 383. The specific gravity was 2.75, while the bulk density was 1600kg/m3. Potable water was used in the experimental work for both mixing and curing companion specimens. High range water reducing admixture confirming to ASTM C94 commonly called as super plasticizers was used for improving the flow or workability for decreased water cement ratio as low as 0.22. In the present investigation, water-reducing admixture Glinium B233 and Conplast SP430 obtained from BASF Chemicals was used.. Silica fume is used to conforming the O-BASF material ASTM C1240-

97B and the particle size range between 5.3-1.8 µm. The specific gravity of silica fume is 2.2.

The materials are listed below in Table 1:

Table 1:

Sample	Specific Gravity	Particle Size
Cement (OPC 53 Grade)	3.15	31 µm -7.5 µm
Silica Fume	2.2	5.3 µm – 1.8 µm
Steel Fibres – 13 mm	7.1	Length 13 mm and dia 0.4 mm
River Sand	2.61	5.3 µm – 1.3µm
Quartz Sand	2.7	0.6 mm - 0.15 mm
Natural Graded Coarse aggregate	2.75	3 mm - 8 mm

B. Experimental Programme

In this investigation, each variable included was studied separately and when an optimum or near optimum procedure was determined for that variable, it was incorporated as the remaining variables were studied. The most fundamental factor in high strength concrete is the cement paste. Without high quality binder, the production of high strength concrete is impossible. For that commercially available OPC cement is used.

The required quantities of the ingredients were taken according to the mix proportion adopted for different trails on the basis of literature. The RPC and MRPC mixes were produced for the required batches using an epicyclic mixer complaint with the requirement of ASTM C 305. The extended mixing time is necessary both to fully disperse the silica fume, breaking up any agglomerated particles, and to allow the super-plasticizing agent to develop its full potential.

In this study compressive and flexural strengths of Reactive Powder Concrete (RPC) with Modified Reactive Powder Concrete (MRPC) are compared by taking different proportions of aggregates by varying w/c ratios. The strengths are tested by using at 28 days by ordinary curing and accelerated curing of 48hrs at 75̊C.

Additional of silica fume as an artificial pozzolanic admixture requires more water for concrete Micro silica makes the concrete sticky in nature and hard to handle, flow of RPC and MRPC as measured workability. The flow initially increases in silica fume content and then decreases after certain level because of water demand increases.

In this investigation flow table test is to be done by the measured to workability of RPC & RPCCA. In this experiment we can observe the workability values and compare to booth of RPC & RPCCA. The workability values are does not come to the replacement of coarse aggregate. Without addition of coarse aggregate the workability results.

B.1. Flow Table test:

From the above figure workability can be measured and find flow of concrete is tabulated as given below in the table 2.

Table 2: Workability Results from the above procedure

W/C Ratio	RPC	RPCCA	RPCSF	RPCCASF
0.27	135 mm	-	132 mm	-
0.25	120 mm	-	118 mm	-
0.24	110 mm	-	108 mm	-
0.22	105 mm	-	100 mm	-

RPC = Reactive Powder Concrete.
RPCCA = Reactive Powder Concrete with Coarse Aggregate.

RPCSF = Reactive Powder Concrete with Steel Fibres.
RPCCASF = Reactive Powder Concrete With Coarse Aggregate and Steel fibres.

B.3. Experimental Investigation:

In this investigation so many cubes and beams are casted by the different types of mix proportions and adopted by the four different w/c ratios. The lowest w/c ratio is 0.22. In that of mix proportions adding of silica fume as 15-28 % and dosage of super plasticizers as 3-4 % of cement content. The size of cubes is casted by the 100 X 100 X 100 mm and beam size is 500 X 100 X 100 mm.

B.3.1. Compressive Strength Test:

The cube specimens were tested in a standard compression testing machine of capacity 300 Tons. The axes of the specimens were carefully aligned at the centre of the loading frame. The load applied was increased continuously at a constant rate until the resistance of the specimen to increasing load breaks down and could no longer sustain. The maximum load applied on the specimen was recorded. The rate of loading was adopted as per IS 516.

B.3.2. Flexural Strength Test:

The beam specimens were tested in a universal testing machine of 40 tons for two-point loading to create a pure bending. The two point bending load applied was increased continuously at a constant rate until the specimen breaks down and no longer can be sustained. The maximum load applied on specimen was recorded.

The modulus of rupture depends on where the specimen breaks along the span.

C. CURING METHODOLOGY:

The development of strength of concrete is a function of not only time but also that of temperature. In RPC the enhancement of microstructure is obtained by means of heat treatment i.e. hot water curing. Heat-treating is performed after the concrete has set, by simply heating at ambient temperature. Heat-treating at 90°C substantially accelerates the pozzolanic reaction, while modifying the microstructure of the hydrates which have formed. However these hydrates remain amorphous. At high temperature the hydration process accelerates and the calcium hydroxide (Ca(OH)2) liberated in the hydration process is not fully utilized by silica fume alone, so crushed quartz is added in RPC to have full utilization of the Ca(OH)2 at higher temperature. For the mixes (HWC) hot water curing was done for 48 hours just after the setting of concrete, for the mix (HWC) after setting the cubes. The variations in the compressive strength gained from the different periods of curing are tabulated in the Table 3&4. The result shows that the hot water curing plays significant role in achieving the high compressive strength for the same proportion. Duration of hot water curing also effect the compressive strength but cost is also another factor to be considered. So, normally hot water curing for 48 hrs at 90°C in hot water bath, after setting is considered as an economical solution.

D. TEST RESULTS:

Table 3: Compressive Strength Results With and without coarse aggregate no addition of steel fibres.

W/C Ratio	RPC	RPCCA
0.27	110	108
0.25	115	112
0.24	122	117
0.22	129	127

Table 4: Compressive Strength Results With and without coarse aggregate addition of steel fibres.

W/C Ratio	RPCSF	RPCCASF
0.27	131	110
0.25	135	115
0.24	142	120
0.22	148	130

Table 5: Flexural Strength Results With and without coarse aggregate no addition of steel fibres.

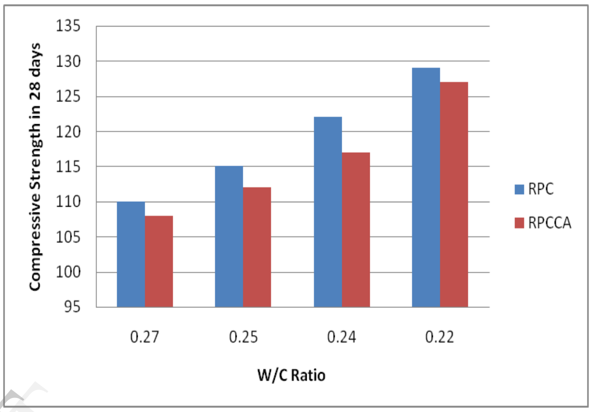
W/C Ratio	RPC	RPCCA
0.27	18.7	12.6
0.25	19.8	13.78
0.24	20	14.19
0.22	22	15.78

Table 6: Flexural Strength Results With and without coarse aggregate addition of steel fibres.

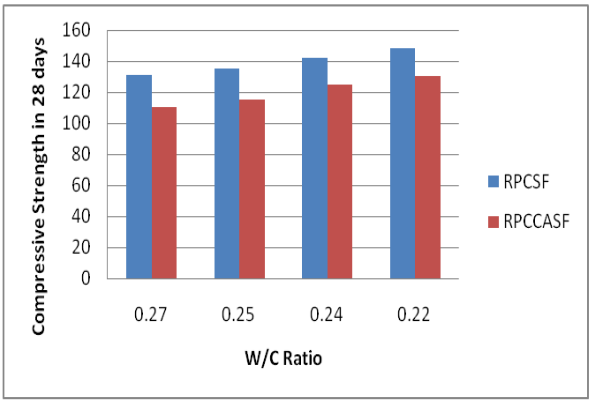
W/C Ratio	RPCSF	RPCCASF
0.27	22	17
0.25	27	19
0.24	29	22
0.22	37	25

E. GRAPHS:

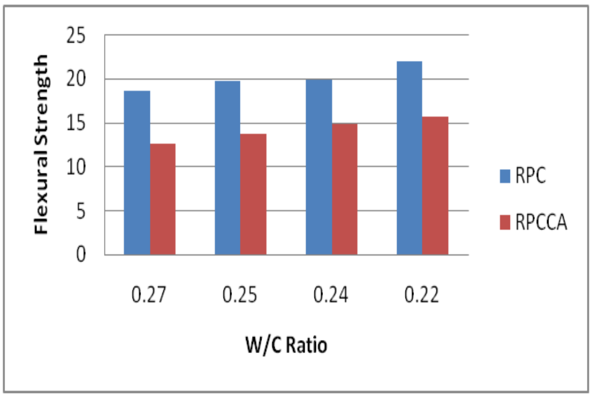
1. Compressive Strength Results With and without coarse aggregate no addition of steel fibres.



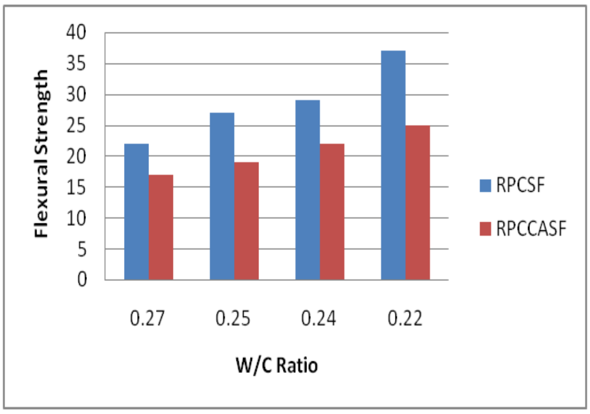
2.Compressive Strength Results With and without coarse aggregate addition of steel fibres.



3.Flexural Strength Results With and without coarse aggregate no addition of steel fibres



4.Flexural Strength Results With and without coarse aggregate addition of steel fibres.



F. CONCLUSIONS:

1. From the above results we can conclude that RPC and RPCCA have very slight variations in compressive strength and also flexural strength values.
2. At water cement ratio as low as 0.22, polycarboxylic ether gives good workable concrete, but normal super plasticizers like SNF requires higher water-cement ratio.
3. The results show that silica fume gives better compressive strength and good flow at lower water-cement ratio.
4. Workability is not achieved when coarse aggregate is used in MRPC.
5. From the table 1 on average compressive strength is increased by 3 % for RPC and RPCCA.
6. From the table 2 on average compressive strength is increased by 20 % for RPCSF and RPCCASF.
7. From the table 3 on average of flexural strength is increased by 6 % for RPC and RPCCA.
8. From the table 4 on average of flexural strength is increased by 8 % for RPCSF and RPCCASF.

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