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Reactive Powder Concrete with Composite Fibres

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Abstract*: Reactive Powder Concrete (RPC) is a composite material characterised with high strength and durability. Reactive powder concrete is a type of concrete which is made without coarse aggregate, contains cement, river sand, micro silica, super plasticizer and composite fibres with low water cement ratio. RPC can attain high strength characteristics with the addition of fibres. In this project we cast Reactive Powder Concrete specimens of suitable mix proportions by trial and error method and tested its compressive strength, tensile strength and flexural strength characteristics. In order to increase the strength of RPC we have adopted hot water curing at 90°C for 24 hours. Hence, rapid hydration of cementitious materials increases the strength of RPC.

Keywords: Reactive Powder Concrete, Micro silica, composite fibres, hot water curing

I. INTRODUCTION

Reactive Powder Concrete is a cementitious composite material developed by P. Richard and M. Cheyrezy in early 1990's. This composite material represents advanced physical and mechanical properties when compared with ordinary concrete or High Performance Concrete (HPC). In order to achieve maximum compressive strength sufficient super plasticizers are added. But the coarse aggregate becomes the weakest link of concrete at such level of strength. Hence, replacing the coarse aggregate of ordinary concrete with micro silica and composite fibres improves the strength of the concrete. This philosophy is employed in RPC. Thus, RPC is made of fine powdered materials which results in increased homogeneity and compactness of concrete.RPC has low water absorption and low permeability properties and enables it in the use of nuclear waste containment.

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II. MATERIALS USED

A. Cement

Fig. 1 Cement

The cement properties are determined to meet the requirements of 12269- 1987: Specification for Ordinary Portland Cement.

TABLE 1 PROPERTIES OF CEMENT

S.No.	Property	Result
1.	Type	53 grade
2.	Specific gravity	2.67
3.	Fineness	96%
4.	Consistency	31%
5.	Initial setting time	35 minutes

B. Micro silica

Fig. 2: Micro Silica

TABLE 2 PROPERTIES OF MICRO SILICA

S.No.	Property	Result
1.	Colour	White
2.	State	Powder
3.	Specific gravity	2.24
4.	Fineness	96%

C. Sand

Fig. 3: Sand

TABLE 3 PROPERTIES OF SAND

S.No.	Property	Result
1.	Specific Gravity	2.67
2.	Fineness Modulus	4.71%

D. Water

Water is the ingredient in the concrete that mixes with cement, forming a binder which establishes bond between aggregates. The pH value of water used in this RPC is 6.7

E. Super plasticizer

The RPC acquires high strength with low water cement ratio and this requires the use of super plasticizers to achieve sufficient workability.**MasterGlenium SKY 8233** a high performance super plasticizer based on polycarboxylic ether is used in this project.

F. Polypropylene fibre

Fig. 4: Polypropylene fibre

TABLE 4 PROPERTIES OF POLYPROPYLENE FIBRE

S.No.	Property	Result
1.	Length	4mm
2.	Diameter	0.045mm
3.	Aspect Ratio	88.88
4.	Thermal Resistance	165°C

G. Coir fibre

Fig. 5 Coir fibre

TABLE 5 PROPERTIES OF COIR FIBRE

S.No.	Property	Result
1.	Length	5.5cm
2.	Diameter	0.02mm
3.	Aspect Ratio	275
4.	Thermal conductivity	Low

III. MIX PROPORTION

The mix proportion for normal RPC is selected based on the trail mix values in Table 6. These proportions were decided based on the previous literatures guidelines on RPC. The mix proportion "N2" was selected for normal RPC based on compressive strength at 7 days curing period. The composite fibres of polypropylene fibre and coir fibre are incorporated to the selected mix ratio "N2". During addition of fibres, the water cement ratio is increased from 0.3 to 0.35 in the mix. The corresponding fibre mix proportions for modified RPC are listed in Table 7.

TABLE 6 MIX PROPORTIONS FOR NORMAL RPC

S.No	Mix Proportions	Cement	MicroSilica	Sand	Water	SP	Compressive strength at 7 days (N/mm)
1.	N1	1	0.13	1.6	0.3	5	16
2.	N2	1	0.15	1.6	0.3	5	18
3.	N3	1	0.17	1.6	0.3	5	16.5
4.	N4	1	0.19	1.6	0.3	5	16

*by weight of cement

From the above mixes the best mix "**N2**" is selected and incorporated with fibres.

TABLE 7 MIX PROPORTIONS FOR MODIFIED RPC

S.No	Mix Proportions	Cement	MicroSilica	Sand	Water	SP	CF	PPF	Compressive strength at 7 days 2 (N/mm)
1.	M1	1	0.15	1.6	0.35	5	1	0.3	12.5
2.	M2	1	0.15	1.6	0.35	5	1.5	0.3	16
3.	M3	1	0.15	1.6	0.35	5	2	0.3	15.5
4.	M4	1	0.15	1.6	0.35	5	1	0.6	17.5
5.	M5	1	0.15	1.6	0.35	5	1.5	0.6	16
6.	M6	1	0.15	1.6	0.35	5	2	0.6	19

7.	M7	1	0.15	1.6	0.35	5	1	0.9	12.5
8.	M8	1	0.15	1.6	0.35	5	1.5	0.9	15
9.	M9	1	0.15	1.6	0.35	5	2	0.9	13

*by weight of cement

Thus mix proportion "**M6**" is opted.

IV. EXPERIMENTAL PROGRAM

A. Compressive strength test

As per IS: 516 – 1959, the compressive strength test was carried out. The compressive strength was determined by the cube specimens of size (100mm x 100mm x 100mm). The required quantities of materials are weighed and mixed manually. The concrete is filled in the mould by layers and with tamping rod every layer is compacted well. The specimens were demoulded and then subjected to curing for about 7 days and 28 days .The specimen is taken out and wiped off the surface dampness.It is then placed on the axis of compression testing apparatusand the load is uniformly applied on the surface perpendicular to the direction of compaction. The load was applied until the failure of cube occurs. The compressive strength of the specimens was calculated and noted in the Table 8 and Table 9.

B. Split tensile strength test

The cylinder of length 300mm and diameter 150mm was cast to test the split tensile strength. Three specimens were tested to determine tensile strength at 7 days and 28 days of curing period. After the curing period the specimens were taken out and wiped off the dampness. To make sure the specimens are in same axial plane when placed in the apparatus, draw diametrical lines on the faces of the specimen. Place the specimen on the plywood strips so that they are immovable from that position. Apply the load at a continuous rate and note the ultimate load and the breaking load. The split tensile strength is then calculated and listed in Table 8 and Table 9.

C. Flexural strength test

The standard size of 100mm x 100mm x 500mm prism was used to determine the flexural strength of concrete. Flexural strength is found using centre point load method. Three specimens were casted and placed in clean water for about 7 days and 28 days. After the curing period the specimens were taken out and wiped off the dampness. The specimen is placed in the Universal Tensile Testing Machine in such a manner that the load is applied on the upper surface of the mould. The load is applied until failure of the specimen occurs. The ultimate load and the breaking load is noted. The flexural strength of the specimens were calculated and listed in the Table 8 and Table 9.

Fig. 6 Universal Tensile testing Machine

V. RESULTS AND DISCUSSIONS

A. Test Results

TABLE 8 FOR NORMAL RPC (N2)

Trail No.	Compressive strength(N/mm^2)		Tensile Strength (N/mm^2)		Flexural Strength (N/mm^2)	
	7 days	28 days	7 days	28 days	7 days	28 days
1.	18	25	0.735	2.12	1.875	9.75
2.	17	25	0.707	1.98	2.25	10.5
3.	18	26	0.749	2.12	1.875	10.5

TABLE 9 FOR MODIFIED RPC (M6)

Trail No.	Compressive strength (N/mm^2)		Tensile Strength (N/mm^2)		Flexural Strength (N/mm^2)	
	7 days	28 days	7 days	28 days	7 days	28 days
1.	26.0	27	1.84	2.26	3.0	6.375
2.	24.5	27.5	1.84	2.33	3.0	6.375
3.	26.0	27.5	1.70	2.26	3.0	6.0

TABLE 10 COMPARISON OF HOT WATER CURING WITH NORMAL CURING

S.No.	Mix No.	1 Day Compressive Strength (Hot Water Curing) (N/mm^2)	7 Days Compressive Strength (Normal Curing) (N/mm^2)	% of Strength Attained in One Day Hot Water Curing
1.	M6	14.5	26.0	55.7
2.	M6	16.0	24.5	65.3
3.	M6	15.0	26.0	57.6

B. Discussions

- The maximum compressive strength, tensile strength and flexural strength results at 7 days and 28 days for Normal RPC was obtained with "N2" mix (because of the 0.15 times of Micro silica content by weight of cement).
- The maximum compressive strength, tensile strength and flexural strength results at 7 days and 28 days for Modified RPC was obtained with "M6" mix (because of the 0.3% of polypropylene fibres and 2% of coir fibres).
- Adopting hot water curing at 90°C for 24 hours attained about 60% of 7 days compressive strength.

VI. CONCLUSIONS

Based on the experiment conducted the following conclusions were made

1. Reactive Powder Concrete can attain high strength characteristics even without coarse aggregates.
2. Mix proportion with 0.3% polypropylene fibre and 2% coir fibre gives the maximum compressive strength and split tensile strength but shows a reduced flexural strength.
3. Hence, this Modified RPC can be used in compression members like columns.
4. Reactive powder concrete with polypropylene fibre produced high flexural strength but when combined with coir fibre flexural strength gets reduced.
5. Adopting hot water curing at 90°C produces higher compressive strength compared to normal water curing.

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