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Reactive Powder Concrete with and without Fibers

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***Abstract* - Reactive powder concrete (RPC) is one of the latest generations of concretes developed in early 1990's which possesses very high mechanical strength parameters. In the present research work an RPC in focused a utility of RPC and also to study the characteristic strength parameter with the incorporation of fibers such as sisal,coir,polypropylene and human hair as integral reinforcing material. RPC mixtures without reinforcing fibers were also studied.**

1. INTRODUCTION:

Reactive power concrete (RPC) isadvanced composite cement based material which originally developed in the early 1990's by Bouygues laboratory in France [1]. The concept of RPC was first developed by P.Richard and M.Cheyrezy of above laboratory. A field application of RPC was done on the pedestrianbike way bridge in the city of Sherbrooke, Quebec,Canada. RPC was nominated for the 1999. Nova awards from the construction innovation forum. RPC has been used successfully for the isolation and containment of the nuclear wastes in Europe due to its excellent impermeability. RPC is an ultra-high strength cementitious composite with advanced mechanical properties.It has micro structure which is optimized by precise gradation of all particles in the mix to yield maximum density.RPC is composed of very fine powders of hydraulic cement,sand,quartz powder and silica fume withsteel fibres(optimal)and a superplasticizer with optimum dosage. This leads to very high compressive strength. However, at such level of high compressive strength of concrete,the coarse aggregate becomes the weak link in concrete. Inorder to increase the value of compressive strength of concrete even further, the only way in to remove the coarse aggregate from the mix. This philosophy has been employed in what is today known as reactive powder concrete. RPC possess good degree of high static and dynamic strength,high fracture capacity,low shrinkage and excellent durability under severe and aggressive conditions [1-4]. The micro structure of RPC is optimized by proper graduation of all constituent material in the mix to yield maximum compactness [5-7].

RPC has got great potential in many fields including providing military engineering facilities and nuclear waste treatment, which has received significant concerns from the experts across the world [8-10]. However its high cost complex preparation and high energy demand of RPC severely limit its commercial development and application in practice [11, 12]. In addition the rigorous curing procedures usually employed in the production of RPC(200ºC auto clave curing or 90ºC heating curing)result in a very low production efficiency and high energy requirements [13-16]. Therefore it is felt that how to increase the ratio of performance to cost parameter for economic application of RPC in practical engineering in the building industry.

Considering all the facts discussed above slight modification are done in the mix design and also in the fibre component in the mix and a high strength RPC was selected for all characteristics and physical parameters. Application of this RPC for other building material such as to replace wood also studies and the result are presented in detail.

2. EXPERIMENTAL:

2.1. Material used:

For the preparation of RPC the following materials were used. Ordinary Portland cement (OPC)43 grade of Dalmia brand conforming to is 8112 was used,Fine River sand grade 2 conforming to IS 650:1991,of specific gravity 2.65 and particle size ranging from 0.3mm to 0.6mm was used. Fly ash was brought from Tuticorine thermal power plant and its specific gravity was 2.3 with particle size 50 micron and down size the micro silica was obtained from M/s ElkemIndia (p) Ltd Mumbai,of grade 920 with bulk density 600-700 kg/m^3 and it conforms to ASTM C1240-97and specific gravity was 2.2.the quartz powder was obtained from M/s kumar mineral powder suppliers, Karur and its specific gravity was 2.7.The superplasticizer of CONXL-PCE 6650 obtained from M/s Chemcon tecsys Chennai of specific gravity 1.12 and the pH was 7 conforming to ASTM C 496 type B type D and type G and it complies with IS 9103-1999.The superplasticizer used was high performance superplasticizer based on polycarboxylate ether polymer the main polymer chain has carbonyl groups for the adsorption on the surface of cement particles andforms long polyethylene oxide graft chains The particles are in the range of 0.25 to 0.35 microns and this product was synthesized through nano-scale polymerization. The water used for mixing the concrete was potable tap water.

2.2. RPC Mix Design:

The process of mixture selection for RPC was based on eleven trail mixtures as given in Table 1. These proportions were selected for trial base after literature review on RPC. The mix designation of **"R10"** was selected based on good workability and high cube compressive strength. Various fibers such as sisal fiber, coir fiber, human hair and polypropylene fiber (Fig 1) were incorporated in the selected mix of "R10" at 2 percent by the mass of cement. The corresponding mix proportions are presented in Table 2. The water to binder ratio of 0.3 for R10 was slightly changed to 0.35 when fibers are added in the mix. Except polypropylene fiber all fibers are treated with 1M NaOH at 80°C for 2 hours (Fig 2), with mechanical stirring.

Table 1: Various trial mixes of the RPC

Mix designation	OPC	Sand	Fly ash*	Micro Silica*	Silica Fume*	Quartz Powder	Super plasticizer %	w/cm	Compressive Strength (N/mm^2)
R1	1	1.25	0.2	-	0.07	-	-	0.45	99.14
R2	1	1.25	-	0.2	0.07	-	-	0.45	124.66
R3	1	1.25	-	-	0.07	0.2	-	0.45	100.13
R4	1	1.25	0.1	0.1	-	0.1	-	0.45	134.71
R5	1	1.25	0.1	0.1	0.07	0.1	-	0.45	96.14
R6	1	1.6	0.05	0.15	-	-	-	0.5	95.83
R7	1	1.6	0.05	0.15	-	0.05	-	0.5	94.11
R8	1	1.6	0.05	0.15	-	-	1.5	0.35	151.32
R9	1	1.6	0.05	0.15	-	0.05	1.5	0.35	148.63
R10	1	1.6	0.05	0.15	-	-	1.5	0.30	184.16
R11	1	1.6	0.05	0.15	-	0.05	1.5	0.30	166.42

*****by mass of cement

From the above mixes the best mix (R10) is selected and it is incorporated with various fibers.


Coir


Hair


Sisal


Polypropylene

Fig 1: Various fibers used in this study

Table 2: Various fiber mixes of the RPC

Mix Design-ation	OPC	Sand	Fly Ash	Micro silica	Super plasticizer (%)	w/cm (%)	Sisal fiber (%)	Coir fiber (%)	Hair fiber (%)	Polypropylene fiber (%)
RF1	1	1.6	0.05	0.15	1.5	0.35	2	-	-	-
RF2	1	1.6	0.05	0.15	1.5	0.35	-	2	-	-
RF3	1	1.6	0.05	0.15	1.5	0.35	-	-	2	-
RF4	1	1.6	0.05	0.15	1.5	0.35	-	-	-	2

Fig 2: Treating the fiber before use

2.3. Specimensfor Testing:

Triplicate specimens were cast for each mix and the average value was recorded in the corresponding table as resulting value of the test.

Compressive strengths of the RPC was obtained for control (no fiber) and other RPCs both cube compressive strength in 150mm x 150mm x 150mm specimens and the cylinder compressive strength with 150mm diameter x 300mm long cylinders after 7 and 28 days of curing in water. No autoclaving or heat curing applied. The Fig 3 and 4 shows the attainment of cube compressive strength (f_{cu}) and cylinder compressive strength (f_{cy}) respectively. Split tensile strength (f_{sp}) of each mix was determined after 7th and 28th day of curing with the specimens of size 150 mm diameters x 300mm long specimens and the results are presented in Fig 5. Flexural strength (f_r) or modulus of rupture was determined using beam specimens of size 50mm x 50mm x 300mm and the results are given in Fig 6 after the specimens are cured for 7 and 28 days. Shear strength of all concrete specimens are determined using a specially fabricated arrangement as shown in Fig 7 and the specimens of size 50mm x 100mm cylinders were used and the load was applied by compression testing machine until the specimen fail by vertical shear at two planes. The results are presented in Fig 8.

Impact resistance of RPC was determined using tile specimens of size 250mm x 300mm x 10mm. theexperimental setup is shown in fig 9 and the results are presented in Table 3. The Fig 10 shows the strain energy absorbed by various RPCs. Table 4 gives the values of dry density, saturated density, percentage of water absorption and the coefficient of water absorption of all RPCs.

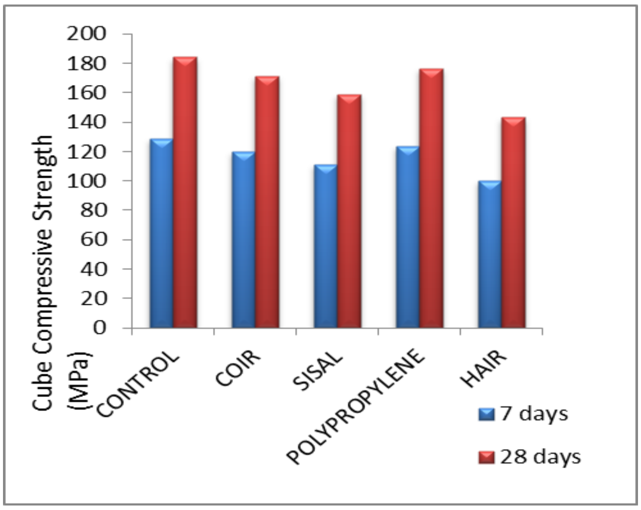

Fig 3: Cube Compressive Strength of Fiber Reinforced RPC after 7 & 28 days

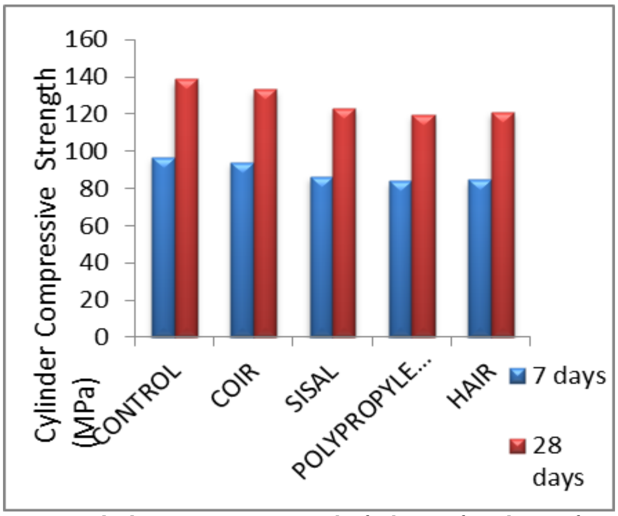

Fig 4: Cylinder Compressive Strength of Fiber reinforced RPC after 7 & 28 days

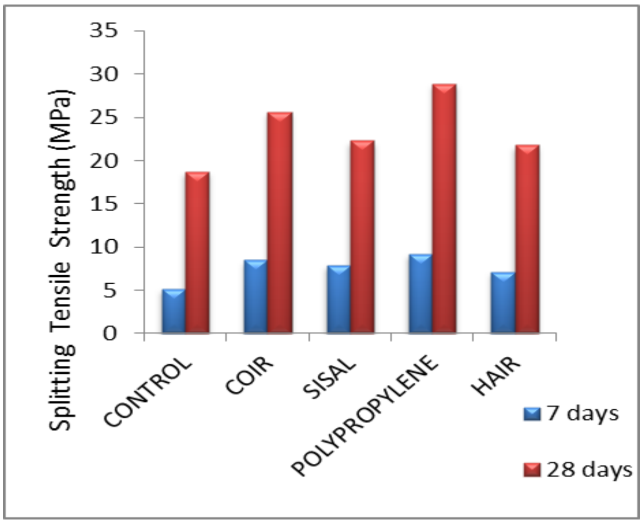

Fig 5: Splitting tensile Strength of Fiber Reinforced RPC after 7 & 28 days

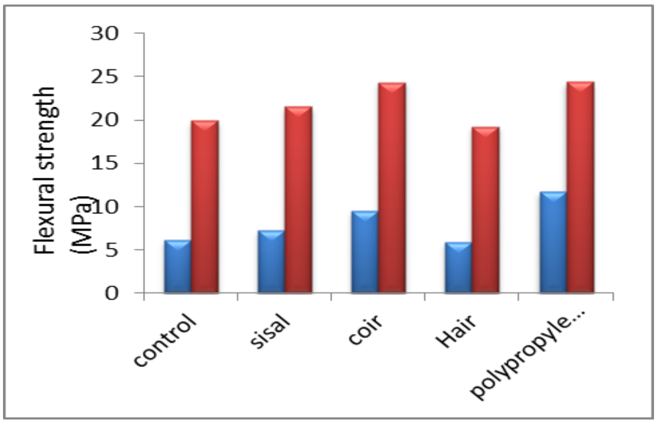

Fig 6: Flexural Strength of Fiber Reinforced RPC after 7 & 28 days

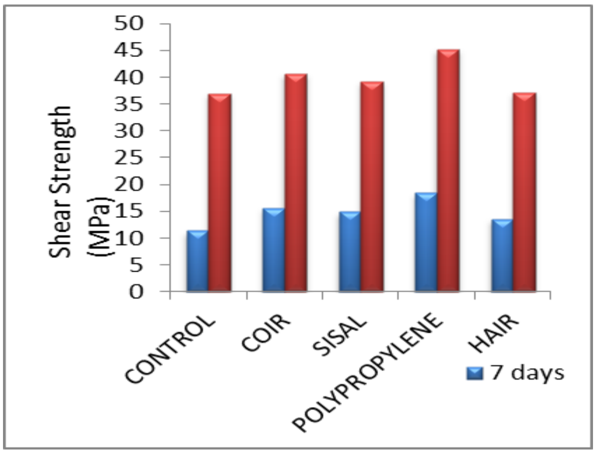

Fig 8: Shear Strength of Fiber Reinforced RPC after 7 & 28 days

Fig 7: Testing arrangement for Shear strength

Table 3: Impact resistance Strength of Fiber reinforced RPC

Specimen Designation	Weight of Steel ball (gm)	Height (mm)	Energy Absorbed (kN mm)
Control	560	560	3.13
Sisal	560	630	3.5
Coir	560	640	3.58
Hair	560	590	3.3
Polypropylene	560	745	4.17

Table 4: Micro structural Properties Fiber reinforced RPC

Specimen	Dry density (kg/m^3)	Saturated density (kg/m^3)	Water absorption (%)	Coefficient of water absorption K_a (m^2/s) $x10^{-10}$
Control	1982.22	2025.74	2.19	1.16
Sisal	1949.91	1990.65	2.08	4.53
Coir	1950.03	1988.32	1.96	5.32
Hair	1958.96	1982.35	1.19	2.45
Polypropylene	1954.69	1986.63	1.63	4.56

Fig 9: Arrangement for Impact resistance Test

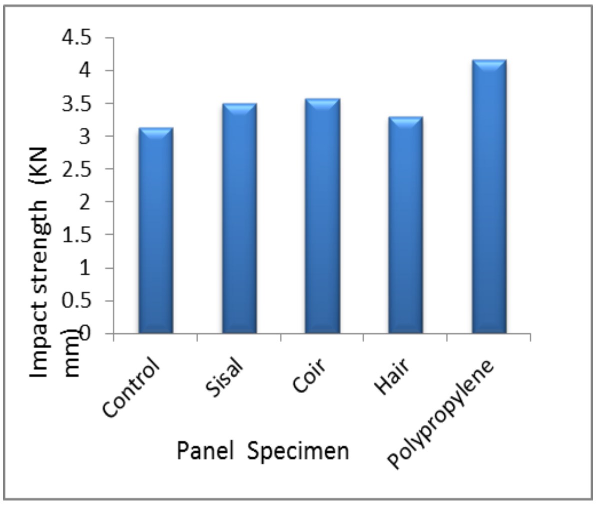

Fig 10: Impact resistance Strength of Fiber reinforced RPC

3. Result and discussion:

The results of compressive strength show that incorporation of fibers reduces the compressive strength. It can be attributed to the fact that the fibers do not undergo any reaction with the cement paste and hence no adhesion or rarely show adherence with surroundings. The control RPC has 184.16 MPa and 138.8 MPa cube and cylinder compressive strength. In cube compression, RPC with human hair showed a least value of 143.2 MPa but in cylinder compression, RPC with polypropylene mixed concrete show the least value of 119.6 MPa.

In tensile strength the control RPC has 10.15% and 10.80% of cube compressive strengthin split tensile test and flexural tensile strength respectively. In general, incorporation of fibers increased the tensile strength of RPC both in split and flexural tensile tests. Polypropylene fibers provide high tensile strength ie 16.36% and 14.95% in split and flexural tensile tests respectively. However sisal fiber provides less split tensile strength of 14.04% and human hair provide less flexural strength of 13.4% of cube compressive strength. From the tensile strength results, hair provide better resistance against direct tensile than flexural tensile strength tests.

Addition of fibers in RPC improved the shear resistance compared to control RPC. Among all fibers, the polypropylene fibers provide good resistance next to hair in RPC.

In energy absorption study ie impact resistance strength, the fiber added RPCs provide high resistance to impact loads, the polypropylene fibers provide good impact resistance which is 33.23% higher compared to control RPC and least energy resistance obtained for hair mixed RPC, which provide 5.43% higher value than the control RPC.

In water absorption study, the fiber mixed RPCs provide comparatively less water absorption than control RPC. Poor water absorption was obtained for hair mixed RPC which is 1.19% and the large was sisal fiber mixed RPC.

The RPC is proved to be an alternative material for wood since it has provided many building materials shapes such as window frames, floor tiles, pressure pipes and other pavement blocks (Fig 11 to Fig 14). The Fig 15 shows that the RPCs are nailable and screwable and hence RPCs can be used as an alternative material for wood.

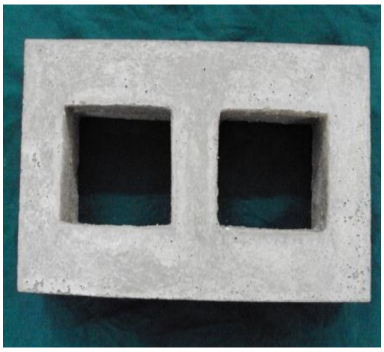

Fig 11: Window frame by RPC

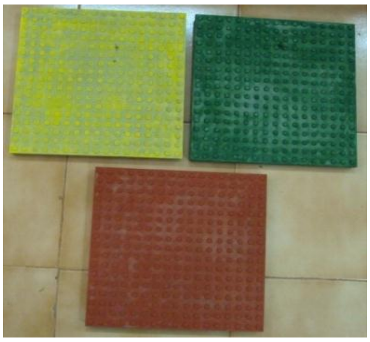

Fig 12: Floor tiles from RPC

Fig 13: Pavement tiles from RPC

Fig 14: Pressure pipes fromRPC

Fig 15: RPC is nailable & Screwable

4. CONCLUSION:

- Inclusion of nonferrous fibers reduces the compressive strength of concrete both in cube and cylinder strength.
- Inclusion of fibers drastically improves the tensile strength of RPC both in split tensile strength and flexural tensile strength.
- The shear strength of RPC has enhanced by the addition of fibers in RPC.
- Though the fibers like coir and sisal mixed in RPC, the water absorption is not increased compared to control RPC.
- RPCs are highly workable and hence moulded to different shapes and sizes. Also, these RPCs are nailable, screwable and cuttable and therefore, this material can be used as an alternative material for wood in addition to structural uses.

5. ACKNOWLEDGEMENT:

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