MECHANICAL PROPERTIES OF STEEL FIBER REINFORCED REACTIVE POWDER CONCRETE USING FLY ASH

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Abstract— ***Reactive Powder Concrete is a developing composite material that will allow the concrete industry to optimize material use, Generate economic benefits, and build structures that are strong, durable,and sensitive to environment. RPC is a new ultra-high performance concrete with wide range of capabilities. RPC was developed in the 1990s by Bouygues' laboratory in France. RPC represents a new class of Portland cement-based material with compressive strengths of 200 MPa range. By introducing fine steel fibers RPC can achieve flexural strength up to 50 MPa. It has no coarse aggregates and contains small steel fibres that provide additional strength.RPC include Portland cement, silica flour, fine sand, superplastizer, water and steel fibres. The main object of this study is to check the effect of replacing silica fume b fl ash and percentage variation of steel fiber on reactive powder concrete, to achieve economy without any significant change in properties of RPC. The silica fume is replaced by the fly ash by its weight variation of 0% to 50% with interval of 10 %.It was found that replacement of fly ash up to 40% by silica fume is economical to achieve high compressive strength upto 90 MPa under normal curing Percentage of fiber content vary from 0 % to 1 % with interval of 0.25%,It was found that addition of 0.75 percentage of fibres content gives better flexural and tensile strength.***

Keywords— ***Fly ash,Precipitated silica, Reactive Powder Concrete, RPC, Steel fibers, Silica fume.***

I. INTRODUCTION

Concrete, one of the most widely used construction materials, has been subject to major research and development over the past century. The high performance concrete (HPC) is also a new trend concrete material that enhances high strength up to 120 MPa, but Richard and Cheyrezy show that Reactive powder concrete (RPC) in which strength is obtained in excess of 200 MPa and flexural strength 30-60 MPa [1]. Physical, mechanical, and durability properties of RPC and HPC (High Performance concrete) show that RPC possesses better strength.

Reactive Powder concrete contains very fine materials such as precipitated silica, crushed sand and silica fume. The basic composition for the production of RPC has been explained by the Richard and Cheyrezy [1]. A very dense matrix is achieved by optimizing the granular packing of these powders [2]. Due to inverse effect of high cement content on the early age shrinkage behavior and decreased hardened performance by micro-cracking, supplementary cementations materials such as fly ash, blast furnace slag, and silica fume are commonly used in cement and concrete industry [3]. It is possible to modify some fresh and hardened properties of composite by utilizing these materials.In this study, it have been checked that effect of fly ash as a replacement of silica fume on the parameters of reactive powder concrete such as compressive, tensile and flexural strength.

II. MATERIAL

A. *Cement*

Cement used for present work are 53 grade ordinary Portland cement.Its properties tested as per IS 269-1989.

B. *Fine Sand*

Artificial sand used is angular in shape. Its properties tested as per I.S.383-1970.

C. *Precipitated silica and Silica flour*

TABLE I : PRICIPITATED SILICA AND SILICA FLOUR

Material→ Properties↓	**Precipitated silica**	**Silica fume**
Particle size	5 to 100nm	300 micron
Colour	White	White

D. *Fly ash*

Fly ash used for this work is pozocrete 60. Its properties are as shown in table II

TABLE II PROPERTIES OF FLY ASH

Appearance	Specific surface area	Specific gravity	Silica content
White	5-100 m^2/g	2.2	65

E. Super plasticizer

Acrylic polymer based-Dynamon SX superplastici-zer used in this work. Its properties are as shown in table III

TABLE III PROPERTIES OF SUPERPLASTICIZER

Consistency	Appearance	Density	Alkali content	Chloride content	Nitrate content
Liquid	Amber	1.07 @20°c	<2.5	<0.1	Nil

III. EXPERIMENTAL ANALYSIS

RPC composition used in this study, we referred Richard and Cheyrezy [6] mix proportion from their research. Using this reference, the trial mix were taken by adjusting percentages of silica fume. According to trial mixes appropriate mixes were taken for actual mixing. The aim was to find out the highest compressive strength at optimum percentage of fly ash and silica fume. The quantity of ingredient materials and mix proportion of RPC is given in following table IV.

Concrete of mix proportion as shown in table IV was prepared and then silica fume content is replaced by fly ash Fly ash content is varies from 10 to 50%.For compressive strength, test specimens (100mm x 100mm x 100 mm) were prepared with the percentage of fly ash which replace silica fume as a 100% SF, 10%, 20%,30%,40%,50%. The mixes are denoted by M_{F10}, M_{F20}, M_{F30}, M_{F40}, andM_{F50} and for flexural strength; specimens were prepared with percentage of steel fiber such as 0.25 to 1 % of volume of concrete used for testing properties of RPC. The mixes are denoted by M_1, M_2, M_3, M_4, andM_5.The specimens were kept in the moulds for 24 hours at room temperature of 20°C. After demolding, the specimens were cured by standard normal curing procedure.

IV. TEST ON HARDENED CONCRETE:CONFIRMING TO IS 516-1959[7]

A. Compressive Strength Test

A cube compression test performed on standard cubes of reactive powder concrete of size 100mmX100mmX100mm after 7 days and 28 days of immersed in water. The compressive strength of specimens was calculated by the following formula

$$F_{cu} = Pc / A \qquad (1)$$

Where

Pc = Failure load in compression, kN

A = Loaded area of cube, mm^2

B. Flexural Strength Test

Standard beams of size 100 x 100 x 500mm were supported symmetrically over a span of 400mm and subjected two points loading till failure of the specimen. The deflection at the center of the beam is measured with sensitive dial gauge on UTM. The two broken pieces (prisms) of flexure test were further used for equivalent cube compressive strength. The flexural strength was determined by the formula.

$$Fcr = Pf\ L / bd2 \qquad (2)$$

Where

Pf = Central point through two point loading system, KN

L = Span of beam, mm

b = Width of beam, mm

d = Depth of beam, mm

C. Split Tensile Strength Test

The tensile strength at which failure occurs is the tensile strength of concrete. In this investigation, the test is carried out on cylinder by splitting along its middle plane parallel to the edges by applying the compressive load to opposite edges. The arrangement for the test is shown in photo with the pattern of failure. The split tensile strength of cylinder is calculated by the following formula.

TABLE IV COMPOSITION OF RPC

Composition	Silica/Crushed sand	Portland cement	Precipitated silica	Silica fume	super plasticizer	Total water
Content (kg/m^3)	1031	937	9.4	225	18	Adjusted

$$f_t = 2P/\pi LD \quad (3)$$

Where

f_t = Tensile strength, MPa
P = Load at failure,KN
L = Length of cylinder, mm
D = Diameter of cylinder, mm

V. RESULTS AND DISCUSSION

A. *Compressive strength*

The results of compressive strength are obtained using (1). Test results of RPC after standard water curing (7 and 28 days) are shown in table V. The compressive strength of 100% silica fume mixture is nearly about 80 MPa and Percentage of fly ash which replaces silica fume upto 20% shows slight increase in compressive strength and at 30% fly ash gives the strength near about 87 Mpa after 28-days standard curing. After that as fly ash content increases compressive strength reduces as shown in *Fig .1.*

Compressive Strength is 82.93 and 89.21 respectively by using steel fiber for 7 days and 28 days. The percentage increase in strength at this volume fraction over RPC at 7 days and 28 days is 10.39% and 3.73% respectively as shown in *Fig.* 2

B. *Flexural Strength*

The results of Flexural strength are obtained using (2) For better flexural strength at 7 and 28 days, we use the proportion of fly ash silica fume is 30:70. From the test result in table VII. It can be seen that, As the volume fraction From the test result in table VI, it can be seen that, As the volume fraction increases from 0.25 to 0.75, Flexural strength increases up to 22 Mpa. It is observed that for 1% fibers, flexural strength decreases as shown in *Fig 3.*

TABLE V COMPRESSIVE STRENGTH

Mixes→ Strengths↓	Curing Days	100 % SF	M_{F10}	M_{F20}	M_{F30}	M_{F40}	M_{F50}
Compressive Strength(MPa)	7	70.75	65.40	68.82	75.12	73.73	68.13
	28	80	77.34	85.67	86	84.3	78.17
% Variation in Compressive Strength(MPa)	7	0.00	7.56	2.72	6.17	1.47	3.70
	28	0.00	3.33	7.08	7.5	4.3	2.22

TABLE VI COMPRESSIVE STRENGTH

Mixes→ Strengths↓	Curing Days	M_0	M_1	M_2	M_3	M_4
Compressive Strength(MPa)	7	75.12	78.14	80.58	82.93	79.31
	28	86	87.34	87.98	89.21	88.31

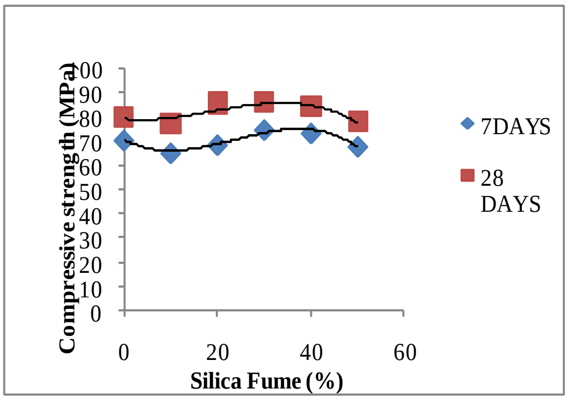


Fig.1:Effect of silica fume on compressive strength

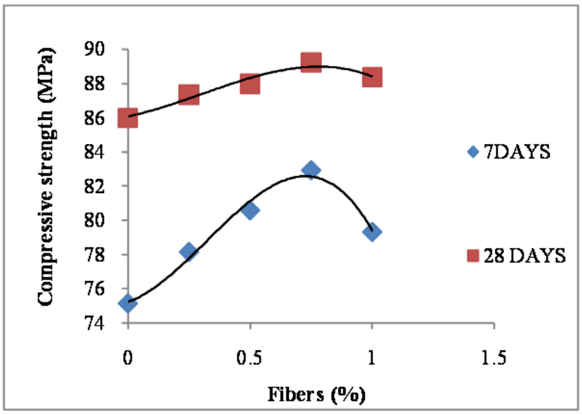


Fig 2: Effect of addition of steel fibers on Compressive strength

C. Split tensile Strength Test on Cylinder

Split tensile strength is obtained for various fiber volume fraction and results are presented in Table VIII. The variation Of Split tensile strength with respect to fiber volume fraction is shown in *Fig. 4*

TABLE VII FLEXURAL STRENGTH

Strengths↓ (Mixes→)	Curing Days	M_0	M_1	M_2	M_3	M_4
Flexural Strength(MPa)	7	9	10.5	13.1	16.3	14.23
	28	11.23	14.7	16.2	22	18.34
% Variation in Flexural Strength(MPa)	7	0.00	16.66	45.55	81.11	58.11
	28	0.00	30.89	44.25	95.90	63.31

TABLE VIII SPLIT TENSILE STRENGTH

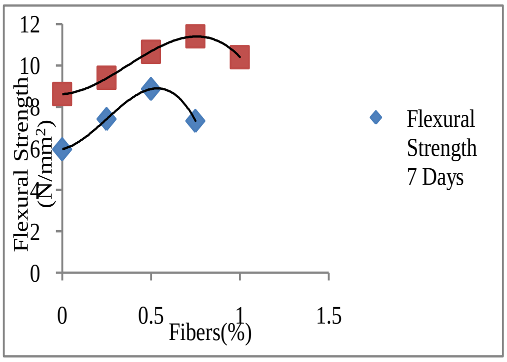
Strengths↓ (Mixes→)	Curing Days	M_0	M_1	M_2	M_3	M_4
Split Tensile Strength	7	4.11	4.9	5.30	6.21	4.63
	28	4.79	5.75	6.3	7.17	5.14
% Variation in Split Tensile Strength (MPa)	7	0.00	19.46	28.95	51.09	12.65
	28	0.00	20.04	31.52	49.68	7.31

From table VIII, the maximum value increase in split tensile strength for RPC is for 7 days is 6.21 and 28 days is 7.17. The split tensile strength increases upto 0.75 % fiber content and then start decreasing for 7 days and 28 days respectively.While testing, it was clearly observed that failure mode changed from brittle to ductile failure. And this ductility was improved, as the percentage of fibers increased in the concrete.

VI. CONCLUSION

The main objective of this study is to Study the effect of replacement of fly ash over silica fume and variation of steel fiber in RPC. This study shows the optimum percentage of fly ash to replace some amount of silica fume.Based on the results obtained from the tests conducted on this study some general conclusions may be drawn.

1. Replacement of fly ash over silica fume is economically. The Compressive strength is increase upto 86 Mpa by increasing fly ash at 30%. After that strength reduces.
2. The composite mineral admixtures is attributed to the partical packing,filling effect,pozzolanic effect which improve strength,very compacted RPC matrix with low porosity.
3. The incorporation of metallic fibers improves the Compressive strength of RPC;Compressive strength is increases upto 16 Mpa by increasing fly ash at 30%.After that strength reduces.
4. The incorporation of metallic fibers improves the flexural strength of RPC;Flexural strength is increases upto 16 Mpa by increasing fly ash at 30%.After that strength reduces.
5. The incorporation of metallic fibers improves the Split Tensile strength of RPC; Split Tensile strength is increases upto7.17 Mpa by increasing fly ash at 30%.After that strength reduces.



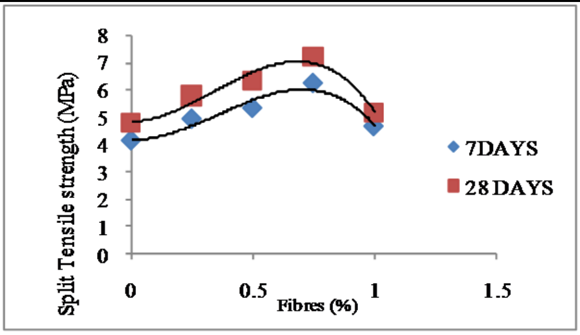


Fig 3: Effect of addition of steel fibers on flexural strength
Fig 4: Effect of addition of steel fibers on Split Tensile strength

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