Flexural Behavior of Concrete Beams using Recycled Fine Aggregate and Steel Fibres

M. Kaarthik, and K.Subrmanian

***Abstract*----**The feasibility of making concrete with silica fume with partial replacement for cement and recycled fine aggregate with partial replacement for Fine aggregate has already been established individually. Its mechanical properties and durability have been extensively studied. However, its application as structural concrete has hardly been studied. This research work focuses on both partial replacement of river sand with R.F.A and partial replacement of Silica fume with cement and by addition of fibers, to minimize the waste disposal problem and also to increase strength of concrete. Different replacement levels were tried and optimum replacement percentage of cement and sand is obtained using Silica Fume and R.F.A. In addition steel fibres were added at various percentage levels with the optimum mix. With the objective of establishing the characteristics of silica fume and R.F.A as a structural material, investigations are carried out by casting concrete beams of size 100mm x 150mm x 1200mm in the laboratory using the optimum mix.

***Keywords*----**Beams, R.F.A, Silica fume and Steel Fibres.

I. INTRODUCTION

AS a construction material, concrete is not regarded to be environment friendly due to its adverse effects on the environment. Nevertheless, it remains to be a most commonly used construction material. Around 10 billion tons of concrete is consumed per year, which means a ton of concrete is consumed per person every year.

This being the current situation, the concrete industry has to conform to sustainable development, predicting the future of concrete and developing necessary strategies concerning this issue. In the future; around 8 to 12 billion tons of natural aggregates will be consumed as of year 2013.The environment will inevitably be degraded by such large consumption of natural aggregates unless suitable substitutes for natural aggregates are instantly resorted to. In spite of the fact that recycling of aggregates has long been possible in the concrete industry, the recycled material has never been effectively introduced. Actually, it is very common to use recycled aggregates in structural constructions, but rather they are mostly used as fillers in road construction and in similar low level applications.

M. Kaarthik, Assistant Professor, Department of Civil Engineering, Coimbatore Institute of Technology, Coimbatore - 641014, Email: kaarthik@cit.edu.in

K.Subrmanian, Professor, Department of Civil Engineering, Coimbatore Institute of Technology, Coimbatore – 641014, Email: hodcivil@cit.edu.in

The waste concrete from any various sources is used to produce recycled aggregate in the crusher plant. Crusher equipment's namely, jaw crusher or barmac rock on rock vsi crushers incorporationg rock on rock crushing technology has revolutionized the art of making recycled concrete aggregates. This technology has been used for producing coarse and fine aggregates of desired quality in terms of shape, texture and grading. The fragment of the crushed concrete which is less than 5mm is separately collected from the crusher and sieved by using I.S.sieves. The fragments passing through 4.75mm sieve is taken as artificial sand, which is used for partial replacement of natural sand.

Most of the HPC produced so far comprised of fumed silica, a high pozzolanic mineral admixture. The reasons cited for the use of fumed silica in concrete structures and earthquake resisting structures etc include low porosity and refined pore structure of the cement paste, high early strength and continued strength development, improved durability in aggressive environment, reduction on cross sections of structural members, energy absorption capacity and reduced maintenance cost.

It has been shown that Yunxing Shi that addition of Silica Fume to OPC resulted in the refinement of pores, i.e.large permeable pores were transformed into small impermeable pores1. At 28 days hydration, the volume of pores greater than 50µm in equivalent mixtures containing Silica fume was lower by significant amount when compared to that of Fly Ash e.t.c. Further the authors have reported that even though the total porosity was greater for mixture containing Silica Fume, the permeability was reduced. This finding was corroborated by Indira2.

The hydration characteristics and microstructure of cement pastes with different water/cement and Silica Fume/cement ratios were investigated by Hooton3. Cement paste made of 0.32 w-c ration on w/c and containing 15% of Silica Fume showed that just after 1 day of hydration most of the Calcium hydroxide had probably reacted with silica fume to form a dense spongy matrix of fibrous CSH.

The influence of the substitution of different percentages of O.P.C by Silica Fume e.g.,5%, 10%, 15% and 20% on the compressive strength of concrete at different ages up to 90 days was investigated by Malthi and Subramanian4. From the test data, the compressive strength has shown improvement over conventional concrete of all the mixes. The workability decreases with 15% as an admixture. The flexural strength

http://dx.doi.org/10.15242/IICBE.C0314041

studies indicate that there is a marginal improvement for all the mixes. But the splitting tensile strength data shows a marginal decreased value.

The paper presents the details about the experimental investigation that was carried out to study the flexural behavior of reinforced concrete beams prepared using R.F.A concrete in which the cement was partially replaced with Silica Fume. The paper presents a discussion on the results obtained and the conclusions drawn there from.

II. Experimental Programme

A. Cement

In this experimental investigation O.P.C of 53 grade confirming to IS: 12269-1987 was used in the preparation of the concrete. The cement was tested as per the procedure given in Indian Standards IS 4031-1988. The results of the physical properties are given in Table I

TABLE.I
PHYSICAL PROPERTIES OF CEMENT.

S.No	Property	Result	Permissible Limit as per IS:12269-1987
1	Normal consistency	32%	-
2	Initial setting Time	26 min	Min 30
3	Final Setting time	120 min	Max 600
4	Specific Gravity	3.17	Not less than 3.15

B. Fine Aggregate

Natural river sand confirming to Zone-II as per IS 383(1987) was used. The fineness modulus of sand used is 2.64 with a specific gravity of 2.6.

C. Coarse Aggregate

Crushed granite coarse aggregate confirming to IS:383(1987) was used. Coarse aggregate of size 12.5mm down having the specific gravity of 2.8 and fineness modulus of 7.2 was used.

D. Superplasticizers

In this investigation Sulphonated Naphthalene (SNF) based Superplasticizer (SP) was used. The superplasticizer used for the study conforms to IS 9103(1999).

E. Admixture

In this investigation Silica fume was used to cement for partial replacement. Physical and Chemical properties of Silica Fume was obtained from ELKEM INDIA (P) LTD., Mumbai are given in Table 2.

Since there is no specific method of mix design found suitable for HPC, a simplified mix design procedure is formulated by combining the BIS method, ACI method of mix design for HSC and the available published literatures on approach as ACI does. The mix proportion designed was 1:1.22:2.4 with w/c ratio of 0.28.

The compressive strength of control concrete and R.F.A concrete with 15% partial replacement of cement and 60:40 ratio of R.F.A and F.A with addition of polypropylene fibres of 0.1%, 0.15% and 0.20% at 3, 7,28, 56 and 90days and also the split tensile and Flexural strength for 28 days was found out and tabulated in Table III.

TABLE II
TEST RESULTS OF SILICA FUME

S.No	Description of Test	Results obtained	Requirements as per ASTM C 1240	Remarks
1.	Physical Test			
	Percent retained on 45 μ	0.63%	10% maximum	Essential Requirement
	Accelerated pozzolanic activity index with OPC at 7 days	127%	85% minimum	Essential Requirement
	Specific Surface area	20.9 m^2/gm	15.30 m^2/gm	Optional Requirement
2.	Chemical Test			
	SiO_2 %	90.0	85.0, minimum	Essential Requirement
	Moisture Content, %	0.5	3.0, maximum	
	Loss on ignition, %	1.65	6.0, maximum	
	Carbon, %	0.88	2.5, maximum	
3.	Other parameters			
	Bulk density, kg/m^3	680	500-750	Not specified in ASTM
	Specifi Gravity	2.2	2.1-2.3	

Four Rectangular beams of sizes 100mm x 150mm x 1200mm with 2 nos. of 8mm diameter rods at top and 2 nos. of 10mm diameter rods at bottom were cast for 4 combinations. The reinforcement details of the beams are shown in Fig.1.The nomenclature of the beam is shown in Table 4. The beam was supported over a distance of 1000mm between their centres. Load was applied on the beam by means of hydraulic jack. Load was applied at the uppermost surface as cast in the mould at a distance of one third of the span from both the supports and Dial gauges were arranged beneath the beam at mid-span as well at third points to measure the deflection. Load was applied at the increment of 20kN and dial gauge readings were taken for each increment of load. Load was monotonically increased till failure of the beam. The observed first crack load and the ultimate load for each beam is shown in Table.IV

TABLE.III
STRENGTH PROPERTIES OF HIGH PERFORMANCE CONCRETE WITH POLYPROPYLENE FIBRES AT DIFFERENT AGES.

Properties	NS	RFA1	RFA2	RFA3
Compressive Strength, MPa				
3-day	30.50	9.50	11.53	10.27
7-day	45.33	54.83	56.86	55.60
28- day	67.56	77.92	78.56	74.40
56-day	72.35	83.85	84.49	80.33
90-day	74.76	88.10	88.74	84.58
Split Tensile strength, MPa	4.38	5.92	6.76	6.50
Flexural Strength, Mpa	6.20	7.86	8.65	8.24

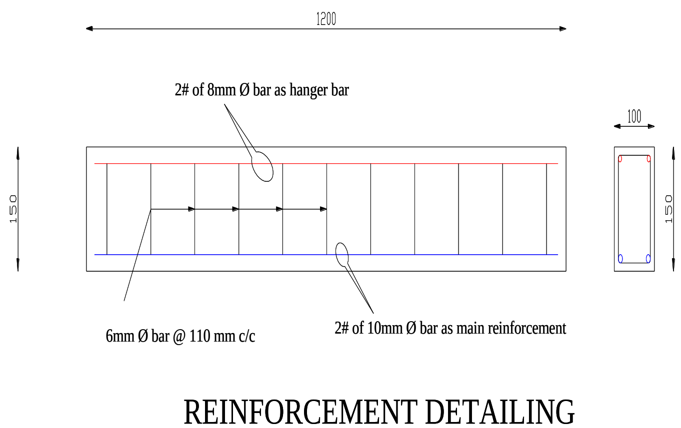

Fig.1 represents Reinforcement Details of the Beam

TABLE.IV
RESULTS OF FIRST CRACK AND ULTIMATE LOAD

Beam Designation	Load at Initial Crack (kN)	Deflection at Initial Crack (mm)	Load at Ultimate Crack (kN)	Deflection at Ultimate Crack (mm)
NM	26.4	5.82	60.2	10.52
R.F.A 1	35.2	5.03	79.2	12.87
R.F.A 2	39.6	5.23	83.6	15.30
R.F.A 3	30.8	4.67	85.8	15.23

The load-deflection curve for all the beams are shown in Fig.2, 3, 4 and 5.

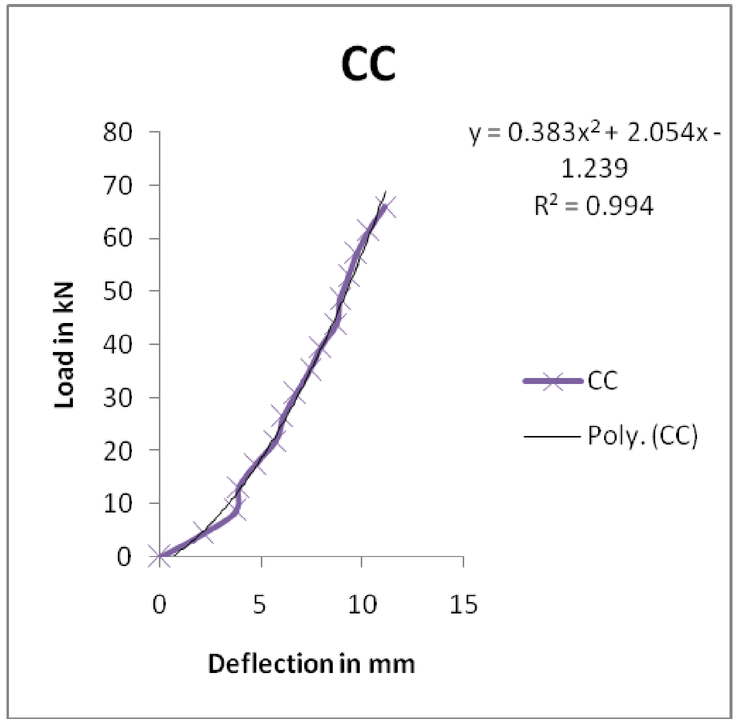

Fig.2 represents Load-deflection curve of Control concrete beam.

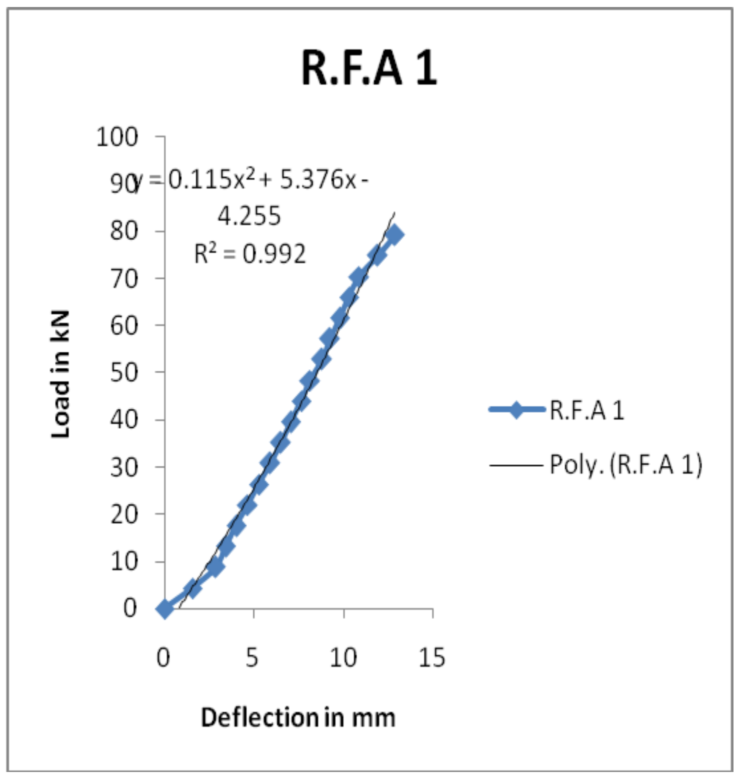

Fig.3 represents Load-deflection curve of R.F.A 1 beam.

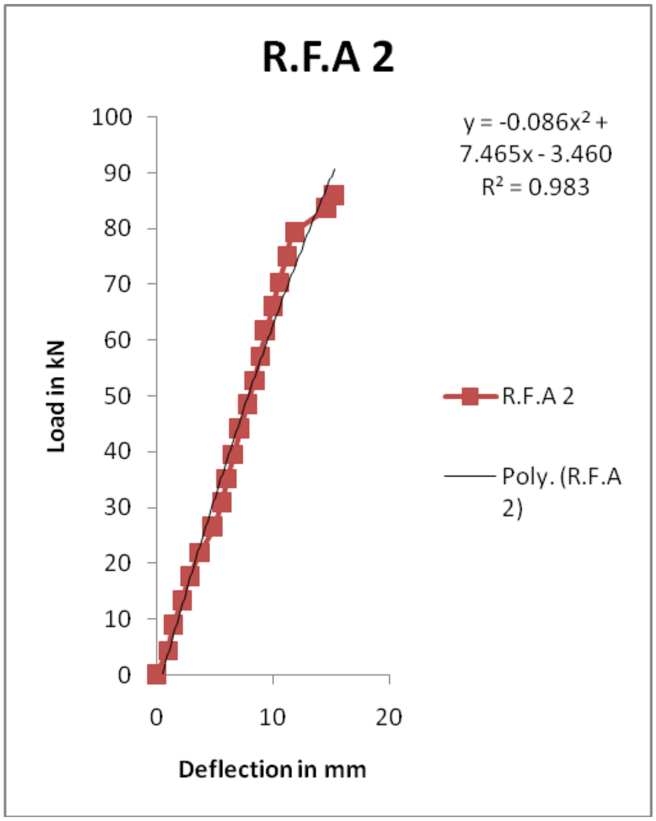

Fig.4 represents Load-deflection curve of R.F.A 2 beam.

III. Results And Discussion

The maximum gain in compressive strength at 28 day of R.F.A2 concrete over the normal concrete was 14%. This shows that addition of Silica fume and fibre had play a major role in strength characteristics than normal concrete.

The first crack load minimum among all the R.F.A concrete beams was found to be 30.8 kN in R.F.A3 and it was higher that of the normal concrete beam, whose value is 25.2 kN. Being a fibrous material, silica fume is able to offer greater resistance to cracking than control concrete. Obviously the resistance to cracking by R.F.A concrete is

1.5 times higher than that of control concrete. From table 4 it is clear that ultimate load carried by R.F.A concrete beam is higher by 1.45 than that carried by control concrete beam.

The R.F.A 2 beam initial crack load was found to be more among all the other R.F.A concrete beams which show that the addition of polypropylene fibre of 0.15% was found to be saturated level among the other addition levels. The load deflection curve for control concrete depicted in Fig.2 shows that the deflection at mid span of the beam is higher than that at third point In this case, the deflection is linear up to about 40kN. In this range the difference in deflection keeps increasing. Beyond that the curve is non-linear. At 70kN the curve becomes asymptotic.

Initially up to about 60kN the normal concrete beam is stiffer than the R.F.A beams. Beyond those R.F.A concrete beams becomes stiffer. Normal concrete beam though initially stiff gets extensively cracked after 60kN load with crack width keeps increasing thus rendering the beam more flexible whereas silica fume being a fibrous material makes the beam ductile by registering more deflection initially under loading. After 60kn load thought the beam cracks extensively its width is reduced because the silica fume bridges the crack and limits its width. As a result of this the beam becomes stiffer.

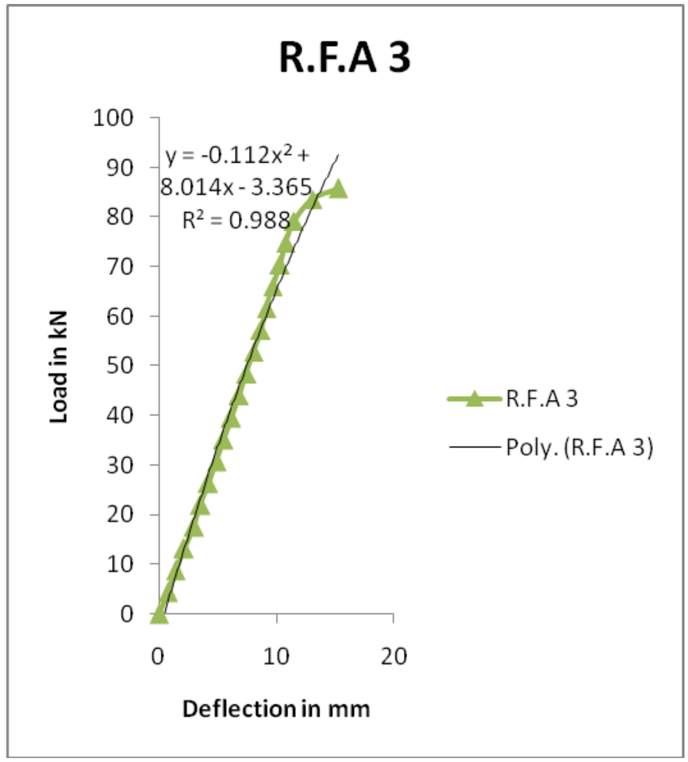

Fig.5 represents Load-deflection curve of R.F.A 3 beam.

IV. Conclusions

In the flexural test on reinforced beam the stiffness of recycled aggregate concrete beam was higher than the conventional concrete 60% of R.F.A and 40% natural sand and 15% of silica fume and 0.15% polypropylene fibre was 39.6kN which was 33.33% higher than and the ultimate load was 28.20% higher than the conventional and other concrete beams.

It has been observed that initially control concrete beams were marginally stiffer than the R.F.A concrete beams. At about 75-80% of ultimate load the trend reverses and R.F.A concrete beams becomes stiffer than control concrete. This is because nearer the ultimate load cracking becomes extensive and their width increases. As silica fume is fibrous it is able to bridge the crack and reduces the width. Thus the stiffness increases. This mechanism is absent in control concrete. So it loses its stiffness. The ductile nature of R.F.A concrete beam in the service load regime is highly advantageous.

This comparison categorically establishes the supremacy of R.F.A concrete beams over that of the control concrete beam. As silica fume is an fibrous material, its use in concrete improved the ductility of the R.F.A beams. This clearly establishes that R.F.A concrete can be used in structural applications with confidence.

REFERENCES

[1] Ganesan N,(2009) "*Strength and durability of fibre reinforced high performance concrete structural elements",* proceedings High performance steel fibre reinforced concrete for seismic resistant structures, pp.1-24.

[2] Hudson B.P.(1997) „*Manufactured sand for Concrete*". The Indian Concrete Journal, pp. 237-240.

[3] Ilangovan R. and Nagamani K. (2006) "*Studies on Strength and Behavior of Concrete by using Quarry Dust as Fine Aggregate".* CE and CR Journal, pp.12-26.

[4] Indira P.V,(2009) "*Mix proportioning and properties of HPC and SFRHPC",* proceedings High performance steel fibre reinforced concrete for seismic resistant structures, pp.31-50.

[5] Subramanian.K, Kalaiarasu.M (2008) *"Studies on Strength and Durability of High Performance Concrete using Recycled Concrete Aggregates"*, pp.89.

[6] *Sundarajan, R., Perumal, K., (2003),"Experimental Investigation on High Performance Concrete Using Silica Fume & Super Plasticizer",* Proceedings of the INCONTEST on 10-12, September, Coimbatore, pp: 303-313.