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PERFORMANCE OF FRC WITH PARTIAL REPLACEMENT OF NATURAL COARSE AGGREGATE BY RECYCLED COARSE AGGREGATE, CEMENT BY FLY ASH AND NATURAL SAND BY QUARRY DUST

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Abstract - The fibre reinforced concrete (FRC) is relatively a new construction material developed through extensive research during the last two decades. It has already found a wide range of practical applications and has proved reliable in construction and is a material having superior performance characteristics. The addition of fibres into the concrete has been found to improve several of its properties like tensile strength, cracking resistance, impact, wear and tear, ductility, fatigue resistance etc. Many types of fibres like steel fibres, carbon fibres, GI fibres, glass fibres, asbestos fibres etc. can be used in fibre reinforced concrete.

The project aims to focus on the possibility of using recycled coarse aggregates and industrial by products like fly ash and quarry dust in an efficient way to minimize environmental hazards caused by construction and demolition waste. The utilization of recycled aggregate is well accepted because of several improvements possible in concrete composites. The present study reports the results of experimental study conducted to evaluate the workability and strength characteristics of FRC by partial replacement of natural coarse aggregate by recycled coarse aggregate in various percentages (0%, 10%, 20%, 30%, 40%, 50%) and fine aggregate replacement by quarry dust and cement replacement by fly ash. The experiment was conducted on M30 grade concrete with 28days of curing.

***Key Words*: Recycled coarse aggregate; quarry dust; fly ash; workability; water absorption; drying shrinkage; strength.**

1. INTRODUCTION

The important material in the construction industry is concrete over a long period of time. It has wide range of application and utilization in construction field. Concrete is a product obtained artificially by hardening the mixture of cement, sand gravel and water in appropriate quantities. Concrete is a composite material which is mostly used in construction industry all over the world. It is artificially obtained by mixing the cementitious materials, aggregate and water in predetermined quantities. The strength properties of the concrete depend upon the properties of constituent material used and their combined action. Technology advancement and increasing economy leads to construction industry to grow rapidly. The growth leads to demand to massive amount of concrete to be produced to satisfy the need.

Natural coarse aggregate is one of the most important constituent materials as far as characteristics strength of concrete is concerned. Increase in demand and decrease in natural sources of natural coarse aggregate for the production of concrete has resulted in the need to identify the new sources of coarse aggregate. RCA is the most emerging replacement for NCA in the production of the concrete.

Fly ash is one of the major residues produced during combustion of coal in thermal power plants and comprises of fine spherical particles that arise with the fuel gases. It is most important commonly used pozzolanic ingredients in the world. The use of fly ash as a supplementary cementitious material in concrete increases the pozzolanic activity by reacting with calcium hydroxide in presence of moisture to form cementitious compounds and calcium silicates hydrates.

Quarry dust is an industrial by product. It is by product of stone crushers. Quarry dust has been proposed as an alternative to river sand that gives additional benefit to concrete.

2. EXPERIMENTAL PROGRAM

2.1 Materials used

2.1.1 Cement

In this experimental work, OPC of 43 grade (confirming to IS: 8112-1989) was used. Cement brand used in this work is Cement Corporation of India (CCI) cement.

Table 1: Physical properties of cement:

Physical properties	Test results
Specific gravity	3.15

Consistency	31%
Initial setting time	30min
Final setting time	400min

2.1.2 Coarse aggregate:

Locally available 20mm and down size crushed coarse aggregate confirming to IS-383:1970 is used in this experimental work.

Table 2: Physical properties of coarse aggregate:

Physical properties	Test results
Specific gravity	2.65
Fineness modulus	6.87

2.1.3 Fine aggregate:

The aggregate which pass through IS 4.75mm sieve are termed as fine aggregate. The fine aggregate confirming to zone II of IS: -383-1970 was used for this experimental work.

Table 3: Physical properties of fine aggregate:

Physical properties	Test results
Specific gravity	2.65
Fineness modulus	2.90
Zone	II

2.1.4 Fly ash:

In this study, fly ash is obtained from Raichur Thermal Power Station (RTPS), confirming to IS:3812(part1).

Table 4: Physical properties of fly ash

Physical properties	Test results
Specific gravity	2.5
Fineness(%)	2.5
Residue on 45-micron sieve, percent	79
Normal consistency	31

2.1.5 Quarry dust

Quarry dust was obtained from locally available quarries. It is by-product which is formed in the processing of rocks which broken down into fine particles less than 4.75mm. In this experimental work, quarry dust was collected from Center of Ash Utilization Technology Shakthinagar, Raichur.

Table 5: Physical properties of quarry dust:

Physical properties	Test results
Specific gravity	2.34
Water absorption	1.3%

2.1.6 Recycled coarse aggregate

In this present study, recycled coarse aggregate were collected from demolished reinforced concrete beams, slabs and columns. In this work aggregate of size 20mm and down size are used.

Table 6: Physical properties of recycled coarse aggregate:

Physical properties	Test results
Specific gravity	2.64
Fineness modulus	6.7

2.1.7 Steel fibers

In the present work steel fibers of 1mm diameter and 50mm length giving aspect ratio of 50mm are used.

2.1.8 Superplasticizers

Superplasticizer used in this work is MASTER GLENIUM SKY 8223. It mainly improves the workability of concrete without affecting the strength properties. It is reddish brown in colour and immediately dispersible in water.

2.2 Mix proportion

The experimental investigation is based on a reference concrete mix of grade M30 using recycled coarse aggregate, quarry dust and fly ash. The mix proportion of reference mix is 1:1.87:3.09.

2.3 Preparation of specimens

The procedure used to cast the specimens is as follows.

- Moulds should be placed on the vibrating table and wet mix should be poured in three layers in to the moulds and thoroughly compacted.
- After well compaction of concrete, level the surface and name the specimens.
- Demould the specimen after 24 hours of casting the specimen
- Keep the specimens for curing.

2.4 Testing of concrete

Concrete cubes of size 150x150x150 mm were tested for compressive strength as per IS 516:1959. To get the tensile strength, cylindrical specimens of size 150mm diameter and 300mm length were tested as per IS 5816:1999. For flexural strength, beam specimens of size 100x100x500mm were tested. Two-point loading was adopted on an effective span of 400mm to get pure bending, as per IS 516:1959. Drying shrinkage, concrete specimens of size 90mmx90mmx190mm were tested. Water absorption test was performed on cube specimen.

2.5 Results and discussion

2.5.1 Workability results

Table 7 gives the workability of FRC in terms of slump, compaction factor and vee bee degree when natural coarse aggregate is replaced by recycled coarse aggregate by different percentages.

It is observed that workability of FRC as measured from slump, compaction factor and vee bee degree go on decreasing as the percentage replacement of natural coarse aggregate by recycled coarse aggregate increase.

Table 7: Workability test results

% replacement of NCA by RCA	Workability test results		
	Slump (mm)	Compaction factor	Vee bee degree (sec)
0	110	0.96	27
10	107	0.94	31
20	103	0.935	34
30	98	0..929	36
40	86	0.924	38
50	83	0.896	39

2.5.2 Water absorption test

Table 8 gives the water absorption results for FRC produced by replacing natural coarse aggregate by recycled coarse aggregate in different percentages. The variation in water absorption is depicted in the form of graph as shown.

Table 8 Water absorption test results

% replacement of NCA by RCA	% of moisture absorptions
0	3.44
10	3.08
20	2.95
30	2.43
40	2.12
50	1.93

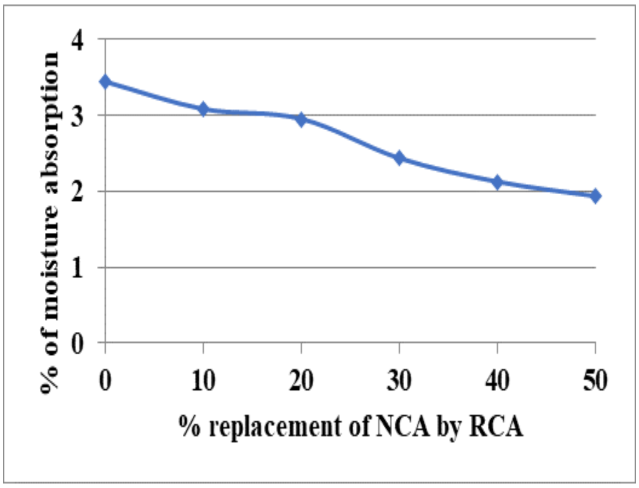

Fig 1 Variation of water absorption

It is observed that the water absorption of FRC go on decreasing as the percentage replacement of natural coarse aggregate by recycled coarse aggregate increase.

2.5.3 Drying shrinkage test

The test results for drying shrinkage are given in the table 9. Variation is drawn in the form of graph as shown.

Table 9 Drying shrinkage for 28 days

% replacement of NCA by RCA	Drying shrinkage in terms of percentage
0	0.3213
10	0.2969
20	0.1559
30	0.1859
40	0.2323
50	0.2582

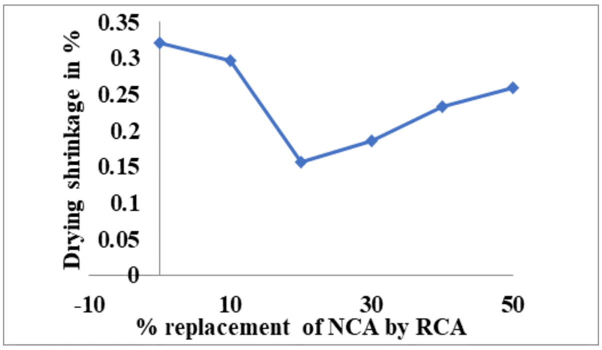

Fig 2 Variation of drying shrinkage

It is observed that the drying shrinkage of FRC go on decreasing up to 20% replacement of natural coarse aggregate by recycled coarse aggregate. Beyond 20% replacement drying shrinkage shows an increasing trend. Thus at 20% replacement level the drying shrinkage is minimum.

2.5.4 Strength tests

2.5.4.1 Compressive strength test results

Table 10 gives the compressive strength test results for FRC produced by replacing natural coarse aggregate by recycled coarse aggregates in different percentages. Table also gives the percentage decrease of compressive strength with respect to reference mix. The variation in compressive strength is depicted in the form of graph as shown.

Table 10 Result of compressive strength

% replacement of NCA by RCA	Compressive strength (MPa)	Percentage increase or decrease of compressive strength w.r.t reference mix
0	35.25	0
10	37.01	+4.99
20	39.03	+10.72
30	36.79	+4.36
40	35.01	-0.68
50	32.19	-8.68

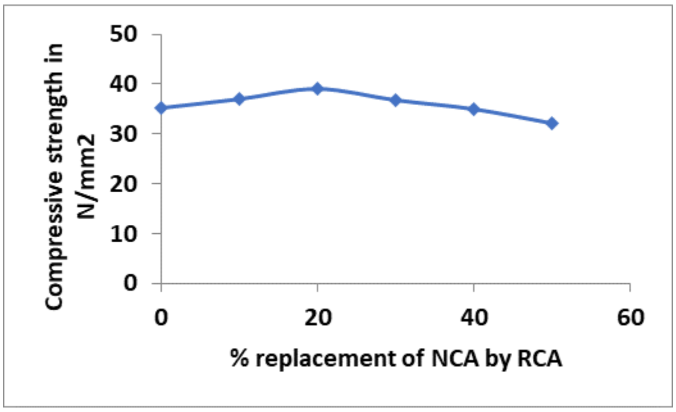

Fig 3 Variation of compressive strength

It is observed that the compressive strength of FRC go on increasing up to 20% replacement of natural coarse aggregate by recycled coarse aggregate. Beyond 20% replacement compressive strength shows a decreasing trend. Thus at 20% replacement level the compressive strength is found to be 39.03 MPa and the percentage increase in compressive strength with respect to reference mix is 10.72%.

2.5.4.2 Split tensile strength test results

Table 11 gives the split tensile strength test results for FRC produced by replacing natural coarse aggregate by recycled coarse aggregates in different percentages. The variation in split tensile strength is depicted in the form of graph as shown.

Table 11 Result of split tensile strength

% replacement of NCA by RCA	Split tensile strength (MPa)	Percentage increase or decrease of split tensile strength w.r.t reference mix
0	3.39	0
10	3.62	6.78
20	3.82	12.98
30	3.6	6.19
40	3.42	0.88
50	3.05	-10.02

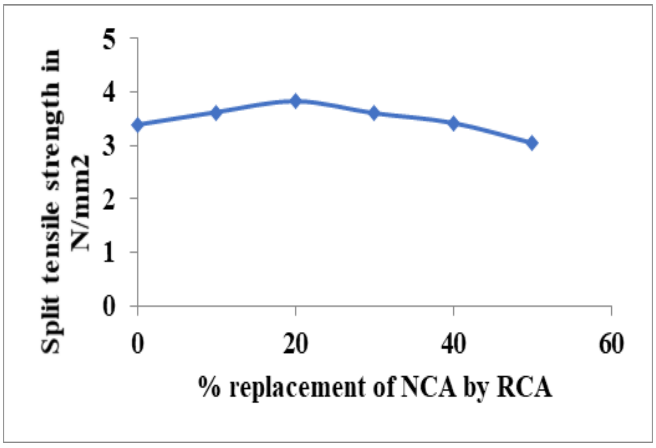

Fig 4 Variation of split tensile strength

It is observed that the tensile strength of FRC go on increasing up to 20% replacement of natural coarse aggregate by recycled coarse aggregate. Beyond 20% replacement tensile strength shows a decreasing trend. Thus at 20% replacement level the tensile strength is found to be 3.82MPa and the percentage increase in tensile strength with reference mix is 12.98%.

2.5.4.3 Flexural strength test results

Table 12 gives the flexural strength test results for FRC produced by replacing natural coarse aggregate by recycled coarse aggregates in different percentages. The variation in flexural strength is depicted in the form of graph as shown.

Table 12 Result of flexural strength

% replacement of NCA by RCA	Flexural strength (MPa)	Percentage increase or decrease of flexural strength w.r.t reference mix
0	8.76	0
10	9.25	5.59
20	10	14.15
30	8.95	2.16
40	8.25	-5.82
50	8.1	-7.53

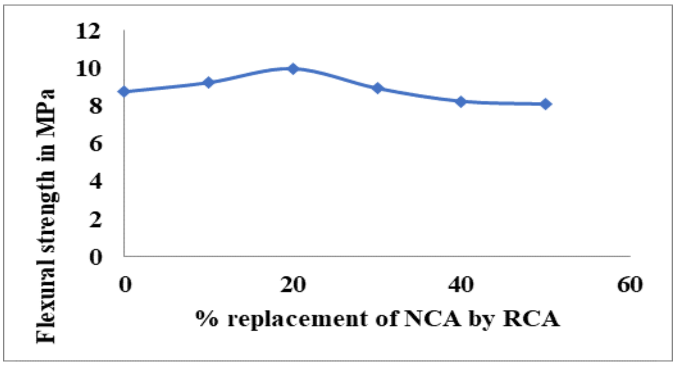

Fig 5 Variation of flexural strength

It is observed that the flexural strength of FRC go on increasing up to 20% replacement of natural coarse aggregate by recycled coarse aggregate. Beyond 20% replacement flexural strength shows a decreasing trend. Thus at 20% replacement level the flexural strength is found to be 10MPa and the percentage increase in flexural strength with reference mix is 14.15%.

3. CONCLUSIONS

Following conclusions may be drawn based on the experimentation conducted on the performance of fiber reinforced concrete with partial replacement of natural coarse aggregate by recycled coarse aggregate, cement by fly ash and natural sand by quarry dust.

- Workability of FRC produced by replacing natural coarse aggregate by recycled coarse aggregate is seriously affected as the percentage replacement increases.

- Water absorption of FRC go on decreasing as the percentage replacement of natural coarse aggregate by recycled coarse aggregate increase.
- Drying shrinkage of FRC is found to be minimum at 20% replacement of natural coarse aggregate by recycled coarse aggregate.
- Compressive strength of FRC is higher at 20% replacement of natural coarse aggregate by recycled coarse aggregate.
- Tensile strength of FRC is higher at 20% replacement of natural coarse aggregate by recycled coarse aggregate.
- Flexural strength of FRC is higher at 20% replacement of natural coarse aggregate by recycled coarse aggregate.

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