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Mechanical and durability properties of concrete by partial replacement of fine aggregate by RFA and cement by silica fume

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Abstract:

In India, traditionally river sand is used as fine aggregate in concrete production. However, due to continuous exploitation of river sand, its availability has become scarce. Construction industry has started using alternate materials as fine aggregate. Out of which manufactured sand is one of the popularly used material as fine aggregate. Materials such as recycled concrete aggregate have issues of dumping and environmental pollution. These materials are viable alternatives for replacement of natural river sand. Recycled concrete, if used as coarse aggregate has problems of water absorption and reduction in strength. Hence, an attempt has been made in this research to use recycled concrete aggregate (RCA) as fine aggregate in concrete. Further, use of RCA as fine aggregate in concrete may reduce the compressive strength of concrete. Hence, it is proposed to use silica fume as a supplementary material in cement with Recycled Fine Aggregate (RFA) as fine aggregate. This study investigates the effect of silica fume and RFA on the mechanical characteristics of concrete mixtures. Mechanical properties and durability properties at 28 days are determined. Silica fume is added to cement in the range of 7.5% and 10% by weight of cement. Natural river sand is replaced with RFA (Recycled Fine Aggregate) in the range of 0%, 50%, 100% by weight of sand. From the study it is found that RFA could be used as alternative material for natural sand. However, as complete replacement of RFA reduces the strength of concrete, silica fume addition is mandatory. A minimum of 7.5% silica fume is required to prevent strength loss in concrete.

Key words: Recycled fine aggregate (RFA), Silica Fume.

I. INTRODUCTION

Construction industry is facing actual shortage of natural fine aggregate. Hence, the industry has started using alternate aggregates. Manufactured sand, sintered flyash, bottom ash, recycled concrete fine aggregate and crushed steel slag are some of the alternative for river sand. Out of the above, manufactured sand is produced from natural stone or rocks. Manufacturing of sintered flyash, is time consuming and the quality of the aggregates depends on the quality control exercised during the sintering. Bottom ash, crushed steel slags are industrial by-products and viable alternative for river sand. In urban locations, dumping of demolition waste is a major problem and researchers have used demolition waste concrete as coarse aggregate and found that this material to decrease the compressive strength and reduce the demolition waste concrete as coarse aggregate. Hence, researches started using demolition waste concrete as fine aggregate is called RFA.

Research work carried out worldwide on replacement of sand with RFA is reported below. Compressive strength of the concrete decreases with increases in replacement of sand with RFA. 100% replacement of gives 33 N/mm^2 strength at 28 days, which is 2% less than conventional concrete (32 N/mm^2). By simultaneous replacement of RFA give more strength in period of 28 days with bonding agent of silica fume. Silica fume content of 7.5% and 10% at the weight of cement increases the strength of concrete.

In this work, it is proposed to replace sand completely with RFA. However, as this would reduce the strength by adding SCM in the mix. SCM will improve the strength of concrete. Metakaolin, flyash and silica fume are the most common SCM materials, it is learnt from literature that silica fume is the best among the available SCM, comparing the cost and performance

1.1 Literature Review

Krishnamurthy Pandurangan and Rajendiran Arunpandian et.al.,(2017) In India, traditionally river sand is used as fine aggregate in concrete production. However, due to continuous exploitation of river sand, its availability has become scarce. Construction industry has started using alternate materials as fine aggregate. Out of which manufactured sand is one of the popularly used material as fine aggregate. Materials such as quarry dust and recycled concrete aggregate have issues of dumping and environmental pollution. These materials are viable alternatives for replacement of natural river sand. Recycled concrete, if used as coarse aggregate has problems of water absorption and reduction in strength. Hence, an attempt has been made in this research to use recycled concrete aggregate (RCA) as fine aggregate in concrete. Further, use of RCA as fine aggregate in concrete may reduce the compressive strength of concrete. Hence, it is proposed to use metakaolin as a supplementary cementitious material in concrete with Recycled Fine Aggregate (RFA) as fine aggregate. This study investigates the effect of metakaolin and RFA on the mechanical characteristics of concrete mixtures. Mechanical properties such as compressive strength, split tensile strength, flexural strength at 7 and 28 days are determined. Metakaolin is added to cement in the range of 7.5% to 20% by weight of cement. Natural sand is replaced with RFA in the range of 0-100% by weight of sand. From the study it is found that RFA could be used as alternative material for natural sand. However, as complete replacement of RFA reduces the strength of concrete, metakaolin addition is mandatory. A minimum of 7.5% metakaolin is required to prevent strength loss in concrete. However, if RFA alone need to be used without addition of metakaolin, only 50% replacement of sand with RFA is recommended.

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Concrete is prepared by mixing various constituents like cement, aggregates, water, etc. which are economically available. Concrete is a composite material composed of granular materials like coarse aggregates embedded in a matrix and bound together with cement or binder which fills the space between the particles and glues those together (NSA, 1982). Production of sand and gravel has increased at an annual rate of less than 1 percent. In essence the amount of crushed stone to be produced in the next 20 years will equal the quantity of all stone produced during the previous century, i.e., about 36.5 billion metric tons. Therefore the use of alternative sources for natural aggregates is becoming increasingly important (NSA, 1982). In the present study the mechanical properties of concrete by replacing cement with different percentages of Silica fume and aggregate by different percentages of Steel slag are studied. The results thus obtained are analyzed using Regression analysis. Results indicated that the replacement of cement by silica fume to the extent of 15% exhibited improved mechanical properties. Further, it has been also observed that with 15% replacement of cement by silica fume and replacement of natural aggregates by steel slag aggregates to the extent of 25% to 50% have shown improved strength compared normal concrete i.e. the concrete with 0% silica fume and 0% steel slag aggregates. Regression analysis has been carried out to compare the experimental results.

Madam Mohan Reddy, K, Ajitha .B, and Bhavani .R (2016) The concrete consist of cement, sand, Aggregate and water. Out of which the aggregate percentage is 60 to 70 % in concrete and from the above observation, it is computed to use the 20% Recycled plastic aggregate in concrete which does not affect the properties of concrete. From the above observation it is possible to use the plastic in concrete mix up to 20 % weight of coarse aggregate. Looking in to above aspect we come to the conclusion that plastic can be in cement concrete mix increase the % in plastic to increase the strength of concrete.

II. MATERIAL PROPERTIES

2.1 Cement

Cement is a binding material in concrete which binds the other material to forms a compact mass. In this project work, OPC 53 grade cement is used for experimental study.

Table 2.1 Properties of Cement

Fineness value	8.5
Consistency	29.5%
Initial setting time	32min
Specific gravity	3.17

2.2 Water

Water conforming to the requirements of IS 456-2000 is found be satisfactory for making concrete. In the present investigation, portable drinking water available in the industrial company was used for mixing and curing the paver block.

2.3 Coarse Aggregate

Locally available crushed stone aggregates of nominal size 10mm.wherever possible size of aggregate 10mm used in the project.

Table 2.2 Properties of Coarse Aggregate

Description of test	Test result obtained	Permissible limits as per IS:383-1970
Specific gravity	2.71	Minimum 2.5
Fineness modulus	7.86	
Unit weight (kg/m^3)	1603	

2.4 Fine Aggregate

A concrete with better quality can be made with sand consisting of rounded grains rather than angular grains. River or pit sand must be used but not used sea sand as it contains salt and other impurities. In this study, river sand has been used as fine aggregate.

Table 2.3 Properties of Fine Aggregate

Description of test	Test result obtained	Permissible limits as per IS 383:1970
Specific gravity	2.63	Minimum 2.5
Fineness modulus	3.06	
Unit weight of sand (kg/m^3)	1687	

2.5 RFA (Recycled Fine Aggregate)

Recycling Fine Aggregate is the material under the process of converting waste conventional waste disposal that can save material and help to concreting without using of river sand. Concrete is a composite material composed of course and fine aggregate bonded together with a fluid cement hat hardens over time.

Table 2.4 Properties of RFA

S. No	Test Properties	RFA
1	Specific Gravity	2.51
2	Water absorption (%)	2.01
3	Bulk density(kg/m^3)	1399
4	Fineness modulus	3.74
5	Zone	1

2.6 Slump Test

This is a test extensively used in construction site. It is very useful in detecting the variation in the uniformity of mix of given nominal proportion. It also give an idea of water cement ratio need for concrete to be used for different works.

III. MIX PROPORTION

In this study, control mix was designed as per IS 10262:2009 for M_{25} grade. RFA is replaced by river sand by 0%,50%and 100% also cement is replaced by 7.5% 10% Silica Fume by weight of concrete. The details of the mix proportions of concrete were given in following table 3.1.

Mix Proportion : 1:2: 3.6

Table 3.1Mix Design

Title	Specification
Grade of Concrete	M25
Type and Grade of Cement	OPC 53 Grade
Size of Coarse Aggregate	10mm & 20mm
Specific Gravity of Coarse Aggregate	2.66
Specific Gravity of Fine Aggregate	2.63
W/C Ratio	0.5

Table 3.2 Mix Proportion Details

Materials	**cement kg**	**Silica fume kg**	**% of RFA**	**Fine aggregate kg**	**Coarse aggregate**	**Water Lit**
Cc	12	-	-	25	40	5
M1	12	1	0, 50, 100	25	40	5
M2	12	2	0, 50 100	11, 25	40	5

IV. EXPERIMENTAL METHODOLOGY

4.1 Compressive strength test

Fig 4.1 Compressive strength test

For cube compression tests on concrete, cube of size 150mm were employed. All the cubes were tested in saturated condition after wiping out the surface moisture from the specimen. For each trial mix, three cubes were tested at the age of 7, 14 and 28 days of carrying 400 tons capacity HELICO compression testing machine referred to BIS: 516-1959.

Table 4.1 Compressive Strength Test

Mix	At 28 Days (N/mm²)
M Conventional	30.83
M1 (7.5% of SF 0% of RFA)	32.75
M2(7.5% of SF 50% of RFA)	34.367
M3(7.5% of SF 1000% of RFA)	32.567
M4(10% of SF 0% of RFA)	31.5
M5(10% of SF 50% of RFA)	30
M6(10% of SF 100% of RFA)	32.03

Fig 4.2 compressive test result

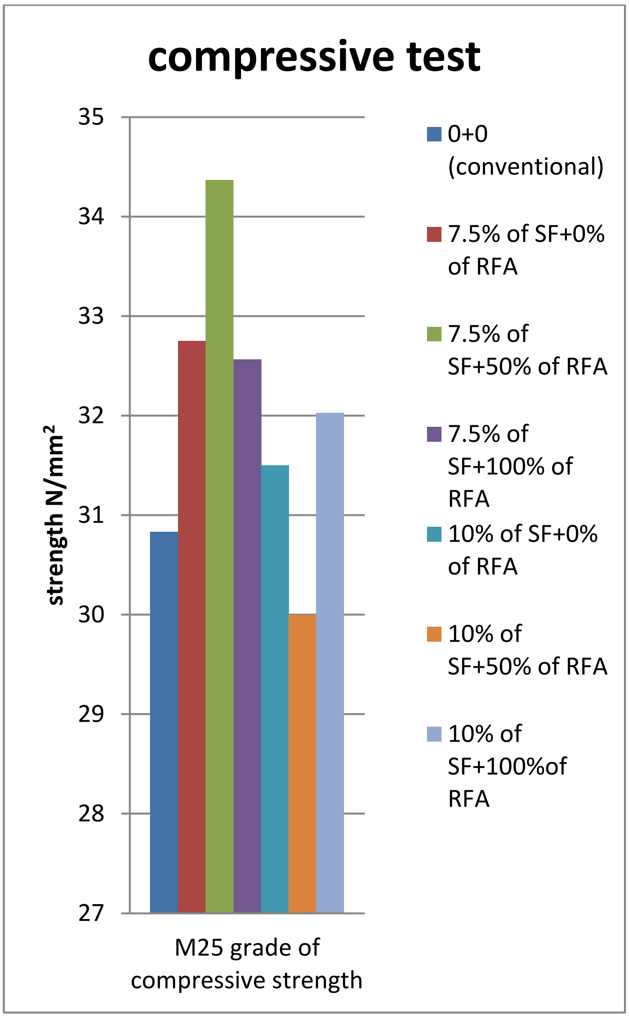

Fig 4.2 Compressive Strength Test

4.2 Split tensile test

Tensile strength is one of the basic and important properties of concrete. The results are required for the design of concrete subject to transverse shear, torsion, shrinkage and temperature effects. Its value is also used in the design of pre-stressed concrete structures, liquid retaining structures, roadways and runway slabs.

Table : 4.2 split tensile strength

Mix	At 28 Days (N/mm²)
M Conventional	4.2
M1 (7.5% of SF 0% of RFA)	4.24
M2(7.5% of SF 50% of RFA)	4.66
M3(7.5% of SF 1000% of RFA)	5.09
M4(10% of SF 0% of RFA)	4.53
M5(10% of SF 50% of RFA)	5.45
M6(10% of SF 100% of RFA)	5.4

Fig 4.2 Split tensile Test

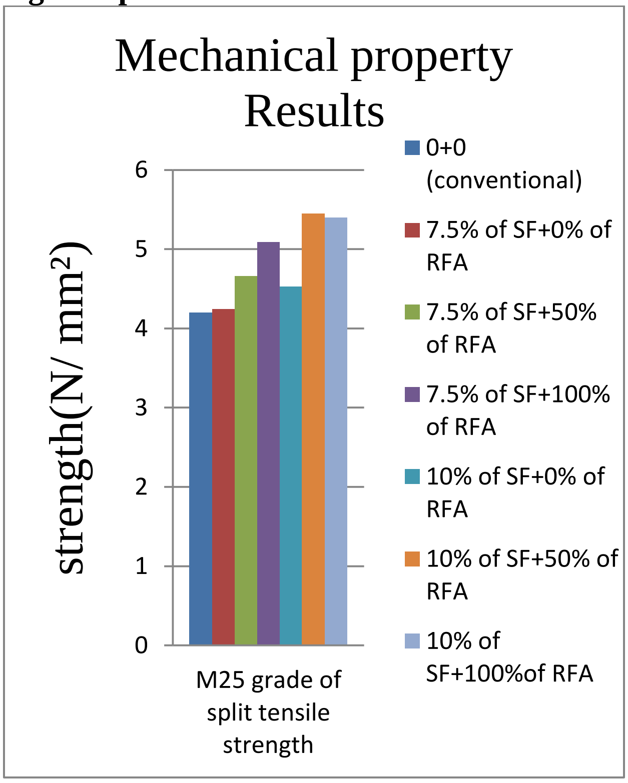

Table : 4.3 Flexural strength

Mix	At 28 Days (N/mm²)
M Conventional	4
M1 (7.5% of SF 0% of RFA)	4.2
M2(7.5% of SF 50% of RFA)	4.36
M3(7.5% of SF 1000% of RFA)	533
M4(10% of SF 0% of RFA)	4.44
M5(10% of SF 50% of RFA)	5.56
M6(10% of SF 100% of RFA)	6.66

Fig no:4.3 Flexural strength Test

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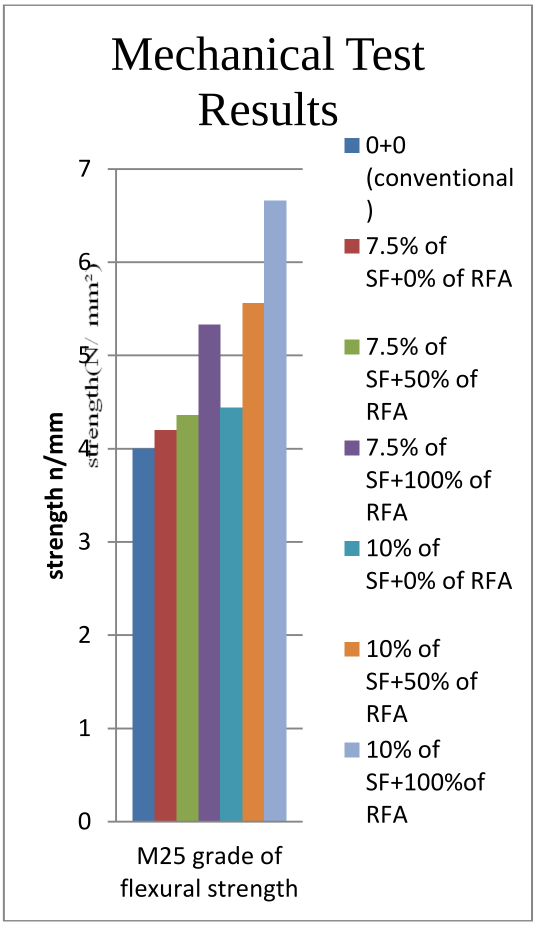

DURABILITY TEST

Acid Attack For Na_2SO_4

Mix	At 28 Days (N/mm²)
M Conventional	1.9
M1 (7.5% of SF 0% of RFA)	2.43
M2(7.5% of SF 50% of RFA)	2.76
M3(7.5% of SF 1000% of RFA)	2.13
M4(10% of SF 0% of RFA)	0.72
M5(10% of SF 50% of RFA)	1.39
M6(10% of SF 100% of RFA)	1.89

Fig 4.4 acid attack Na_2So_4

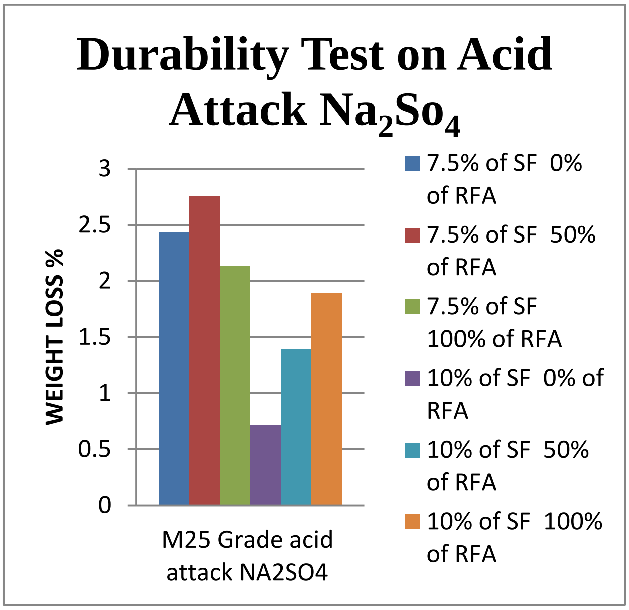

Table 4.5 Acid attack H_2So_4

Mix	At 28 Days (N/mm²)
M Conventional	1.01
M1 (7.5% of SF 0% of RFA)	1.92
M2(7.5% of SF 50% of RFA)	1.01
M3(7.5% of SF 1000% of RFA)	1.28
M4(10% of SF 0% of RFA)	1.23
M5(10% of SF 50% of RFA)	1.45
M6(10% of SF 100% of RFA)	1.25

Fig 4.6 acid attack H_2So_4

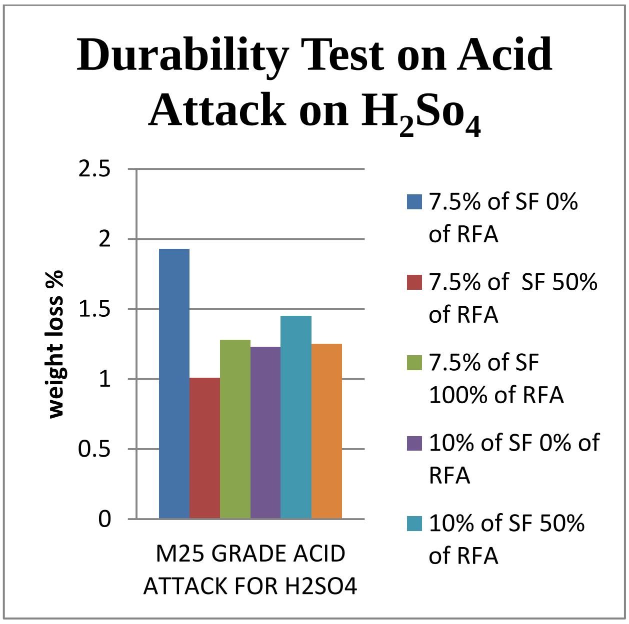

Table 4.6porocity Test

Mix	At 28 Days (N/mm²)
M Conventional	7.5
M1 (7.5% of SF 0% of RFA)	7.84
M2(7.5% of SF 50% of RFA)	7.52
M3(7.5% of SF 1000% of RFA)	7.62
M4(10% of SF 0% of RFA)	7.53
M5(10% of SF 50% of RFA)	7.81
M6(10% of SF 100% of RFA)	7.83

Fig 4.2 porosity Test

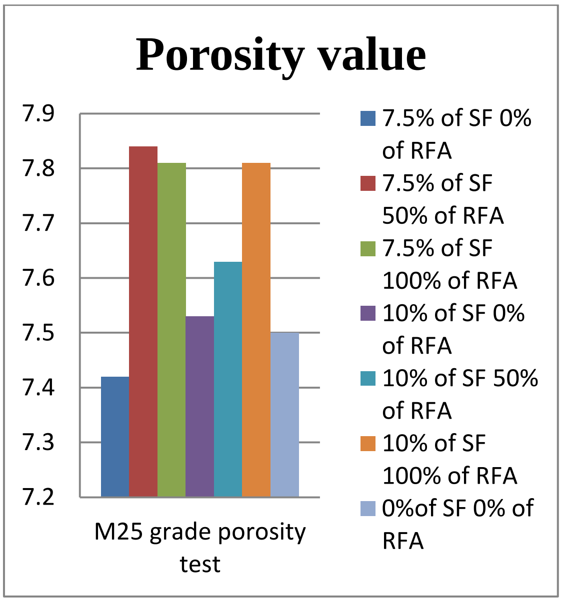

Fig 4.6 Porosity Test

V. RESULTS & DISCUSSION

Specific gravity of RFA higher than river sand.

Based on various researches it is observed that 10% replacement of silica fume generally gives maximum strength compared to conventional concrete.

This concrete more economical compared to conventional concrete using river sand.

Workability of the concrete goes on continuously increasing in the percentage of RFA.

Compressive strength of concrete is increased by addition of silica fume and RFA,

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