Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 5, Issue 04, April -2018

"STRENGTH AND DURABILITY STUDY OF CONCRETE USING PARTIALLY REPLACED RECYCLED FINE AND COARSE AGGREGATES ALONG WITH SILICA FUME"

[1]Alitha Aasif mehbub, [2]Dr. K B Parikh, [3]Prof. M A Jamnu,

[1]*M.E Student, Dept. of Structural Engineering GEC Dahod,, Gujarat, India*
[2]*Associate Professor, Applied Mechanics Department GEC Dahod, Gujarat, India*
[3]*Assistant Professor, Applied Mechanics Department GEC Godhra, Godhra, Gujarat, India*

ABSTRACT:- *To support the goal of "SAVE ENVIRONMENT", today's need is to use recycled materials as maximum as possible. As Concrete is the most demanded material after water in present developing countries. There is need of present globe to find the alternative materials for ingredients of concrete which can replace natural ingredients especially aggregates. Earlier researchers have presented good results of concrete using recycled coarse aggregates. Here an attempt is made to prepare concrete using recycled coarse aggregates as well as fine aggregates. Coarse aggregates have been replaced in percentages of 0,50 and 100 while fine aggregates will be replaced as 10%and 20%. 10% Silica fumes has also been used to improve the properties of the said concrete. Three grade viz. M40, M50 and M60 of Concrete have been prepared with and without silica fume to avail detailed study. The analysis is based on compressive strength and durability criteria. Comparative analysis of Fresh and Hardened properties of normal concrete and concrete using replacement of recycled coarse and fine aggregates along with and without silica fume has been carried out, which shows that initially the replacement of recycled aggregates alone decreases the strength. The result of compressive strength shows that replacement of coarse aggregate 50%, the reduction in strength is 9 to 12% while for 100% the reduction in strength is 22 to 30%.*

KEYWORD:*Cement***,** Recycled *Fine Aggregate*, Recycled *Coarse Aggregate*, *S*ilica fume, *Superplasticizer*

INTRODUCTION

Concrete is widely used construction material all over the world for various types of structures due to its strength and stability. The ingredients of concrete like cement, fine aggregates and coarse aggregates plays an important role in the strength and durability of structures. The ordinary Portland cement is one of the main ingredients used for production of cement causes various environmental problems involves emission of large amount of CO2 gas into the atmosphere, a major contribution for greenhouse effect and global warming. So to reduce these problems we use the supplementary cementations materials like fly ash, silica fume, ground granulated blast furnace slag, rice husk ash, metakaolin as a partial replacement material of cement. A number of studies are going on in India and other countries to study the effect of these materials as replacement materials. Silica fume is a mineral admixture and a very reactive pozzolan and it causes high strength and durability. Silica fume a byproduct of producing silicon metal or ferrosilicon alloys[1].

Coarse aggregates are the major ingredient of concrete and play an also important role in strength of concrete. But due to increase in population in India, the requirements of natural aggregates are not

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only required to fulfill the demand for the upcoming projects, but also are the needs of the extensive repairs or replacements required for existing infrastructure. So to reduce burden on natural resources, we can easily use recycled concrete aggregates which are easily available from demolished buildings or structures [1].

Furthermore, sustainable waste management is another major issue faced by countries all over the world. In order to minimize the environmental impact and energy consistency of concrete used for construction facilities, reuse of construction and demolition (C&D) wastes can be a beneficial way which leads sustainable engineering. approaches to concrete mix design[8].To achieve this, major emphasis must be laid on the use of wastes and byproducts in cement and concrete used for new constructions. The utilization of recycled aggregate is particularly very promising as 75 per cent of concrete is made of aggregates. The use of recycled aggregates from construction and demolition wastes is showing prospective application in construction as alternative to primary (natural) aggregates. In general, RCA contains 65-70% of natural aggregate (coarse and fine) and 30-35% of cement paste by volume (Kong 2010)[16]. concrete strength decreases when RA is used and the strength reduction could be as low as 40%[4,16].The use of recycled aggregate generally increases the drying shrinkage, creep and water sorptivity and decreases the compressive strength and modulus of elasticity of recycled aggregate concrete compared to those of natural aggregate concrete [2]. The poor performance of the recycled aggregate concrete is associated with the cracks and fissures, which were formed in recycled aggregate during processing, thereby rendering the aggregate having weaker and more susceptible to permeation, diffusion and absorption of fluids [4,2]. Some authors have reported differences between NAC and RAC regarding carbonation rates , while others found that the carbonation depth decreases in concrete with high percentages of RA. Thomas et al. reported that there is no significant increase in the rate of carbonation with the RA incorporation. Pereira et al. used two types of superplasticizers (SP) in RAC with fine recycled aggregate. They found that the performance of RAC with incorporation of RA was poorer than the performance of NAC. However, the mechanical performance of RAC was generally increased when SP was utilized in the mixture. They observed that the compressive strength of RAC was affected by RA; because fine ingredients decreased the compressive strength[4]. Also, it was observed that high water absorption had a negative effect on the strength of RAC. These drawbacks limit the utilization of the recycled aggregate with higher percentages (>30%) in structural concrete[2].It is reported in an experimental study carried out by Corinaldesi and Moriconi, that the compressive strength of RAC can be improved to equal or exceed that of natural aggregate concrete (NAC) by adding mineral admixtures. Moreover, replacements used as mineral admixtures are fly ash, silica fume (SF) and ground granulated blast furnace slag (GGBFS)[8]. Addition of silica fume to concrete has many advantages like high strength, durability and reduction in cement production[4]. The optimum silica fume replacement common cement percentage for obtaining maximum 28- days strength of concrete ranged from10 to 20 %. When pozzolanic materials are incorporated to concrete, the silica present in these materials react with the calcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate (C – S – H), which improve durability and the mechanical properties of concrete. In this paper suitability of silica fume has been discussed by replacing cement with silica fume at varying percentage and the strength parameters were compared with conventional concrete.

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EXPERIMENTAL WORK

Materials

Cement

Ordinary Portland Cement of Ultra tech brand of 53 grade confirming to IS: 12269-1987(9) was used in the present study. The properties of cement are shown in Table 1.

Table 1 physical properties of cement

Test/Properties	Result	As per Is:1489(part-1) 1991
specific Gravity	3.15	-
standard consistency	28.2	-
inial setting time	128 min.	30 min.
final setting time	192 min.	600 min.

Fine Aggregate

Natural sand as per IS: 383-1987 was used. Locally available River sand having bulk density 1860 kg/m3 was used The properties of fine aggregate are shown in Table 2

Table 2 physical properties of fine aggregates

Sr.no.	Test/Properties	Value
1	Specific Gravity	2.6
2	Water absorption	1.10%
3	Fineness modulus	2.56
4	Grading zone	II

Coarse Aggregate

Crushed aggregate confirming to IS: 383-1987 was used. Aggregates of size 20mm and 12.5 mm of specific gravity 2.8 and fineness modulus 4.31 were used.

Silica Fume

Silica fume used was confirming to ASTM- C(1240-2000) and was supplied by "ELKEM INDUSTRIES" was named Elkem – micro silica 920 D. The Silica fume is used as a partial replacement of cement. The properties of fine aggregate are shown in Table 3.

Table 3: Chemical properties of silica fume

Content	Result
Sio_2	>85
Cao	0.2
So_3	-
Density	2.2I
Al_2o_3	0.7
Fe_2o_3	1.2
Specific surface area (m^2/kg)	15000

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Mix Proportioning

Concrete mix design in this experiment was designed as per the guidelines specified in ACI234R – 96 "Guide for the use of silica fume in concrete" by ACI committee 234(7).All the samples were prepared using design mix. M40,M50 and M60 grade of concrete was used for the present investigation. Mix design was done based on I.S 10262-1982.

Table 4: Mix proportion 1 cubic meter concrete for M40 Grade

VOLUME OF CONCRETE	WATER	CEMENT	FINE AGGREGATE	COARSE AGGEGATE	SP DOSAGE(KG)
1 m3	149.76	422	686	1206	2.24
	0.40	1	1.62	2.85	0.6

Table 5: Mix proportion 1 cubic meter concrete for M50 Grade

VOLUME OF CONCRETE	WATER	CEMENT	FINE AGGREGATE	COARSE AGGREGATE	SP DOSAGE(KG)
1 m3	169	456.75	675	1187	2.74
	0.37	1	1.47	2.6	0.6

Table 6: Mix proportion 1 cubic meter concrete for M60 Grade

VOLUME OF CONCRETE	WATER	CEMENT	FINE AGGREGATE	COARSE AGGREGATE	SP DOSAGE(KG)
1 m3	169	482.85	666	1172	2.89
	0.35	1	1.38	2.42	0.6

Test for Workability of Fresh Concrete

Workability is defined as the properties of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished. The workability was measured by conducting slump cone test and compaction factor test in accordance with IS: 1199-1959. The trials were carried out to improve the workability and cohesiveness of the fresh concrete by incorporating a super plasticizer.

Experimental Procedure

The specimen of standard cube of (150mm x 150mm x 150mm) were used to determine the compressive strength of concrete. Three specimens were tested for 28 days with each proportion of recycled fine and coarse aggregates with and without silica fume as partial replacement of cement.

Tests Performed

Slump test:

- Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. The slump test is used for the measurement of a property of fresh concrete as per IS: 1199 - 1959

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- The apparatus for conducting the slump test essentially consists of a metallic mould in the form of frustum of cone having the internal dimensions as under: Bottom diameter: 20 cm. Top diameter: 10 cm. Height: 30 cm

• Compressive Strength Test

- Compressive strength is one of the most important engineering property of Concrete which designers are concerned of. It is a standard industrial practice that the concrete is classified based on grades. This grade is nothing but the Compressive Strength of the concrete cube or cylinder. Cube or Cylinder samples are usually tested under a compression testing machine to obtain the compressive strength of concrete. Cubes of size 150 X 150 X 150 mm were casted and cured for 28 days and tested on compression testing machine of capacity 3000kN.
- The compressive strength of cube specimen is calculated using the following formula:

$$\sigma = P/A$$

Where P = failure load

A = cross sectional area in mm

Table 7: Compressive Strength M40 (Without SF)

SR.NO.	%RCA	%RFA	%SILICA FUME	COMPRESSIVE STRENGTH N/mm^2 (28 DAYS)	PERCENTAGE variation
1	0	0	0	50.26	-
2	50	0	0	45.56	-9.35
3	100	0	0	38.90	-22.60
4	0	10	0	48.95	-2.6
5	0	20	0	48.55	-3.4
6	50	10	0	43.90	-12.65
7	100	10	0	37.88	-25.22
8	50	20	0	43.48	-13.48
9	100	20	0	36.63	-27.10

(-ve sign indicates decrease in compressive strength)

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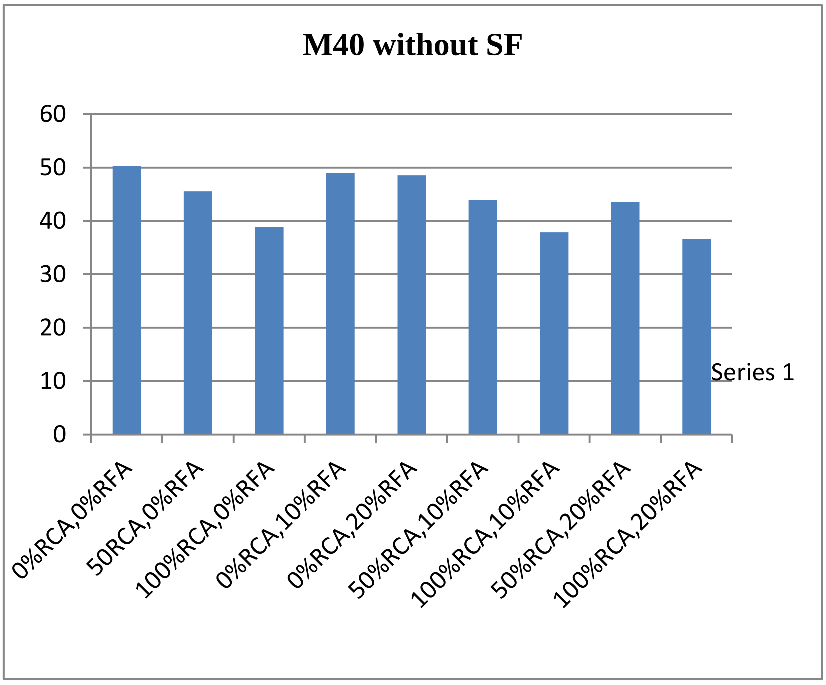

Graph 1: Compressive Strength M40 (Without SF)

Table 8: Compressive Strength M40 (with SF)

SR.NO.	%RCA	%RFA	%SILICA FUME	COMPRESSIVE STRENGTH N/mm^2 (28 DAYS)	PERCENTAGE Variation
1	0	0	10	54.33	8.09
2	50	0	10	47.10	-6.28
3	100	0	10	39.80	-20.81
4	0	10	10	51.96	3.38
5	0	20	10	50.55	0.57
6	50	10	10	45.40	-9.66
7	100	10	10	38.25	-23.89
8	50	20	10	44.60	-11.26
9	100	20	10	36.90	-26.58

(-ve sign indicates decrease in compressive strength)

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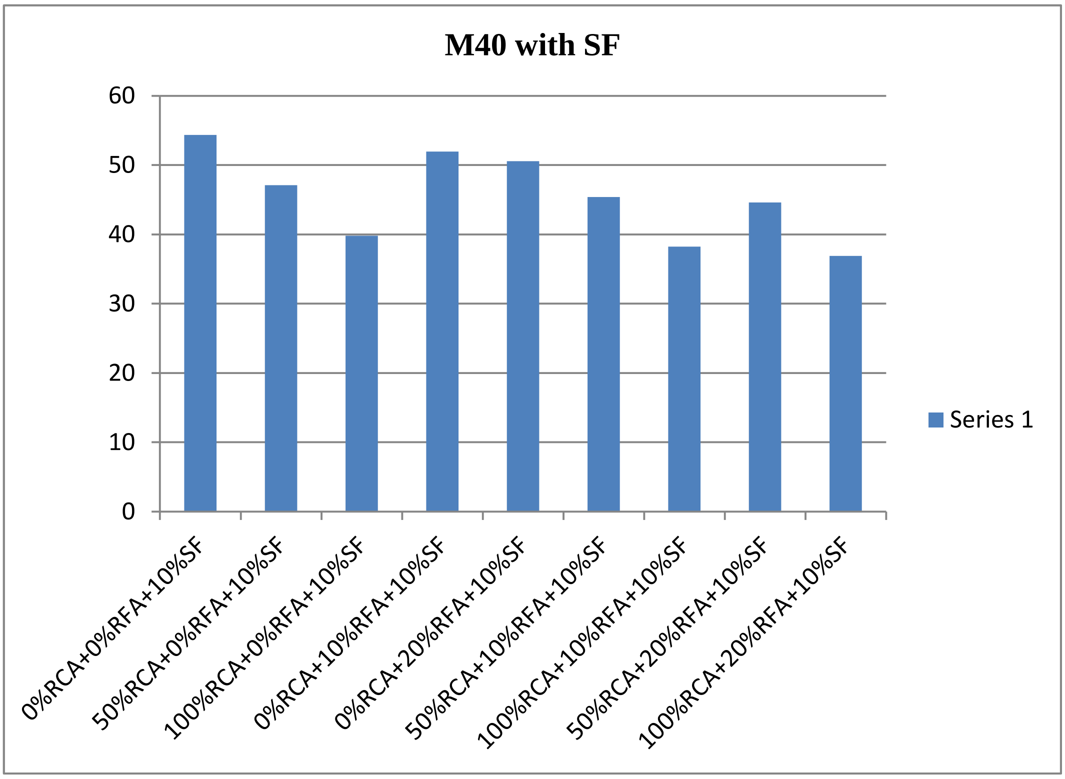

Graph 2: Compressive Strength M40 (With SF)

Table 9: Compressive Strength M50 (Without SF)

SR.NO.	%RCA	%RFA	%SILICA FUME	COMPRESSIVE STRENGTH N/mm^2 (28 DAYS)	PERCENTAGE variation
1	0	0	0	59.73	-
2	50	0	0	53.08	-11.13
3	100	0	0	43.33	-27.45
4	0	10	0	57.96	-2.96
5	0	20	0	57.53	-3.68
6	50	10	0	51.09	-14.45
7	100	10	0	41.02	-31.02
8	100	20	0	50.60	-15.28
9	100	20	0	40.80	-31.69

(-ve sign indicates decrease in compressive strength)

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Graph 3: Compressive Strength M50 (Without SF)

Table 10: Compressive Strength M50 (with SF)

SR.NO.	%RCA	%RFA	%SILICA FUME	COMPRESSIVE STRENGTH N/mm^2 (28 DAYS)	PERCENTAGE variation
1	0	0	10	63.73	7.39
2	50	0	10	54.60	-8.59
3	100	0	10	44.20	-26.00
4	0	10	10	61.45	2.88
5	0	20	10	59.96	0.38
6	50	10	10	56.31	-11.64
7	100	10	10	44.98	-29.42
8	50	20	10	55.56	-12.81
9	100	20	10	43.78	-31.16

(-ve sign indicates decrease in compressive strength)

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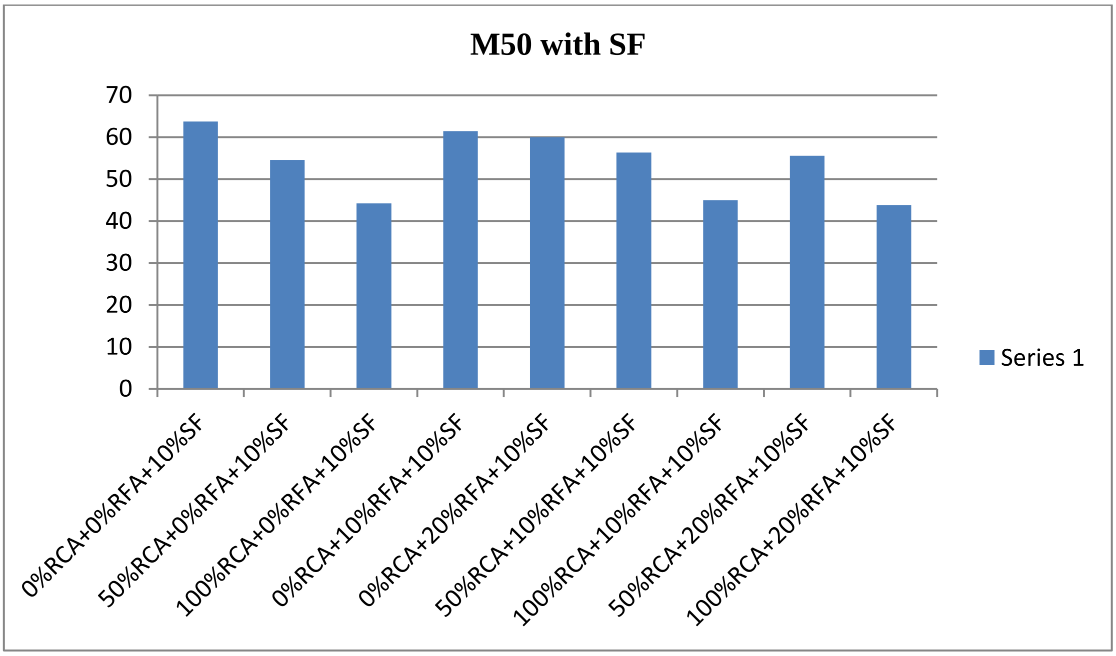

Graph 4: Compressive Strength M50 (With SF)

Table 11: Compressive Strength M60 (Without SF**)**

SR.NO.	%RCA	%RFA	%SILICA FUME	COMPRESSIVE STRENGTH N/mm^2 (28 DAYS)	PERCENTAGE Variation
1	0	0	0	69.55	-
2	50	0	0	60.10	-12.74
3	100	0	0	47.97	-30.35
4	0	10	0	66.32	-3.71
5	0	20	0	65.73	-4.57
6	50	10	0	59.06	-15.08
7	100	10	0	46.40	-33.28
8	50	20	0	58.76	-15.51
9	100	20	0	46.04	-33.80

(-ve sign indicates decrease in compressive strength)

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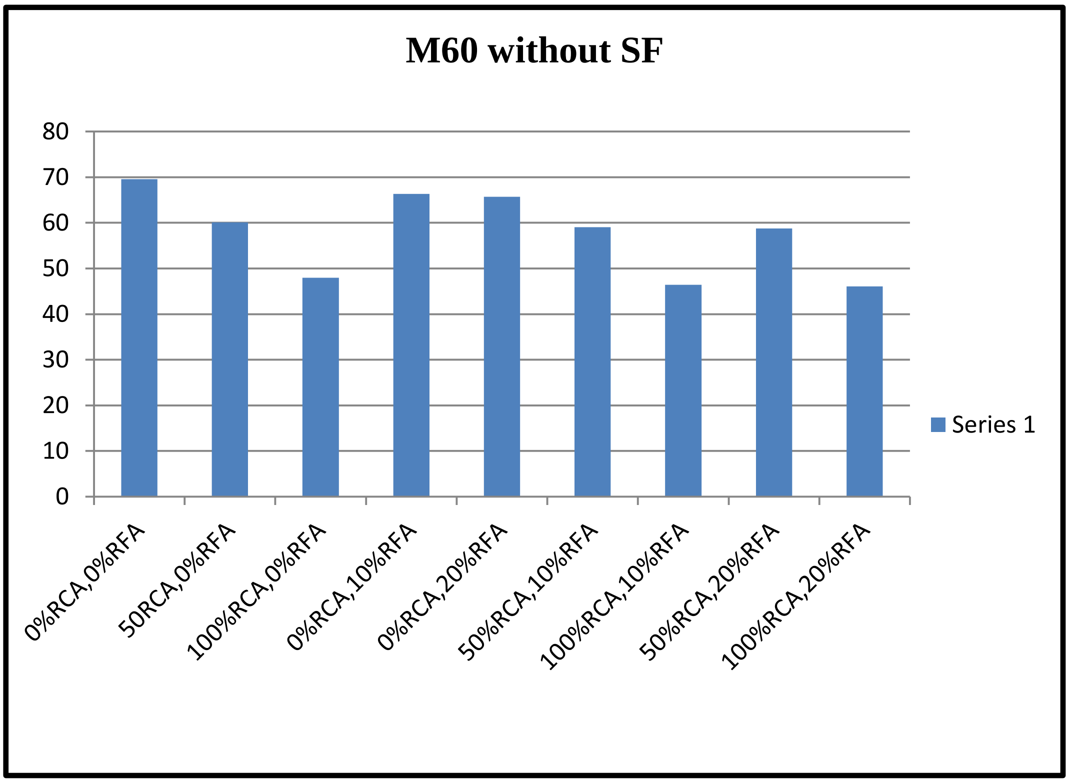

Graph 5: Compressive Strength M60 (Without SF)

Table 12: Compressive Strength M60 (with SF)

SR.NO.	%RCA	%RFA	%SILICA FUME	COMPRESSIVE STRENGTH N/mm^2 (28 DAYS)	PERCENTAGE variation
1	0	0	10	73.11	5.12
2	50	0	10	62.49	-10.12
3	100	0	10	49.55	-28.75
4	0	10	10	70.40	1.22
5	0	20	10	69.16	-0.56
6	50	10	10	60.80	-12.58
7	100	10	10	47.20	-32.13
8	50	20	10	59.20	-14.88
9	100	20	10	46.31	-33.41

(-ve sign indicates decrease in compressive strength)

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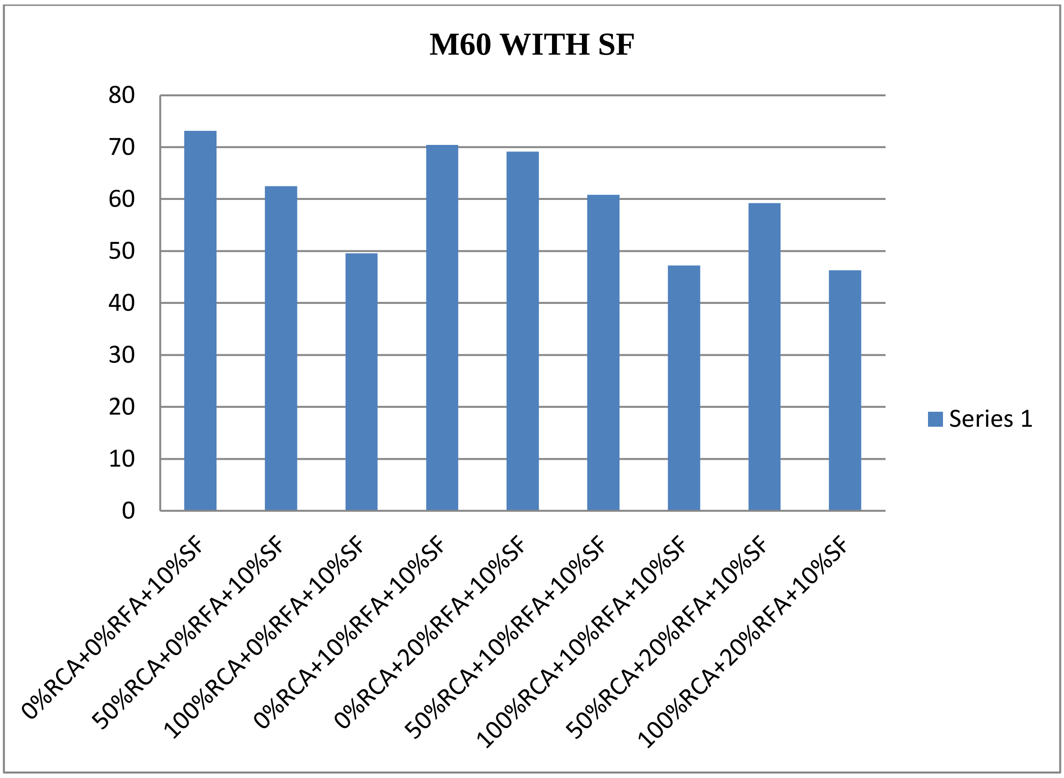

Graph 6: Compressive Strength M60 (With SF**)**

- **Rapid Chloride Penetration Test**

Corrosion is mainly caused by the ingress of chloride ion into the concrete. Rapid chloride penetration test (RCPT) has been developed as a quick test to measure the rate of transport of Chloride ions in concrete. Concrete disc specimens of size 100mm diameter and 50mm thick were cast using, with and without copper slag. After 24 hours, the disc specimens were removed from the mould and subjected to curing for 28 days in chloride free water. After curing, the specimens were tested for chloride permeability. All the specimens were dried free of moisture before testing. This is a two component cell assembly checked for air and watertight. The cathode compartments filled with 3%NaCl solution and anode compartment is filled with 0.3 NaOH solutions. concrete specimens were subjected to RCPT by impressing a 60V from a DC power source between the anode and cathode. Current is monitored up to 6 hours at an interval of 30 minutes.

From the current values, the chloride permeability is calculated in terms of coulombs at the end of 6 hours by using the formula.

$Q = 900 (I_0 + 2I_{30} + 2I_{60} + 2I_{90} + \ldots\ldots\ldots\ldots + 2I_{300} + 2I_{330} + I_{360})$

Where,

Q = Charge passed (Coulombs)

I_0 = Current (amperes) immediately after voltage is applied

I_t = Current (amperes) at t min. after voltage is applied

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Table 13: Chloride Ion Penetrability Based On Charge Passed

Charge Passed,(Coulomb)	Chloride Penetrability
>4000	High
2000 to 4000	Moderate
1000 to 2000	Low
100 to 1000	Very low
<100	Negligible

Table 14: Result of rapid chloride penetration test

Mix	Grade of concrete	Charge passed in coulombs (28 day)
50% RCA and 10% SF	M40	1302
50% RCA and 10% SF	M50	1036
50% RCA and 10% SF	M60	842

CONCLUSION

In this study, the effects of Recycled aggregates with/without SF on the physical and mechanical properties of concrete are presented. Based on the above results, the following conclusions can be drawn:

1. The compressive strength of the Recycled aggregates concrete gradually decreases as the amount of Recycled aggregates increases.
2. At 100% of recycled coarse aggregates replacement level, the concrete strength decreases about 22.60, 27.45 and 30.35 % for gradeM40, M50 and M60 respectively at 28 days. At over 50% of replacement level, the strength reduction is more significant.
3. The compressive strength of the specimens containing 10% SF contents increases by replacing of the NCA with RCA at 28 days.
4. Addition of 10% silica fume was observed to be optimum resulting in an increase of 8.09, 7.39 and 5.12% in compressive strength for grade M40, M50 and M60 respectively when compared to a sample with no silica fume.
5. Chloride permeability of concrete decreases for grade of concrete increases.

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