Strength and Durability Study of Recycled Aggregate Concrete Containing Silica Fume as Partial Replacement for Cement

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Abstract - *The purpose of this study is to find the properties of RCA and compare the same with the concrete produced with natural aggregates. This thesis presents a study conducted on mechanical and durability properties of recycled aggregates concrete. The investigation covered concrete mixes at water cementitious material with ratio of 0.4. Ordinary Portland cement of 43-grade was used in this study. The percentage of recycled aggregates that partially replaced natural aggregates by weight were 0%, 10%, 20%, 30%, 40% and 50%. Concrete cubes and cylinders were casted and tested in laboratories. The optimum proportion of replacement was found by conducting tests on mechanical properties like Compressive strength test and Split tensile strength test. To assess the corrosion and durability characteristics of recycled concrete aggregates Acid and alkalinity resistance test, Ultrasonic Pulse Velocity (UPV) test, Initial surface absorption test and Capillary suction test were performed. The results show that the optimum replacement of recycled aggregates with natural aggregates was 30%. Up to 30% replacement, it is possible to gain the same strength as conventional concrete. Beyond 30% replacement the strength results following decreasing trend. Moreover, initial surface absorption increases with increase in replacement levels and the same is true for sorptivity. It was also found that the recycled aggregates concrete performs well in terms of UPV.*

Key Words: UPV, Compressive strength, Durability, Silica Fume.

1. INTRODUCTION

Now-a-days concrete industry is consuming lot of natural resources. This causes lot of damage to environment and mother earth. So, the less cement and natural aggregates that are used in concrete production, the lower the impact on environment. The increase in cost of landfill, scarcity of natural resources for aggregate, encourages the use of construction waste as a source of aggregate. A sustainable construction has become a great concern over construction practice at the expense of the future of our planet. This is due to the fact that the construction industry is a massive consumer of natural resources and a huge waste producer as well. High value of raw material consumption in the construction industry becomes one of the main factors that cause environmental damage and pollution to our mother earth and the depletion of natural and mineral resources. The main objective of this study is to develop and test the concrete properties by partial replacement of natural coarse aggregates with recycled coarse aggregates. Feasibility of using recycled coarse aggregates as coarse aggregates in concrete and to investigate the influence of the use of admixtures (silica fume) and super plasticizers on the properties of recycled coarse aggregate concrete, and further to study the literature review of different papers based on recycled aggregates concrete and their properties. The more precise objective of the study is as follows

- To investigate the mechanical properties of concrete produced with recycled coarse aggregates.
- To investigate the durability properties of concrete produced with recycled coarse aggregates.

2. MATERIAL PROPERTIES

2.1 Cement:

Although all materials that go into concrete mix are essential, cement is very often the most important because it is usually the delicate link in the chain. Any variation in its quantity affects the compressive strength of the concrete mix. In the present investigation, Ordinary Portland Cement (OPC) of 43 Grade was used for all concrete mixes.

2.2 Fine Aggregate:

IS: 383-1970 defines the fine aggregate, as the one passing 4.75mm IS sieve. The fine aggregate is often termed as a sand size aggregate. Locally available riverbed sand was used in the present study. The per cent passing 600 micron sieve = 62.35. The sand confirms to grading Zone – III as per IS: 383 – 1970 respectively.

2.3 Coarse Aggregate:

The coarse aggregate is defined as that retained on 4.75 mm IS sieve. To increase the density of the resulting concrete mix, the coarse aggregate is frequently used in two or more sizes. Two types of aggregates with different sizes have been used in the present study.

The details of the same are as below:

- Aggregate passing 20 mm sieve
- Aggregate passing 10 mm sieve.

The coarse aggregate used were washed and kept in water for 24hrs to remove dust and dirt and were dried to surface dry condition.

2.4 Natural Coarse Aggregate:

Crushed granite with nominal sizes of 10 mm and 20 mm were used as natural coarse aggregate.

2.5 Recycled Coarse Aggregate:

Concrete wastes of material testing laboratory was used as a coarse aggregates. Both natural and recycled aggregates followed the same grading and the same is shown in Table-1.

Table 1: Gradation of Aggregates

20mm size % retained per 100kg		
sieve size	**% retained on sieve**	**Cumulative % retained**
20 mm	5%	5%
16+12.5+10mm	60%	65%
4.75 mm	25%	90%
2.36 mm	10%	100%

10mm size % retained per 100kg		
sieve size	**% retained on sieve**	**Cumulative % retained**
12.5 mm	8%	8%
10mm	32%	40%
4.75 mm	55%	95%
2.36 mm	5%	100%

2.6 Silica Fume:

The terms of micro silica, condensed silica fume, and silica fume are often used to describe by-products extracted from the exhaust gases of ferrosilicon, silicon. And other metal alloy smelting furnaces. However, the terms of silica fume and micro silica are used for those condensed silica fumes that are of high quality for using in the cement and concrete industry.

2.7 Water:

As per IS: 456-2000 potable water is generally considered satisfactory for mixing and curing of concrete. Accordingly potable water was used for preparation of all concrete specimens.

2.8 Admixtures:

Water-reducing and set-retarding admixtures are permitted in order to increase the workability of the concrete and to extend the time of discharge from 60 to 90 minutes. These admixtures are permitted and often required for superstructure concrete. Chemical admixtures and mineral admixtures as defined by ASTM C 494 are as follows:

Super plasticizer CONPLAST SP 430 is a chloride free workability retention admixture based on selected organic polymers. Silica fume was used as a mineral admixture. It acts as a filler material, and gives the early strength to the concrete.

3. EXPERIMENTAL PROGRAMME

Cube specimens of size 150 mm x 150 mm x 150 mm were used for Initial Surface absorption Test, Ultrasonic pulse velocity (UPV) measurement, Acid resistance test and alkalinity resistant test. Whereas cylinder specimens with 100 mm diameter and 50mm depth sliced from 200 mm long cylinders were used for capillary suction test. Cubes of size 100 mm x 100 mm x 100 mm were used for obtaining compressive strength and split tensile strength of the various mixes.

4. MIX DESIGN

Quantities of materials for mix of concrete:

Different quantities of materials and the mix proportions of the materials for each mixes with OPC 90% and SF 10% are shown in Table-2

Mixes	**CAG**		**RCA**	
	20mm	**10mm**	**20mm**	**10mm**
M1	50%	50%	0%	0%
M2	45%	45%	5%	5%
M3	40%	40%	10%	10%
M4	35%	35%	15%	15%
M5	30%	30%	20%	20%
M6	25%	25%	25%	25%

5. TEST PROCEDURE

- Slump cone test
- Compressive strength test
- Split tensile strength of test
- Initial surface absorption test
- Capillary suction test
- Ultrasonic Pulse Velocity(UPV) Test
- Acid Resistance Test
- Alkalinity Resistance Test

6. TESTS AND RESULTS

This chapter aims at collecting the results of different tests performed on all the concrete mixes at different curing ages. This chapter is useful to examine the strength and durability properties of recycled aggregate concrete and to find out the optimum replacement levels of recycled aggregates. The results examined and discussed for the different tests conducted are listed as below.

1. Slump cone test of concrete mix
2. Compressive strength test of concrete
3. Split tensile strength test of concrete
4. Acid resistance test of concrete
5. Alkalinity resistance test of concrete
6. Ultrasonic Pulse Velocity (UPV) test
7. Initial surface absorption test on concrete
8. Capillary suction test on concrete

Table 2: Quantities of materials for mix of concrete

Mixes	CAG		RCA	
	20mm	10mm	20mm	10mm
M1	50%	50%	0%	0%
M2	45%	45%	5%	5%
M3	40%	40%	10%	10%
M4	35%	35%	15%	15%
M5	30%	30%	20%	20%
M6	25%	25%	25%	25%

Table 2 represents the quantities of material that are used in the mix of concrete. Here S.F refers to Silica Fume, Cag is coarse aggregates and RCA is recycled concrete aggregates. M1 is the first mix with 0% replacement of recycled aggregates; M2 is the second mix with 10% replacement of recycled aggregates and for M3 with 20% replacement, M4 with 30% replacement, M5 with 40% replacement and finally M5 with 50% replacement of recycled aggregates in the concrete mixes.

6.1 Slump Test:

Table 3: Slump values for different concrete mixes

Mix description	Slump (mm)
M1 0%RA +100%NA + 10% SF	113
M2 10%RA +90%NA + 10%SF	108
M3 20%RA +80%NA + 10%SF	100
M4 30%RA +70%NA + 10%SF	98
M5 40%RA +60%NA + 10%SF	95
M6 50%RA +50%NA + 10%SF	90

6.2 Compressive strength:

Table 4: Compressive strength (MPa) values of all mixes at different curing ages

Mix description	Compressive Strength(MPA)			
	7	28	56	90
M1 0%RA +100%NA	31.1	34.6	37.4	41.5
M2 10%RA +90%NA	30.0	34.4	37.5	41.0
M3 20%RA +80%NA	29.6	34.0	37.0	39.7
M4 30%RA +70%NA	30.8	34.2	36.9	39.3
M5 40%RA +60%NA	26.3	31.3	33.2	36.4
M6 50%RA +50%NA	25.9	31.8	32.6	35.7

6.3 Split Tensile Strength Test:

Cubes of size 100×100×100mm were cast and cured for 7, 28, 56 and 90 days. After curing age the cubes were allowed to dry in the sunlight for 1 day and were tested under strength testing machine by placing the cubes diagonally in the centre. The load was increased until the specimen fails. The maximum load taken by the specimen was noted.

Table 5: Split tensile strength test (MPa) values of all mixes at different curing ages

Mix description	Split Tensile Strength(MPA)			
	7	28	56	90
M1 0%RA +100%NA	3.70	4.16	4.45	4.99
M2 10%RA +90%NA	3.76	4.22	4.37	4.91
M3 20%RA +80%NA	3.67	4.23	4.32	4.83
M4 30%RA +70%NA	3.65	4.13	4.27	4.74
M5 40%RA +60%NA	3.19	3.96	4.21	4.64
M6 50%RA +50%NA	2.91	3.78	3.94	4.47

6.4 UPV Test:

Cubes of size 150×150×150mm were cast and cured for 56 and 90 days. After 56 and 90 days cubes were taken out and allowed to dry in sunlight for 1 day.

Table 6: UPV Test Results at 56 days

Mix description	Distance (mm)	Transit time (μ sec)	Average pulse velocity(km/sec)	Quality of concrete
M1 0%RA +100% NA	150	32.15	4.76	Excellent

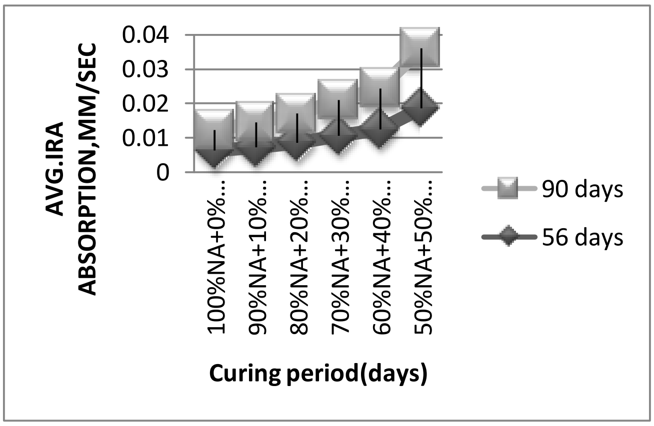
M2 10%RA +90%NA	150	32.7	4.68	Excellent
M3 20%RA +80%NA	150	31.9	4.30	Excellent
M4 30%RA +70%NA	150	31.8	4.51	Excellent
M5 40%RA +60%NA	150	30.9	3.63	Good
M6 50%RA +50%NA	150	30.5	3.57	Good

Table 7: UPV Test Results at 90 days

Mix description	Distance (mm)	Transit time(μ sec)	Average pulse velocity(km/sec)	Quality of concrete
M1 0%RA +100%NA	150	33.4	5.26	Excellent
M2 10%RA +90%NA	150	33.8	5.08	Excellent
M3 20%RA +80%NA	150	32.8	4.90	Excellent
M4 30%RA +70%NA	150	32.5	4.81	Excellent
M5 40%RA +60%NA	150	31.6	4.14	Good
M6 50%RA +50%NA	150	31.1	3.73	Good

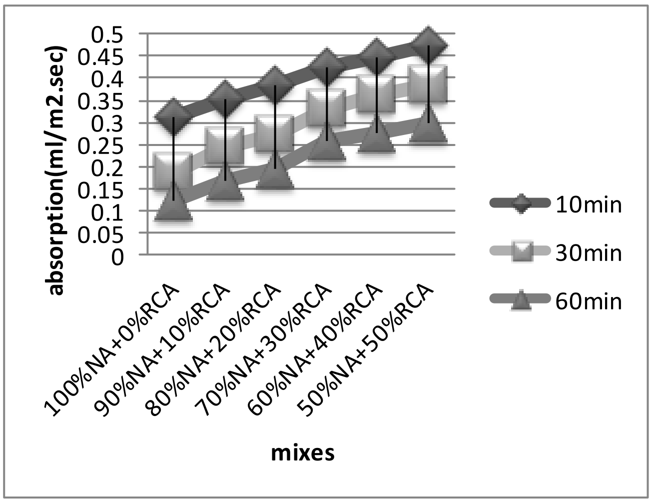
6.5 Capillary Suction (Sorptivity) Test:

The results of the capillary suction tests conducted on concrete specimens of different mixes cured at different ages are presented and discussed in this section. Each set of plots refer to the three specimens tested for each concrete mix. The tests conducted on the three specimens at a particular curing time give identical slopes, particularly during the early part of the test, i.e. the relationship between cumulative water absorption and the square root of time exposure begins to deviate from linearity after about 6 hours.

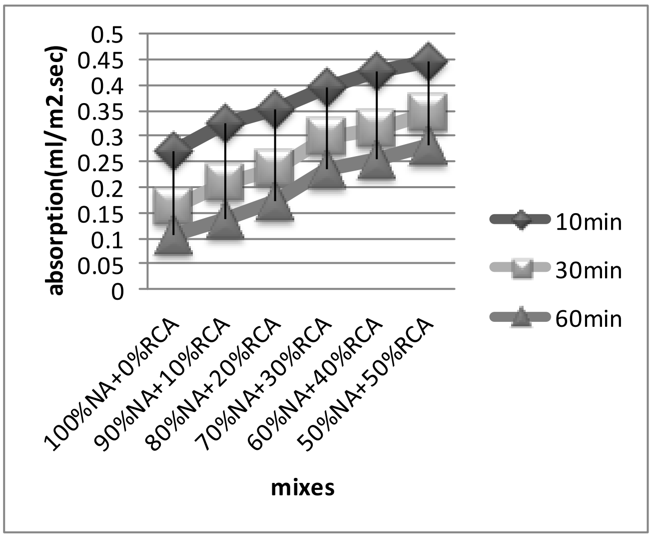


Graph 1: Variation in average IRA values of concrete mixes at different curing ages

6.6 Initial surface absorption test:



Graph 2: ISAT results at 56 days of curing



Graph 3: ISAT results at 90 days of curing

6.7 Acid Resistance Test:

For acid resistance, 1% dilute sulphuric acid (H2SO4) by volume of the water with pH value of 2 was maintained. Cubes were immersed in acid for a period of 28 days. The action of acids on hardened concrete is the conversion of ferrous compounds into the ferrous salts of the attacking acid. As a result of these reactions, the structure of concrete gets destroyed. The dimension of cube specimens was reduced 3mm at all sides at 28 days of curing.

Fig 1: Acid tested specimen and normally cured specimen

6.8 Alkalinity resistance test:

For alkalinity test 5% sodium hydroxide (NaOH) by volume of the water with pH value of 12 was maintained. Cubes were immersed in the above solution for a period of 28 days. It was observed that the weight of specimens increased when kept in solution after 28 days curing.

Fig 2: Base tested specimen and normally cured specimen

7. CONCLUSIONS

1. The higher water absorption capacity of recycled aggregates has great influence on the water added to the mix, which can affect concretes workability

2. It is possible to gain the same compression and split tensile strength as conventional concrete up to 30% replacement of natural aggregate with recycled ones. But from the overall study, both the compression and split tensile strength values are decreasing with the increase in replacement levels of recycled aggregates

3. The increase of recycled aggregates content beyond 30% has negative effect on compressive strength of recycled aggregates concrete. The reduction in compressive strength after 28 days is about 10% when 50% recycled aggregates are used.

4. Split Tensile results also show down trend like compressive strength beyond 30% replacement of recycled aggregates.

5. The pores filling capacity of silica fume enhances the both mechanical and durability properties of recycled aggregates concrete. The use of silica fume as a partial replacement of cement decrease the water absorption of recycled aggregate concrete.

6. Ultrasonic pulse velocity (UPV) values are decreasing with the increasing in the recycled content in the mix. But the overall performance of RCA on UPV test is good, and it generally achieves an average of 4.5km/s.

7. From the initial surface absorption test (ISAT), the recycled aggregate concrete is absorbing more water in the initial stages. The increase in absorption capacity at 10 min after 56 days is about 35% from 0% to 50% replacement of RCA in the mix.

8. The capillary suction test (CSAT) test results clearly confirm that the recycled aggregate concrete is having high porosity and the absorption increases with increase in the recycled content in the mix. So, water absorption value is directly proportional to the level of the RCA replacement.

9. The concrete containing recycled aggregates was found to be low resistant against H2SO4 solution than the control concrete with 0% recycled aggregates. The maximum weight loss recorded was 5.35% by weight of cube.

10. Control specimens showed higher resistance to alkalinity attack than recycled aggregates specimens. But the overall performance of all the mixes against alkaline solution was good in terms of weight loss and strength loss.

8. REFERENCES

1. AASHTO M 307 ASTM C 1240. “Standard Specification for Silica Fume Used in Cementitious Mixtures”, American society for Testing and Materials, Annual Book of ASTM Standards, Volume04.02, West Conshohocken, Pennsylviania.

2. Ajdukiewicz, A., and Kliszczewicz, A. (2002). Influence of recycled aggregates on mechanical properties of HS / HPC, 24, 269–279.

3. Asamoah, M., and Afrifa, R. O. (2010). A study of concrete properties using phyllite as coarse aggregates. Materials and Design, 31(9), 4561–4566. .

4. ASTM standards C 1585-04 "Standard test method for measurement of rate of adsorption of water by hydraulic cement concretes", American society for Testing and Materials, Annual book of ASTM Standards, Volume04.02, West Conshohocken, Pennsylviania.

5. British Standard, BS 1881-208:1996 "Recommendations for the determination of the initial surface absorption of concrete", BSI 389 Chiswick High Road London W4 4AL

6. British Standard, BS 812 series, "Describes methods for determining the flakiness index of coarse aggregate", BSI 389 Chiswick High Road London W4 4AL

7. Binici, H., Shah, T., Aksogan, O., and Kaplan, H. (2008). Durability of concrete made with granite and marble, Materials Processing Technology, 8, 299–308.

8. Brito, J. De., Matias, D., Rosa, A., and Pedro, D. (2013). Mechanical properties of concrete produced with recycled coarse aggregates – Influence of the use of superplasticizers. Construction and Building Materials, 44, 101–109.

9. Butler, L., West, J. S., and Tighe, S. L. (2013). Effect of recycled concrete coarse aggregate from multiple sources on the hardened properties of concrete with equivalent compressive strength. Construction and building materials, 47, 1292– 1301.

10. Cabral, B., Eduardo, A., Schalch, V., Carpena, D., Dal, C., Luis, J., and Ribeiro, D. (2010). Mechanical properties modeling of recycled aggregate concrete. Construction and Building Materials, 24(4), 421–430.

11. Chen, H., Yen, T., and Chen, K. (2003). Use of building rubbles as recycled aggregates, Cement and Concrete Research, 33(May 2002), 125–132.

12. Corinaldesi, V., and Moriconi, G. (2009). Behaviour of cementitious mortars containing different kinds of recycled aggregate. Construction and Building Materials, 23(1)

13. Corinaldesi, V., and Moriconi, G. (2009). Influence of mineral additions on the performance of 100 % recycled aggregate concrete. Construction and Building Materials, 23(8), 2869–2876.

14. Corinaldesi, V. (2010). Mechanical and elastic behaviour of concretes made of recycled-concrete coarse aggregates. Construction and Building Materials, 24(9), 1616–1620.

15. Debieb, F., Courard, L., Kenai, S., and Degeimbre, R. (2010). Cement and Concrete Composites Mechanical and durability properties of concrete using contaminated recycled aggregates. Cement and Concrete Composites, 32(6), 421–426.

16. Evangelista, L., and Brito, J. De. (2007). Mechanical behaviour of concrete made with fine recycled concrete aggregates. Cement & Concrete Composites, 29, 397-401.

17. Evangelista, L., and Brito, J. De. (2010). Cement and Concrete Composites Durability performance of concrete made with fine recycled concrete aggregates. Cement and Concrete Composites, 32(1), 9–14.

18. Fonseca, N., Brito, J. De, and Evangelista, L. (2011). Cement and Concrete Composites The influence of curing conditions on the mechanical performance of concrete made with recycled concrete waste. Cement and Concrete Composites, 33(6), 637–643.

19. Ganjian, E., Khorami, M., and Akbar, A. (2009). Scrap-tyre-rubber replacement for aggregate and filler in concrete. Construction and Building Materials, 23(5), 1828–1836.