Performance Assessment of Recycled Aggregate Concrete

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***Abstract*— Sustainable construction is one of the important task to be achieved by the construction industry currently. This is due to the rapid growth resulting in the continued use of natural resources. Hence an alternative is to be found out which should also serve as a solution to reduce the waste generated from the demolition of buildings which on average is 300-600 kg per m^2. The transportation of these wastes increase in cost and causes acute shortage of land to be dumped. As a solution, recycling of aggregates from parent concrete serves in reducing the burden on disposal of wastes and preserving the natural resources. Hence an experimental investigation is undertaken to assess the properties of recycled aggregate concrete. M20 grade concrete is designed as per Indian standards without using superplasticizers. The concrete is designed by taking into account the properties of Natural aggregates for a slump of 75mm. The Natural aggregates are partially (about 20%) replaced by Recycled coarse and Fine Aggregates. Four mixes are considered in the study. Mix-1 represents the Control mix made of Natural aggregates. Mix-2 represents 20%replacement of Natural Coarse aggregate with recycled coarse aggregate, Mix-3 represents 20%replacement of Natural Fine aggregate with Recycled Fine aggregate and Mix-4 constitutes 20% both Recycled coarse and fine aggregate. The workability of Mix-2, Mix-3 and Mix-4 of concrete is improved by adding adequate amount of superplasticizer and conversely the hardened properties of concrete are also assessed. The durability tests such as acid and sulphate attack is carried out for Mix-4.**

After the experiments, Mix-4 and Mix-3 resulted in highest compressive strength and split tensile strengths respectively. A marginal decrease in compressive strength is noticed during durability tests. Hence there is a significant potential for recycled aggregate concrete as an appropriate and green solution for sustainable development in construction industry.

Keywords- Sustainable Construction; Recycled Aggregates; Durability

I. INTRODUCTION

According to the Building Material Promotion Council (BMPTC) India generates about 150 million tonnes of Construction and Demolition (C&D) waste annually, out of which India manages to recover and recycle only about 1% of it. There is no uniformity among cities to quantify and characterize C&D waste to know how and what to segregate. The source for such a waste may be increase in the population due to modernization, modification in the bye-laws, capacity of old road not being sufficient to accommodate the growing traffic and natural as well as man-made disaster.

Furthermore, there is an increased demand for construction materials in housing as well as road development sectors. Majority of the developing and developed nations assume that the C&D waste as non-hazardous, less toxic and inert materials which does not cause adverse effects to the environment. They are often dumped in land without any further treatment even though it leads to ill effects such as illegal dumping. Further, this creates an additional burden on landfill spaces and increase in the transportation cost for their disposal.

From the viewpoint of sustainable development, it is essential to prevent the over-use of natural resources and also make efforts towards waste reduction.

Hence recycling of aggregates from demolition waste may serve as a solution to reduce the problems of demand-supply problems, decrease the burden of dumping and also preserving the natural resources.

II. EXPERIMENTAL WORK

A. Problem Statement

The use of concrete waste as a source of aggregate for the production of new concrete has become more common in the recent decade. At optimum replacement of recycled aggregates (upto 30%) the hardened properties of concrete are quite satisfactory. However, the reduction in workability of concrete is noticed, even at 20% replacement of recycled aggregates. Hence the experimental study is undertaken to improve the workability of concrete using chemical admixture and thereby assessing the hardened properties.

B. Objectives:

- To ascertain the basic properties of Recycled Coarse Aggregate (RCA) and Recycled Fine Aggregate (RFA) recovered from the concrete waste.
- To enhance the workability of concrete with chemical admixture and thereby assessing its hardened properties for the mix containing 20% of Recycled Coarse Aggregate (RCA), 20% of Recycled Fine Aggregate (RFA) and 20% of both recycled coarse and fine Aggregate.
- To assess the durability characteristics such as Acid Attack and Sulphate attack of the concrete containing 20% of Recycled coarse and Fine Aggregate

C. Methodology:

Conventional materials such as cement, sand and natural coarse aggregate are purchased by the local vendors in the city. Whereas recycled concrete aggregates is produced by crushing the tested concrete specimens in the laboratory. The process of crushing of aggregates is done manually using hammer followed by separation of

aggregates using IS sieves. The Physical Properties of recycled aggregates as well as conventional aggregates are assessed as per Indian Standards.

The grade of the concrete is M20 and designed as per Indian Standards by considering the properties of conventional aggregates and without using super plasticizer for a slump of 75mm.Further 20% of recycled coarse and fine aggregates are replaced in the mix. The details of the Concrete Mixes used in the experimental study are given below:

- **Mix-1:** Concrete made of Conventional Materials or Natural Aggregates and designated as Control Mix(CM)
- **Mix-2:** Concrete with 20% of RCA, designated as **20RCA**
- **Mix-3:** Concrete with 20% of RFA, designated as **20RFA**
- **Mix-4:** Concrete with 20% of RCA and 20% of RFA and designated as **20RCFA**

Mixing of the concrete ingredients is carried out by using Electric Pan Mixer of 100 Liter Capacity in order to achieve cohesiveness and the compaction is done by using Vibrating table.

The workability properties of the concrete are assessed by conducting slump cone and compaction factor test. The compressive strength of the concrete is assessed at 3, 7 and 28 days, whereas the split tensile strength is carried out at 28days.

The durability properties of concrete Mix-4(20RCFA) is assessed by immersing the concrete cubes for 28 days in the acid solution comprising 3% of Concentrated H_2SO_4 and sulphate solution Comprising 3% of Na_2SO_4. After 28 days of soaking, the concrete specimen is tested for its density and Compressive strength.

D. Scope of the study:

The Experimental work deals recycling of concrete waste as coarse and fine aggregate in the production of M20 grade concrete. The replacement is restricted to 20% and the fresh properties of concrete is enhanced by adding super plasticizers (by Trial and Error Method) to attain required workability. The dosage of super plasticizers is determined by trial and error method to achieve a slump of 75-100mm for concrete mixes. The water cement ratio of the concrete is maintained constant i.e. 0.55 throughout experimental work.

The Acid and Sulphate attack tests are conducted to the Mix-4 comprising 20% of both recycled aggregates (RCA and RFA).

III. MIX DESIGN

M20 grade concrete is designed as per IS 12062:2009 by considering the properties of natural aggregates.

Two fractions of coarse aggregates are used in the Mix design:

- One fraction is passing 20mm and retained on 10mm IS sieve and proportion is 60% of total coarse aggregate content.
- Remaining 40 % of the aggregates are the fraction passing 10mm and retained 4.75mm IS sieve.

TABLE I: Mix proportions:

Sl no.	**w/c ratio**	**Slump (mm)**	**CF**	**7 day strength**	**28 day strength (N/mm^2)**	**Observation**
1	**0.55**	**78**	**0.923**	**24.14**	**42.06**	**Cohesive mix**

TABLE II: Quantities per m^3

Mix design-nation	Cement (kg)	Fine aggregates		Coarse aggregates		Dosage of super-plasticizers	
		NFA	RFA	NCA	RCA	In litres	In %
CM	350	699.26	-	1128	-	-	-
20 RFA	350	559.41	120.27	1128	-	2.8	0.8
20 RCA	350	699.26	699.26	902.4	201.46	2.8	0.8
20 RCFA	350	559.41	120.27	902.4	201.46	2.8	0.8

IV. TEST RESULTS AND DISCUSSIONS

The basic properties of the materials procured are tested as per IS requirements and they are tabulated as below:

TABLE III Basic tests on cement:

Sl.No	Tests	Results
1	Specific Gravity	3.08
2	Fineness (%)	5.94
3	Standard Consistency (%)	30
4	Initial Setting Time (min)	80
5	Final Setting Time (min)	210
6	28 Day Compressive Strength, N/mm^2	46.37

TABLE IV Basic Properties of Fine aggregates

Sl.No	Tests	NFA	RFA
1	Specific Gravity	2.61	2.26
2	Fineness Modulus	3.17	3.2
3	Bulk Density (kg/m^3)	1710.75	1417.46
4	Bulking (%)	26.4	37.50

TABLE V Basic properties of coarse aggregates

Sl.No	Tests	NCA	RCA
1	Specific Gravity	2.614	2.33
2	Water Absorption (%)	0.224	4.3
3	Crushing Value (%)	28.64	32.78
4	Impact Value (%)	21.78	23.32
5	Fineness Modulus	6.7	6.55
6	Bulk Density (kg/m^3) (20mm>10mm)	1498.62	1408.97
	Bulk Density(kg/m^3) (10mm>4.75mm)	1475.86	1339.31
7	Elongation Index (%) (20mm>16mm,10mm>6.3)	22.06	5.9
8	Flakiness Index (%) (20mm>16mm,10mm>6.3)	22	15.14
9	Angularity Number (20mm>16mm)	6.865	6.074
	Angularity Number (10mm>6.3)	4.01	5.342

E. FRESH AND HARDENED PROPERTIES OF CONCRETE

Slump test:

The results of slump tests are given in the table below and represented graphically in the below figure:

TABLE VI Slump test results

Mix Designation	Slump Value in mm	Dosage of Super Plasticizer in %
CM	78	0
20RFA	100	0.8
20RCA	115	0.8
20RCFA	108	0.8

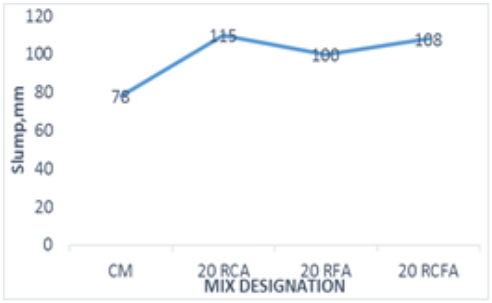

Figure-1: Slump Test

Compaction Factor test:

The results of compaction factor test are tabulated below and represented graphically as shown in the below figure:

TABLE VII Compaction factor test

Mix Designation	Compaction factor	Dosage of Super Plasticizer in %
CM	0.923	0
20RFA	0.902	0.8
20RCA	0.933	0.8
20RCFA	0.926	0.8

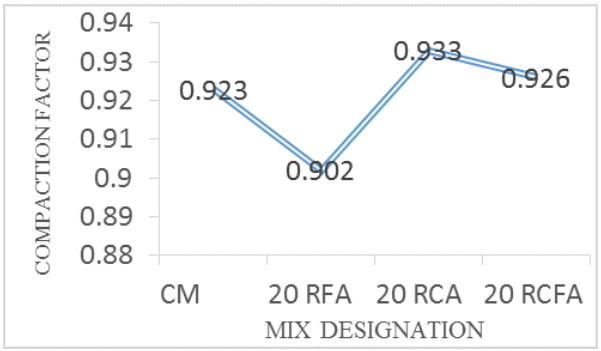

Figure-2: Compaction Factor

TABLE VIII Compressive Strength

Mix Designation	Compressive strength in N/mm^2		
	3-days	7-days	28-days
CM	15.2	24.14	42.06
20 RFA	18.105	37.62	55.52
20 RCA	16.23	35.99	58.37
20 RCFA	24.96	36.56	58.51

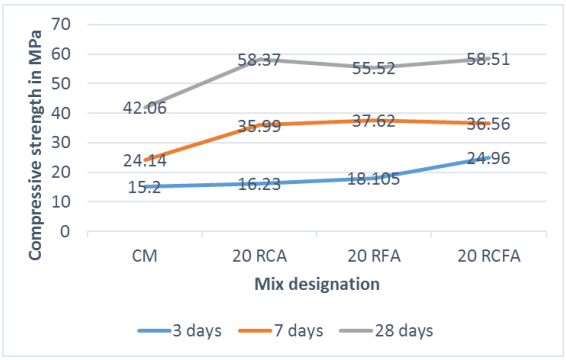

Figure-3: Compressive Strength Results

After compressive strength, it was observed that the mix 20RCFA showed highest compressive strength of 58.51N/mm^2. Also the mixes containing recycled aggregates showed higher strengths compared to control mix.

Split Tensile strength:

TABLE IX Split Tensile strength results

Mix	Density in kg/m^3	Split tensile
CM	2386.16	2.645
20 RFA	2418.86	3.499
20 RCA	2405.03	2.97
20 RCFA	2401.88	2.76

Figure-4: Split Tensile strength results

After split tensile strength, it was noticed that the mix 20RFA showed the highest value of 3.49N/mm^2. However, there is a marginal variation of the mixes with recycled aggregates compared to that of control mix.

F. DURABILITY*:*

Acid Attack:

- Acid attack is found out by immersing test specimens of size 150 X150 X 150 mm size cubes in 3% H_2SO_4 solution.
- The deterioration of specimens is represented in the form of percentage reduction in weight and percentage reduction in compressive strength concrete of specimens after 28 days.

TABLE X Acid attack results

Cube Designation	Weight before immersion in H_2SO_4 solution	pH	Weight before testing	Compressive strength in N/mm^2
20RCFA1	7.92	0.58	7.88	36.9
20 RCFA2	7.89		7.89	35.76
20RCFA3	8.06		8.05	34.56
20RCFA4	8.07		8.06	35.29

Sulphate Attack:

- Sulphate resistance of concrete is determined by immersing test specimens of size 150 X150 X 150 mm cubes in 3% sodium sulphate.
- The deterioration of specimens is represented in the form of percentage reduction in weight and percentage reduction in compressive strength concrete of specimens after 28 days of immersion.

TABLE XI Sulphate attack results

Cube Designation	Weight before immersion in Na_2SO_4 solution	pH	Weight before testing	Compressive strength in N/mm^2
20RCFA5	8.00	8.7	7.95	45.35
20RCFA6	7.98		7.92	45.98
20RCFA7	8.12		8.05	46.92
20RCFA8	8.05		7.98	46.46

After conducting acid attack test and sulphate attack tests, it was noted that there is a reduction in compressive strength of concrete with the replacement of 20% of both recycled coarse and fine aggregates.

V. CONCLUSIONS:

- By the addition of super plasticizer, the increase in compressive strength is recorded for the mix 2, 3 and 4 comprising recycled materials as compared to that of control mix.
- The maximum compressive strength of 58.51 MPa is obtained for the mix with 20% of RCA and RFA. The variation in strength between three mixes is quite marginal.
- A split tensile strength of 3.499 MPa for mix constituting 20% RFA, which is highest among four mixes.
- Decrease in compressive strength is observed during the durability test (3% acid and sulphate attack).
- There is a predominant potential for growth of recycled aggregate as a significant and green alternative for sustainable development in construction industry.

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