International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Experimental Study of Use of Partially Processed Recycled Coarse Aggregates in Concrete Production

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Abstract: ***Recycling is the act of processing the used material for use in creating new products. The use of recycled product is increasing with modernization in present scenario. The use of recycled aggregates in concrete can also be useful for environmental protection. Recycled aggregates are the materials of the future. The consumption of waste products in the manufacturing of new product is a challenging job. The natural resources will deplete in a short period and therefore the use of waste product is essential. There are a large number of old buildings and structures which needs demolition today. The reuse of that demolished waste is a good solution to deal with the difficulty of an excess of waste material. Aggregates play an important role in strength characteristic of concrete. This paper focuses on the possibility of use of recycled coarse aggregate in concrete as a new structural material. For that purpose a literature survey for use of recycled aggregate concrete is done. Recycled coarse aggregate (RCA) is obtained from demolished concrete rubble and different demolished work. The aim of this project is to determine the strength characteristic of recycled aggregate concrete using recycled coarse aggregate concrete by using different percentage of recycled aggregates in M25 Grade.***

Keywords: Recycle coarse aggregate, Recycled coarse aggregate concrete, compressive strength, workability

1. Introduction

During the last few decades, the recycling of waste product has become important to produce new products suitable for the sustainable environment. The demand for new construction is growing with the rise in population that is why the infrastructure industry became second largest segment after agriculture in India.

The use of demolition and concrete waste aggregates in concrete is being tried over a few years. But due to the concern over its strength from structural point of view, it is not largely accepted as a structural material, hence RCA concrete is being used for less important works. The management of construction and demolition waste is a major concern due to increasing quantities of demolition waste[1]. The continuing shortage of dumping sites, increases the cost of dumping and shipping, and above all the concern about environmental degradation. The global construction industries are using billions tons of cement and billions tons of sand, gravel, and crushed rock every year. A considerable percentage of raw material can be replaced by demolition waste.

Considering from the environmental point of view, the production of 1 ton of natural aggregate is associate with emissions of 0.0046 million tons of carbon where as for 1 ton recycled aggregate produces only 0.0024 million tons carbon. Considering the global use of 10 billion tons/year of aggregate for concrete production, the carbon footprint can be determined from the natural aggregate as well as for the recycled aggregate[7]. The reduction of the existing landfills and the lack of natural resources for aggregates encourage the use of construction and demolition (C&D) waste as a source of aggregates in the production of concrete.It is well known that the strength of concrete depends on quality, shape and size of aggregates used in concrete.

This study aims to envisage the use of recycled aggregate in cement concrete, which consists of various percentages of recycled aggregate. Control mix, used as a reference while other samples contain different ratios of recycled aggregate in cement concrete. Decision analysis reveals that the characteristics of aggregates used are different than normal aggregate. The control mixture shows better results compared with mixes containing recycled aggregate for the same quantity of cement. Work shows that the results are encouraging to use concrete with RCA.

2. Experimental Work

The experimental study was divided into four major segments viz-
1) Materials and their testing.
2) Concrete mix design.
3) Checking the fresh properties of the mixes for M25 grade.
4) Tests on hardened concrete specimens: Compressive Strength Test.

3. Experimental Materials

3.1 Cement

The Ordinary Portland Cement of 43 grades conforming to IS: 8112-1989 is used in the work. Following tests was conducted on cement; which are consistency tests,setting time tests and compressive strength (28 days).

Table 1: Properties of Ordinary Portland Cement 43 Grade

Sr. No	*Physical Properties of OPC 43Cement*	*Results*	*Requirements As per IS:8112-1989*
1	Specific Gravity	3.12	3.10-3.15
2	Standard Consistency (%)	31.5	30-35
3	Initial Setting Time (min)	42	30 minimum
4	Final Setting Time (min)	385	600 maximum
5	Compressive Strength (At 28 days in N/mm2)	43	43 N/mm^2 Minimum

3.2 Aggregate

Aggregate is one of the main constituent in concrete. The strength of the concrete, mainly depends on the properties of aggregates used. The construction industry is increasingly posing a higher demand of fresh coarse aggregate. The use of recycled aggregates needs to be accommodated in production of cement concrete with appropriate change in design philosophy. Recycled aggregates comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition wreckage. These materials are generally from buildings, roads, bridges, and sometimes even from catastrophes, such as wars and earthquakes.

Recycled coarse aggregate were obtained by crushing the aheady tested concrete cubes received in the concrete laboratory from various departments for testing. Loosely attached cement mortar with the recycled aggregates is removed by attrition action by putting these aggregate in Los-angeles abrasion testing machine. The machine is run at 25–30 rpm for two minutes and the aggregates are sieved by 4.75mm sieve. Coarse aggregates of requisite size are obtained by use of appropriate sieve. It is observed that about 80%–90% attached mortar is removed from recycled aggregates and corners & edges of aggregates gets worn out. Recycled aggregate are likely to absorb more water, but due to worn out corners the decrease in workability is likely to get compensated.

The fraction above 4.75 mm is called as coarse aggregate. The natural coarse aggregates are obtained from the crushed basalt/trap and similar rocks. Following properties of coarse aggregates needs to be evaluated before making use in concrete.

Figure 1: Recycle Aggregate and Natural Aggregate

Table 2: Properties of Natural & Recycled Aggregates

Property	*Natural Coarse Aggregate*	*Recycle Coarse Aggregate*
Specific Gravity	2.7	2.7
Water absorption (%)(20 mm)	0.08	0.76
Water absorption (%) (10 mm)	0.10	1.373

3.3 Fine aggregate

The fractions from 4.75 mm to 150 microns are termed as fine aggregate. The river sand is used as fine aggregate in this work. The properties of which are as follows-

Table 3: Properties Of Fine Aggregate

Property	*Value*
Fineness modulus	3.41
Specific Gravity	2.63
Water absorption (%)	0.78%
Zone	1

3.4 Water

Water used should be clean. The quantity and quality of water are required to be looked into very carefully. Tube well water of MITS is used for thesis work. Following are the properties of water-

Table 4: Properties of Water

Property	*Value*	*Requirements As per IS:456-2000*
pH	7.3	6.5-8.5
TS	810 mg/l	2000 mg/l
DS	800 mg/l	2000 mg/l
Acidity (Volume of N/50 NaOH required to neutralize 100ml of water sample using phenolphthalein indicator)	0.8 ml	< 5 ml
Alkalinity (Volume of N/50 H_2SO_4 required to neutralize 100ml of water sample using methyl orange indicator)	7.2 ml	< 25 ml

4. Design Mix Methodology

A mix M25 grade was designed as per IS: 10262-1982 and the same was used to prepare the test samples containing different percentages of RCA. The design mix proportion is shown in Table 5.

Table 5: Concrete Design Mix Proportions
(Slump value = 60mm-75mm)

	Water	*Cement*	*Fine Aggregate*	*Coarse Aggregate*
By Weight, [Kg]	196.68	381.64	710.33	1184.35

The mix proportion was arrived at as 1:1.565:3.106, (cement: FA: CA) with 0.515 as the water –cement ratio. A control concrete mix was prepared with the above proportion using conventional ingredients such as natural coarse aggregate and natural fine aggregate. Other concrete mixes were prepared with 30%, 40%, 50%, 60%, 70%, 80% and 100% replacement of natural aggregate by recycled aggregate, Admixtures are not used in this work. The cube samples were cast in the mould of size (150×150×150) mm. These test specimens were cured in water until the age of testing. The compressive strength consided as the average reading of three cubes that was determined at 7 days & 28 days. After this period compressive test was done. The different percentages of RCA in concrete mixes are shown in table 6.

Table 6: Details of M25 Grade Concrete with Different Percentage of RCA

Mix	*Water (in Kg)*	*Cement (in Kg)*	*Fine Aggregate (in Kg)*	*Combined Coarse Aggregate (in Kg)*	*Combined Recycle Aggregate (in Kg)*
CTRL	4.866	9.448	16.565	32.845	-
S1 (30%)	4.866	9.448	16.565	22.991	9.853
S2 (40%)	4.866	9.448	16.565	19.707	13.138
S3 (50%)	4.866	9.448	16.565	16.422	16.422
S4 (60%)	4.866	9.448	16.565	13.138	19.707
S5 (70%)	4.866	9.448	16.565	9.853	22.991
S6 (80%)	4.866	9.448	16.565	6.569	26.276
S7 (100%)	4.866	9.448	16.565	-	32.845

5. Experimental Results

5.1 Slump test

The slump test is a method of assessing the consistency of fresh concrete. It is used, indirectly, as a means of checking that the correct amount of water has been added to the mix. The slump value of above referred different concrete mixes are shown in table 7.

Table 7: Slump Value For M25 Grade Mix

Mix	*Slump Value (mm)*
CTRL	75
S1	70
S2	66
S3	66
S4	62
S5	60
S6	59*
S7	54*

*w/c ratio is adjusted latter on by trials to get slump value (60mm-75mm)

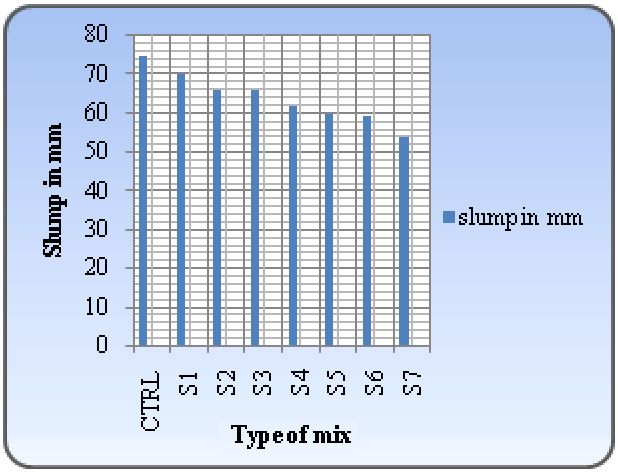

Figure 2: Mix containing various %of RCA v/s slump value

The mix S6 and S7 does not give the desirable slump value, theirfore w/c ratio is adjusted by trials to get the desired range of slump. The following table 8 shows the revised mix design of S6 and S7 mixes (containing modified quantity of water and accordingly quantity of cement).

Table 8: Revised Design of S6 And S7 Mixed

Mix	*Water (in Kg)or ratio*	*Cement (in Kg)*	*Fine Agg. (in Kg)*	*Combined Coarse Aggregate (in Kg)*	*Combined Recycle Aggregate (in Kg)*	*Slump (in mm)*
S6	5.216 (0.552)	9.449	15.864	6.531	26.125	65
S7	5.216 (0.552)	9.449	15.864	-	32.657	63

5.2 Compressive Strength

Compressive strength tests were done on compression testing machine as per IS: 516-1959. Three samples per batch were tested with the average strength values. The results are shown in table-9.

Table 9: Compressive Strength Of Cubes At 7 Days And 28 Days

Sr. No.	*Mix*	*Average Compressive Strength in N/mm²*	
		7 Days	*28 Days*
1	CTRL	21.62	31.80
2	S1	21.33	29.72
3	S2	21.29	27.96
4	S3	20.33	26.88
5	S4	20.62	26.51
6	S5	20.48	26.41
7	S6*	19.62	25.75
8	S7*	18.66	24.20

**Revised mix design*

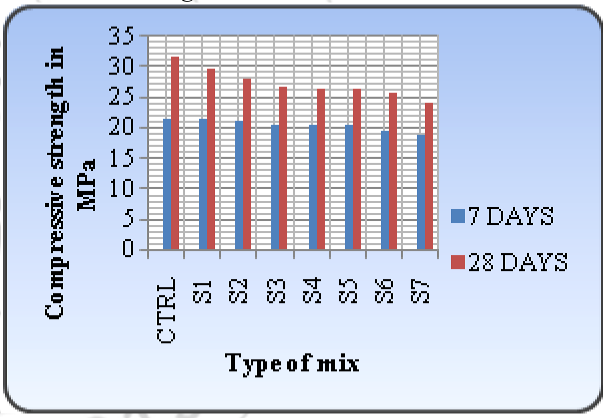

Figure 3: Different types of mix v/s compressive strength

It is observed that as the quantity of recycled aggregate is increased there is a decrease in the strength of the cubes. The target mean strength of M 25 grade concrete is 31.6 MPa, to achieve this strength only S1, S4 and S7 mixes are tried due to a limited scope of work. The mix proportions of these mixes are revised up to three trials. The trials of S1 grade are shown in table 10.

Table 10: Mix Proportion of S1 Grade Concrete Cubes

Mix	*Water (in Kg)*	*Cement (in Kg)*	*Fine Agg. (in Kg)*	*Combined Coarse Aggregate (in Kg)*	*Combined Recycle Aggregate (in Kg)*	*Slump (in mm)*
CTRL	4.866	9.448	16.565	22.991	9.853	70
S1 (30%)	5.072 (1st trial)	9.848	15.04	22.76	9.754	71
	5.174 (2nd trial)	10.048	14.81	22.473	9.631	75
	5.277 (3rd trial)	10.248	14.739	22.291	9.553	81

The compressive strength test results of S1 grade concrete cubes after 7 days and 28 days is shown in table 11.

Table 11: Compressive Strength of S1 Grade Concrete Cubes at 7 Days and 28 Days

Mix	*Average Compressive Strength in N/mm²*	
	7 Days	*28 Days*
CTRL	21.62	31.80
S1 (1st trial)	21.48	31.6
S1 (2nd trial)	22.62	32.72
S1 (3rd trial)	22.86	34.20

The above results (table 11) of revised mix design of S1 mix shows that increase in the quantity of cement, the strength also increases. And target mean strength of M 25 grade concrete is 31.6 N/mm^2 which is likely same in 1st trial. Hence, the 1st trial mix is proposed for 30% replacement of natural coarse aggregate. The trials of S4 grade are shown in table 12.

Table 12: Mix Proportion of S4 Grade Concrete Cubes

Mix	*Water (in Kg)*	*Cement (in Kg)*	*Fine Agg. (in Kg)*	*Combined Coarse Aggregate (in Kg)*	*Combined Recycle Aggregate (in Kg)*	*Slump (in mm)*
CTRL	4.866	9.448	16.565	13.138	19.707	62
S4 (60%)	5.127 (1st trial)	10.048	14.81	12.841	19.262	68
	5.277 (2nd trial)	10.248	14.739	12.737	19.106	72
	5.380 (3rd trial)	10.448	14.58	12.658	18.987	80

The compressive strength test results of S4 grade concrete cubes after 7 days and 28 days is shown in table 13.

Table 13: Compressive Strength of S4 Grade Concrete Cubes at 7 Days and 28 Days

Mix	*Average Compressive Strength in N/mm²*	
	7 Days	*28 Days*
CTRL	21.62	31.80
S4 (1st trial)	20.17	30.96
S4 (2nd trial)	21.66	32.0
S4 (3rd trial)	23.41	33.20

The above results (table 13) of revised mix design of S4 mix shows that increase in the quantity of cement, the strength also increases. And target mean strength of M 25 grade concrete is 31.6 N/mm^2 which is likely same in 2nd trial. Hence, the 2nd trial mix is proposed for 60% replacement of natural coarse aggregate. The trials of S7 grade are shown in table 14.

Table 14: Mix Proportion of S7 Grade Concrete Cubes

Mix	*Water (in Kg)*	*Cement (in Kg)*	*Fine Agg. (in Kg)*	*Combined Coarse Aggregate (in Kg)*	*Combined Recycle Aggregate (in Kg)*	*Slump (in mm)*
CTRL	5.216	9.449	15.864	-	32.657	63
S7 (100%)	5.656 (1st trial)	10.248	14.395	-	31.833	68
	5.877 (2nd trial)	10.648	14.078	-	31.584	76
	5.988 (3rd trial)	10.848	13.919	-	30.964	86

The compressive strength test results of S7 grade concrete cubes after 7 days and 28 days is shown in table 15.

Table 15: Compressive Strength Of S7 Grade Concrete Cubes at 7 Days And 28 Days

Mix	*Average Compressive Strength in N/mm²*	
	7 Days	*28 Days*
CTRL	21.62	31.80
S7 (1st trial)	19.17	29.76
S7 (2nd trial)	21.66	31.96
S7 (3rd trial)	22.91	35.48

The above results (table 15) of revised mix design of S7 mix shows that increase in the quantity of cement, the strength also increases. And target mean strength of M 25 grade concrete is 31.6 N/mm^2 which is likely same in 2nd trial. Hence, the 2nd trial mix is proposed for 100% replacement of natural coarse aggregate.

As per the above trials considered for S1, S4 and S7 mixes , the correspondence mix proportions for 1 m^3 concrete is shown in table 16.

Table 16: Mix Proportion for 1 M^3 Concrete

Mix	*Water (in Kg)*	*Cement (in Kg)*	*Fine Agg. (in Kg)*	*Combined Coarse Aggregate (in Kg)*	*Combined Recycle Aggregate (in Kg)*
S1	200.36	389.05	594.19	819.88	351.38
S4	208.02	403.94	582.28	457.90	686.85
S7	216.63	420.66	556.16	-	1134.53

6. Cost Analysis

Cost analysis is performed for 100 m^3 of concrete according to table 17. The rate of materials is taken as our locality (Gwalior) after detailed survey.

The cost of components are taken as-
Cement - Rs 300/- per bag (50 Kg)
FA - Rs 1140/- per m^3
CA (Natural aggregate taking 30 KM haulage)
- Rs 1848/- per m^3
CA (Recycled aggregate taking 15 KM haulage)
- Rs 630/- per m^3

Table 17: Cost Analysis For 100 M^3 Concrete

Mix	*Material*	*100m3(Kg)*	*Rate(in Rs.)*	*Total (in Rs.)*
CTRL	Cement	38164 (764bag)	229200	341065
	Sand	71033	30790	
	Aggregate	118435	81075	
30%	Cement	38905 (778bag)	233400	321105
	Sand	59419	25755	
	Aggregate	117127	61950	
60%	Cement	40394 (807bag)	242100	313413
	Sand	58228	25240	
	Aggregate	114476	46073	
100%	Cement	42066 (842bag)	252600	300637
	Sand	55616	24107	
	Aggregate	113453	23930	

Saving in cost of 100 m^3 concrete using RCA is shown in table 18.

Table 18: Saving Results

Mix	*Percentage Saving*
30 %	5.85 %
60 %	8.10 %
100 %	11.85 %

7. Conclusion

The following conclusions were made for M25 grade concrete:-

1) The strength of recycled aggregate concrete specimens gradually decreases up to 100% replacement of natural aggregate by RCA using same amount of water and cement as used in controlled concrete.
2) Slump value of RCA concrete decreases with increase in percent replacement of natural aggregate by recycled aggregate using the same quantity of water and cement as used in controlled concrete.
3) When the quantity of the cement in RCA is increased, appropriately the strength of the concrete also increases.
4) Cost saving is up to 11.85 %. It is expected that the enhanced cost due to use of extra cement could be set off by the low price of recycled concrete aggregate (RCA) used in place of costly fresh natural aggregate.
5) Save environment: Use of recycled aggregate will reduce carbon emission and may prove more beneficial where stone quarries are located remote.
6) Referable to the role of recycled aggregate in construction industry, cost of conveyance and disposal of C&D waste will get significantly reduced. This in turn will directly reduce the impact of waste material on the environment also.
7) For use of recycled aggregate in concrete, there is need to develop some IS code provisions so that concrete mix design can be done with the least number of trials and more accurately.

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