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Experimental Studies on Concrete by Using Recycled Coarse Aggregates

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***Abstract*— In the present work, The strength of the concrete produced is dependent on the properties of aggregates used. Recycled waste concrete from demolition of reinforced concrete buildings, which is in the form of recycled concrete aggregate (RCA). It covers 70% strength of the total for any concrete mix. In the present work carried out using detailed strength and durability. Replacing the coarse aggregates in high strength concrete mixes by 0, 15, 25, 35 & 45% of recycled coarse aggregates for the different w/c ratio. In work a combination of technical, economic and environmental parameters and inter-dependencies between these need to be considered when optimizing the use of RCA. The research evaluates the cost-benefit of replacing NA with RCA in structural concrete considering the above parameters.**

***Keywords*—Recycled Coarse Aggregate, Demolition wastes material concrete**

I. INTRODUCTION

The utilization of recycled aggregate is particularly very promising as 70 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 aggregates. The investigation was carried out using workability test, compressive test, indirect tensile test and modulus of elasticity test. There were total of ten batches of concrete mixes, consists of every 10%-15% increment of recycled aggregate replacement from 0% to 45%.The water/cement ratio of 0.35 and 0.45. Recently the use of recycled concrete as a structural fill material, in lieu of natural aggregate, has recently been increasing. In some regions, recycled concrete aggregate may cost 20 % to 30 % less than natural aggregate

Objectives of the Study- The first and main scope of this study is to save natural aggregates. For reaching this aim, environmental management plays an important role in protecting natural resources. First, concrete should be crushed in several nominal sizes. Second, the crushed concrete will be used as aggregates in recycled concrete.

II. EXPERIMENTAL PROGRAM

2.1 Material Characterisation

2.1.1 Cement

Ordinary Portland cement (OPC) 43 grade conforming IS-8112-1989 was used. Cement is tested as per IS codes and results are as follows:-

Table 1:
Physical properties of Portland cement

Sr. No.	Characteristics	Values obtained	Standard values
1	Normal Consistency	29.5%	-
2	Initial setting time	1 hours 35 min	Not to be less than 30 minutes
3	Final Setting time	3 hours 40 min	Not to be greater than 600 minutes
4	Fineness	2.5%	4 <10%
5	Specific gravity	3.38	-

2.1.2 Aggregates

(A) Coarse aggregates (20 mm and 10mm size) from local quarry (Kakani) have been used.

Table 2
Gradation of natural coarse aggregate

Sieve size (mm)	% passing Required [IS383:1970]	Weight retained (kg)	Cumulative % weight	Retained %passing For NA
20	100	0	0	100
12.5	90-100	1.040	12.40	87.6
10	40-85	3.50	47.4	52.6
4.75	0-10	4.77	95.1	4.9

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(B) For Recycled Aggregate

Table 3:
Gradation of recycled coarse aggregate

Sieve size (mm)	% passing Required [IS383:1970]	Weight retained (kg)	Cumulative % weight	Retained %passing For RCA
20	100	0	0	100
12.5	90-100	1.040	12.40	85.7
10	40-85	3.50	47.4	58.3
4.75	0-10	4.77	95.1	3.5

(C) Physical properties of the recycled and natural course aggregate

Table 3:
Gradation of recycled coarse aggregate

Properties	Natural Aggregate	Recycled Coarse Aggregate
Specific gravity	2.34	2.6
Water absorption (%)	1.6	2.4
Fineness modulus (%)	6.7	7.1

(D) Fine aggregates from local river (Binawas) have been used

Table 5:
Sieve Analysis of fine aggregates

S. No.	Sieve No. Weight	Weight Retained (gms)	Percentage Retained%	Percentage Passing %	Cumulative % Retained
1	4.75 mm	95	9.5	90.5	9.5
2	2.36mm	42.5	4.25	86.25	13.75
3	1.18mm	110.5	11.05	75.2	24.8
4	0.600mm	128.5	12.85	62.35	37.65
5	0.300mm	308.0	30.8	31.55	68.45
6	0.150mm	281.0	28.1	3.45	96.55
7	PAN	34.5	3.45	-	-
				ΣF=	250.5

Fineness Modulus of fine aggregate = ΣF/100 = 250.5/100=2.50

(E) Physical properties of fine aggregate.

Table 6:
Physical properties of fine aggregate

S. No.	Characteristics	Value
1	Type	Natural Sand
2	Specific Gravity	2.65
3	Fineness Modulus	2.505
4	Grading Zone	III

(F) Properties and Characteristics of Recycled Coarse Aggregate-

A concrete pavement's strength and performance is very dependent on the aggregates used to produce the concrete. Recycled concrete aggregates are different in many ways from virgin aggregates as shown in Table 7.

Table 7:
Property of Virgin Aggregate and Recycled Aggregate

Property	Virgin Aggregate	Recycled Coarse Aggregates
Shape and Texture	Well rounded, smooth (gravels) to angular and rough (crushed rock).	Angular with rough surface.
Absorption Capacity	0.8 – 3.7 percent	3.7 – 8.7 percent
Specific Gravity	2.4 – 2.9	2.1 – 2.4
L. A. Abrasion Test Mass Loss	15 – 30 percent	20 – 45 percent
Sodium Sulphate Soundness Test Mass Loss	7 – 21 percent	18 – 59 percent
Magnesium Sulphate Soundness Mass Loss	4 – 7 percent	1 – 9 percent
Chloride Content	0 – 1.2 kg/m3	0.6 – 7.1 kg/m3

(G) Super plasticizer-

SikaVisco Crete -SC 001, the super plasticizer supplied by Sika India Pvt. Limited is used in our investigations-

Table 8
Technical data of Super plasticizer

S. No.	Characteristic	Value
1	Colour	Dark brown Liquid
2	Specific gravity	1.17
3	Air Entrainment	Maximum 1%
4	Ph	7 to 8

(H) Chemical Admixtures- The use of super plasticizer generally reduces the amount of water required by 15%-40%. Super plasticizers are usually chemical compounds such as Sulphonated Melamine Formaldehyde (SMF), Sulphonated Naphthalene Formaldehyde (SNF), and Modified lingo sulshonates. SMF and SNF based admixtures are the most commonly used. They work by helping to disperse particles of cement when mixing water is added, which causes the cement paste to behave more like a fluid.

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This deflocculation of cement particles plasticizer the paste to such a degree that these compounds are dubbed as "Super plasticizers".

2.2 Development Of Concrete Mixes

After getting results mix was designed as per IS 10262-2009 to achieve M-35 grade of concrete.

Table 9:
Concrete ingredients

Cement	340 kg/m^3	1
Water	153 kg/m^3	0.45
Fine aggregates	714 kg/m^3	2.1
Coarse aggregates	1241kg/m^3	3.65

In this project IS Method of Design shall be used.

Table 10:
Initial data for mix design

Target strength (MPa)	35
Water/cement ratio	0.45/0.35
Aggregate / cement ratio	3.65
Weight of cement per bag (kg)	50

Trial mix was conducted to achieve the target strength. For 0.45w/c ratio and 0.35w/c ratio.

Table 10:
Percentage of aggregate used in all 5 batches of mixes.

Mix Batch	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5
Natural Aggregate (%)	100	85	75	65	55
Recycled Aggregate (%)	0	15	25	35	45

Table 11 :
Proportion and Weight of Each Mix Material by Weight

Trial Mix	Cement Kg/m3	Water Kg/m3	Sand Kg/m3	Coarse Aggregates Kg/m3
1	340	153	714	1241
2	344	155	722	1256
3	348	157	731	1270
4	350	158	735	1278

2.3 Casting Of Cubes

All required raw materials were populated at laboratory. Moulds for cube of 150mmx150mmx150mm were made with the help of recycled coarse aggregate. Burnt oil was applied on sides of moulds for easy de-molding of cubes. Electrically operated mixer as per IS 1791:1968 and vibrator as per IS 2505:1980 were used for casting.

2.4 Curing

Each set of cubes were demoulded after 24 hrs. of casting and placed in water curing tank for 7 & 28 days. Curing of concrete was at laboratory temperature. Cubes were taken out and kept in laboratory after 7 & 28 days curing period.

2.5 Testing Of Specimens

After 7 & 28 days compressive strength was determined.

Figure-1 (Compressive Strength Test) (moulds for cubes)

III. RESULTS

3.1 Interpretation of Test Results

3.1.1 Slump Test Result and Analysis

The slump test results shows decreasing workability when the percentage of recycled aggregate increased. Below shows the average slump value in the table no 12 & graph 1 during the test.

Table No 12:
Slump test result with respect to the water cement ratio

Percentage of Recycled Aggregate (%)	Slump (mm) 0.45w/c	Slump (mm) 0.35w/c
0% recycled aggregate	92	76
15% recycled aggregate	90	75
25% recycled aggregate	87	72
35% recycled aggregate	85	71
45% recycled aggregate	83	70

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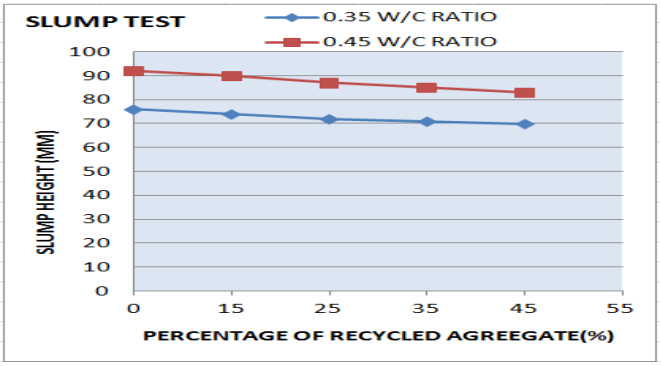


Graph 1: Showing the Result of Slump Test

According to the results-(0.45w/c ratio)
The highest slump= 92mm
The lowest slump= 83mm
The average slump= 87.4mm
According to the results-(0.35w/c ratio)
The highest slump= 76mm
The lowest slump= 70mm
The average slump= 72.8mm

The target slump is in the range from 50mm to 100mm. The workability was good for 0% recycled aggregate to 45% recycled aggregate. The slump from 0% recycled aggregate to 45% recycled aggregate were considered moderate due to the drop in the range of 5mm to 10mm.

3.1.2 Compression Test Result and Analysis

The compression test results are increasing trend of compressive strength. It shows that the strength of recycled aggregate specimens is lower than natural aggregate specimens. The Figure 2 below shows a graphical results in variation of compressive strength.

The target strength= 35MPa (0%- RCA)

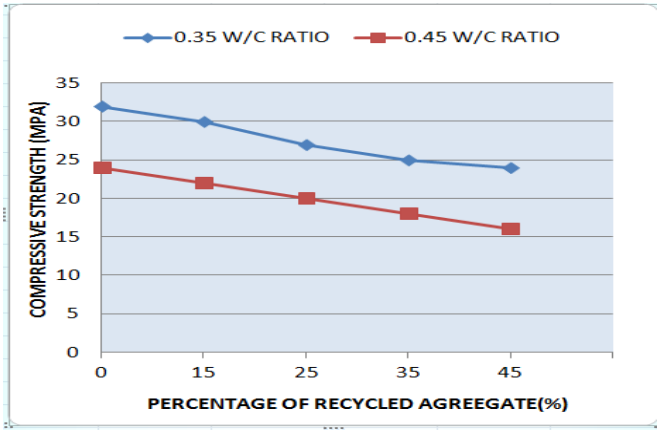
The results shows that the compressive strength of the concrete specimens for 45% of RCA with 0.45 w/c ratio is 36MPa & with 0.35 w/c ratio is 37MPa.The strength is reduced by water cement ratio increasing & strength is increase by reducing water cement ratio. The maximum replacement in between 30-35% of RCA with reduced w/c ratio the target strength will achieved.

Table 13 –
7th Day Compressive Test Result

Percentage Of Recycled Aggregate (%)	7 Day Compressive Strength (MPa) (0.45 w/c)	7 Day Compressive Strength (MPa) (0.35 w/c)
0%	24	32
15%	22	30
25%	20	27
35%	18	25
45%	16	23

Table 14 –
28th Day Compressive Test Result

Percentage Of Recycled Aggregate (%)	28 Day Compressive Strength (MPa) (0.45 w/c)	28 Day Compressive Strength (MPa) (0.35 w/c)
0%	36	37
15%	33	36
25%	29	35
35%	26	33
45%	23	31



Graph 2: Variation of compressive strength after 7 days

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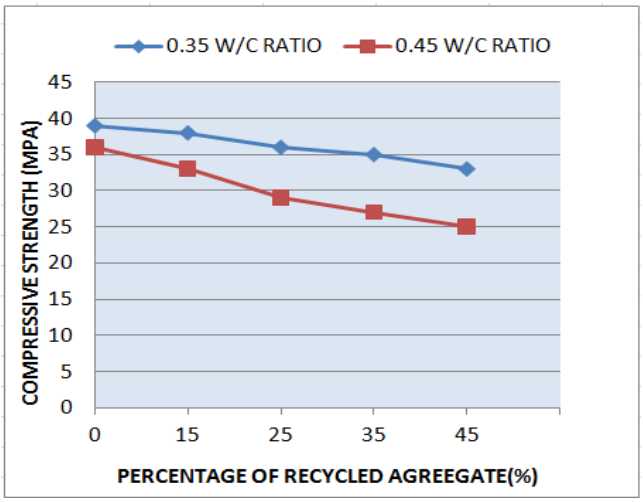


Graph 3: Variation of compressive strength after 28 days

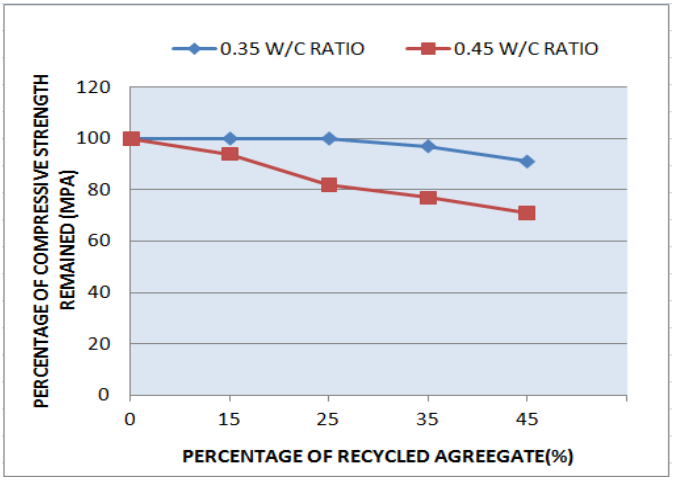
In Figure 4 shows that when the percentage of RCA is increased then the percentage of compressive strength remained. The strength is based on 28 day strength .The compressive strength of 0% recycled aggregate was taken as the 100% compressive strength.

The batch of 45% RCA has minimum compressive strength remained and that is 71% and it is drop of 29% with compare to natural aggregate mix design (0% Replacement). After the decrement of 77% water-cement ratio the compressive strength is increase and the drop strength is reduced.

From the obtained result, it is possible that the use of 30-35% RCA for 0.35w/c ratio the target strength of the concrete mix design.

Table 15 –
Percentage of Compressive Strength Remaind Test Result

Percentage Of Recycled Aggregate	Remained Of Compressive Strength (0.45w/c)	Dropped Of Compressive Strength	Remained Of Compressive Strength (0.35w/c)	Dropped Of Compressive Strength
0%	100%	0%	100%	0%
15%	94%	6%	100%	0%
25%	82%	18%	100%	0%
35%	77%	23%	95%	5%
45%	71%	29%	89%	11%



Graph 4: Showing percentage of Compressive Strength remained

3.1.3 Acid Resistance Test

The results are tabulated in Table 16

Process- 45 days in 3% sulphuric acid and find out the loss of weight of concrete cubes and find results that for low water cement ratio (0.35w/c) the loss is less.

Table 16 –
Reductions in Compressive Strength Based On Acid Resistance Test

Percentage Replaced (0.45w/c)	28 day Compressive Strength (MPa)	Percentage Reduction in weight	Compressive Strength (MPa)	Percentage Reduction in compressive strength compared to 28 day strength
0	36	0.48	33.3	7.5
15	33	0.52	30.1	8.78
25	29	0.57	26.2	10.27
35	26	0.61	22.9	11.92
45	23	0.64	26.0	13.04
Percentage Replaced (0.35w/c)	**28 day Compressive Strength (MPa)**	**Percentage Reduction in weight**	**Compressive Strength (MPa)**	**Percentage Reduction in compressive strength compared to 28 day strength**
0	37	0.42	34.7	6.21
15	36	0.45	33.2	7.78
25	35	0.49	32.1	8.28
35	33	0.55	29.6	10.30
45	31	0.61	27.5	11.29

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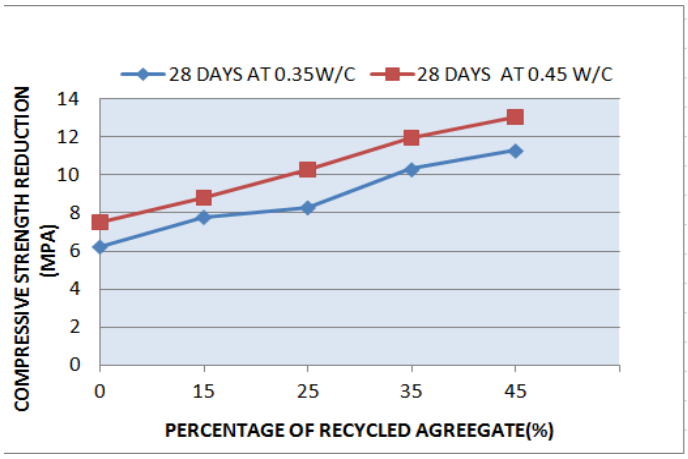


Graph 5: - 28th Day Comparison b/w Normal and Acid Compressive Test Result (0.40w/c ratio)

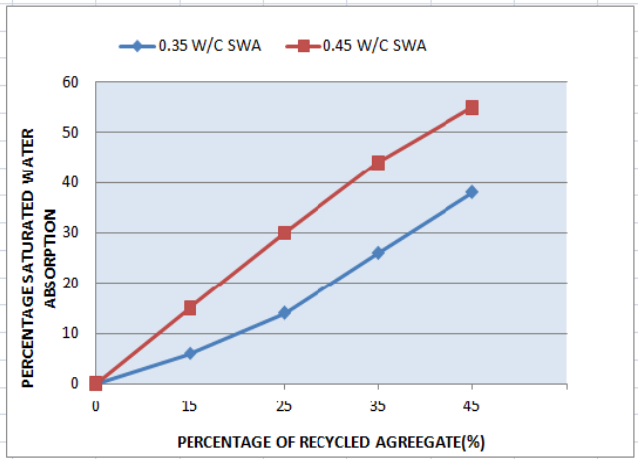
The figure 5 shows that the decrement of the strength after 28th days is linear with the recycled aggregate percentage. This is for the 0.45 w/c ratio for normal test and acid test for the specimen. The figure 5 shows that the 0% to 45% recycled aggregate strength decrement for 0.45 w/c ratio. But when the w/c ratio reduces the strength of specimen is increase for 45% of recycled aggregate. The change of variation show in figure 5 for 45% recycled aggregate in different w/c ratio. That is the effect of acid in the 45 days in compressive strength result.

3.1.4 Tests for Saturated Water Absorption and Porosity

The results of water absorption tests & porosity are tabulated in Table 17 & 18. From the table results the water absorption is increase for the increment of RCA. For the lower w/c ratio the saturated water absorption is decrease.

Table 17
Test For Saturated Water Absorption

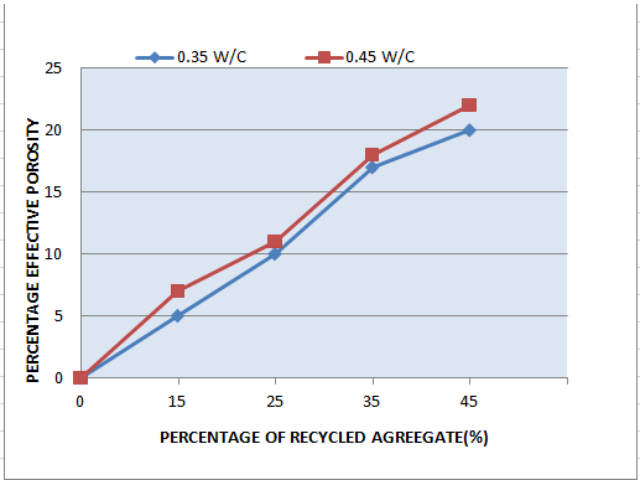
Percentage Replaced	Saturated Water Absorption (0.45w/c)	Percentage Increase in Saturated Water Absorption	Saturated Water Absorption (0.35w/c)	Percentage Increase in Saturated Water Absorption
0	1.15	0	1.04	0
15	1.33	15	1.10	6
25	1.50	30	1.19	14
35	1.66	44	1.31	26
45	1.79	55	1.44	38



Graph 6: –Saturated Water Absorption Test Result

Table 18
Test For Effective Porosity

Percentage Replaced	Effective Porosity (0.45w/c)	Percentage increase in Effective Porosity (0.45w/c)	Effective Porosity (0.35w/c)	Percentage increase in Effective Porosity (0.35w/c)
0	3.10	0	2.67	0
15	3.31	7	2.81	5
25	3.45	11	2.95	10
35	3.65	18	3.13	17
45	3.77	22	3.22	20



Graph 7: – Effective Porosity Test Result

3.2 Summary

The experimental results show the recycled aggregate will influence much in fresh and hardened properties of a concrete. As the percentage of the recycled aggregate increased, the workability and strength of the concrete will decreased. By comparing the different type of 100% recycled aggregate specimens, it was found that fly ash cement recycled aggregate concrete mix batch were not sufficient to achieve the high strength target. The reduced water (0.35 water/cement ratio) recycled aggregate concrete mix indicates a higher strength but the workability is not very satisfied.

IV. CONCLUSION

This on-going research project is to determine the strength characteristics of recycled aggregate for potential application in the high concrete structural concrete. The study shows that when the water/cement ratio was decreased, the compressive strength can reach 35MPa. This is classified as high strength concrete and they can be applied in the infrastructures, which need compressive strength up to 35MPa. Furthermore, with the cheaper price of recycled aggregate compared to natural aggregate, the builders can carry out the construction task with lesser material costs.

The results shows that concrete with RCA is negatively affected. However research also shows that if the concrete mixture proportioning, setting and curing is controlled the RCA concrete can be created with similar properties as Natural coarse aggregate. And also the quality and amount of RCA is an important factor for how the concrete is affected. With a low replacement rate of up to 25 or 30% and the use of high quality RCA the concrete properties is not severely affected. After my opinion this leads to possibilities of utilizing RCA concrete on both the construction sites and in prefabrication processes.

1) Use of waste material and save environment. The RCA give same results as natural aggregate with reduced the water-cement ratio for the concrete mix design.
2) The compressive strength 35MPa is achieved by 25-30% replacement of RCA and with decrease on water-cement ratio with admixture content of mix.
3) In the low water-cement ratio the 35MPa strength concrete give better result in the acid attack test. The effect is very less for the replacement of 25-35% of RCA concrete.

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