"A STUDY ON VARIOUS STRENGTH PARAMETERS OF RECYCLED COARSE AGGREGATE BLENDED WITH GGBS"

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Abstract- With the rapid growth in construction activities, it is important to assess the amount of construction and demolition waste being generated and analyze the practices needed to handle this waste from the point of waste management and disposal and also with regard to waste utilization in concrete from the sustainability aspects. Construction and Demolition (C&D) waste constitutes a major portion of total solid waste production in the world, and most of it is used in landfills. Research by concrete engineers has clearly suggested the possibility of appropriately treating and reusing such waste as aggregate once again in concrete, especially in applications such as bed concrete and in road beds for pavement i.e. where works are of less importance as regards to the strength. The use of such waste as recycled aggregate in concrete can be useful for both environmental and economic aspects in the construction industry. In present study, five concrete mixes were used; first mix had only natural coarse aggregate and in remaining mixes natural coarse aggregate was partial replaced by 10%, 20%, 30% and 40% recycled coarse aggregate. In all the mix cement was replaced by 10% GGBS. Here an attempt is made to assess the strength and durability characteristics of concrete made using construction and demolition waste recycled coarse aggregate.

Key Words: Strength, durability, concrete, recycled aggregate, GGBS, mix proportion.

1. INTRODUCTION

1.1 General

Due to high demand for construction activities in recent years in India and all over the world, the natural aggregates resources are remarkably waning day by day. On the other hand, millions of tons of construction and demolition (C&D) residues are generated. The amount of construction and demolition waste has increased enormously over the last decade in the entire world. Construction and demolition disposal has also emerged as a problem in India. India is presently generating construction and demolition (C&D) waste to the tune of 23.75 million tons annually and these figures are likely to double fold in the next 7 years [12]. C&D waste and specifically concrete has been seen as a resource in developed countries. Therefore, the recycling of waste concrete is beneficial and necessary for the environmental preservation and effective utilization of natural resources. The use of recycled coarse aggregate obtained from construction and demolition waste in new concrete is a solution for effective waste utilization.

Concrete made with recycled coarse aggregates and conventional fine aggregate can obtain an adequate compressive strength. The use of recycled fine aggregate can result in minor compressive strength reductions. However, drying shrinkage and creep of concrete made with recycled aggregates is up to 100% higher than concrete with corresponding conventional aggregate. This is due to the large amount of old cement paste and mortar especially in the fine aggregate. Therefore, considerably lower values of drying shrinkage can be achieved using recycled coarse aggregate with natural sand [13]. As with any new aggregate source, recycled concrete aggregate should be tested for durability, gradation, and other properties. Recycled concrete used as coarse aggregate in new concrete possesses some potential for alkali-silica-reaction if the old concrete contained alkali-reactive aggregate. The alkali content of the cement used in the old concrete has little effect on expansion due to alkali-silica-reaction. For highly reactive aggregates made from recycled concrete special measures discussed under "Alkali-Silica Reaction" should be used to control ASR (Alkali-Silica Reaction) also, even if expansive ASR did not develop in the original concrete it cannot be assumed that it will not develop in the new concrete if special control measures are not taken. Petro graphic examination and expansion tests are recommended to make this judgment.

1.2 C&D WASTE

Construction and demolition wasteisgenerated w heneverany construction demolition activity takes place, such as, building roads, bridges, flyover, subway, remodeling etc. It consists mostly of inert and non-biodegradable material such as concrete, plaster, metal, wood, plastics etc. While retrievable items such as bricks, wood, metal, titles are recycled, the concrete and masonry waste, accounting for more than 50% of the waste from construction and demolition activities, are not being currently recycled in India. Recycling of concrete and masonry waste is, however, being done abroad in countries like U.K., USA, France, Denmark, Germany and Japan. Concrete and masonry waste can be recycled by sorting, crushing and sieving into recycled aggregate.

C&D waste is waste material produced in the process of construction, renovation, or demolition of structures. These structures include buildings of all types in residential and nonresidential as well as roads and bridges.

1.3 OBJECTIVES

- To study the performance of RCA as the coarse aggregates in concrete at various proportions.
- Five different mixes were obtained by varying the amount of RCA (0%, 10%, 20%, 30% and 40%) to study strength characteristics.
- In case of concrete produced by 100% natural coarse aggregate and concrete with 20% recycled coarse aggregate, durability tests were carried out. Durability tests conducted are saturated water absorption, sulphate, chloride and acid resistant test. Six cubes were casted to perform each durability test, at the end of 28 and 56 days.
- Test results obtained for RCA (10%, 20%, 30% and 40%) concrete were compared with that of natural coarse aggregate (RCA 0%) concrete.

2. EXPERIMENTAL PROGRAM

2.1 MATERIALS

Cement: Cement used for the test procedure was 43 Grade Ordinary Portland cement confirming to IS 12269-1987. The cement used has a specific gravity of 3.10. Fine aggregate: Locally available manufactured sand, free from silt and organic matter was used in the present mix design. The sand used was passing through 4.75mm sieve. Coarse aggregate: (a) Natural Coarse Aggregate (NCA) used was crushed angular granite stones of 20mm maximum size with specific gravity 2.65 (b) Recycled coarse aggregate (RCA) used was construction and demolition waste generated from some known working construction site which had specific gravity 2.59. Ground granulated blast furnace slag (GGBS): GGBFS is a by-product from the blast-furnaces used to make iron. GGBS specific gravity was 2.9. Superplasticizer: Superplasticizer used in present study is CAC-Superflow. CAC-Superflow is a superplasticising admixture to produce flowable or pumpable concrete, without bleeding and segregation.

2.2 MIX PROPORTIONS

The concrete mix proportion per cubic meter for OPC blended with 10% GGBS adopted in the experiment is shown in Table 1.

Table-1: Concrete mix proportion for M40 grade (per m^3)

Replacement %	W/C ratio	Cement (kg)	GGBS (kg)	NCA (kg)	FA (kg)	RCA (kg)	S.P (kg)	Water (kg)	Extra Water (kg)	$(W/B)_{eff}$
0	0.38	373	42	1186.18	658.39	0	4.15	157.6	0	0.38
10		373	42	1067.562	658.39	118.618	4.15	157.6	3.83	0.389
20		373	42	948.944	658.39	237.236	4.15	157.6	7.66	0.398
30		373	42	830.326	658.39	355.854	4.15	157.6	11.49	0.407
40		373	42	711.708	658.39	474.472	4.15	157.6	15.32	0.417

2.3 EXPERIMENTS

For all the mixes standard cubes, cylinder and prism were casted to compare the strength and durability properties.
STRENGTH: In all the mixes, 3 cubes each for 14 day, 28 day a)compressive strength b) Tensile strength and c) Flexural strength were casted. The test setup for which is shown in Figure 1, 2 and 3

Fig-1: Compression Test

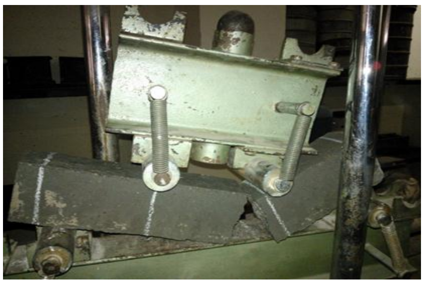

Fig-2: Flexural Test

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Fig-3: Tensile Test

DURABILITY: For the mix with RCA 0% and RCA 20% a) 6 cubes for fully saturated water absorption (SWA) test b) 6 cubes each for acid, chloride, sulphate resistant test were casted. All the casted specimens were demoulded one day after casting and kept in water tank for 28 days curing.

In acid, chloride, sulphate resistant test carried out on RCA 0% and RCA 20% mixes, wetting and drying was carried out for every two days upto 56 days and for every 8 days the loss in weight was taken. Specimens in acid, chloride and suphate solution are shown in Figure 4, 5 and 6.

Fig 4 Cubes in acid solution **Fig 5** Cubes in chloride solution **Fig 6** Cubes in $MgSO_4$

4. Results and Discussions:

4.1 STRENGTH

Compressive strength, tensile strength and flexural test of all specimens were carried out as per IS: 516-1959. The results of 7 days and 28 days compressive strength of all mixes; and 28days tensile strength and flexural test are shown in the Table 2 below.

Table-2: Compressive strength results

RCA (%)	Compressive Strength (N/mm²)		Average Compressive Strength (N/mm²)	
	7 days	28 days	7 days	28 days
0	34.98	46.14	34.91	45.82
	34.32	47.35		
	35.45	43.98		
10	32.32	42.25	33.58	42.85
	34.57	42.14		
	33.68	44.18		
20	33.38	41.08	32.81	41.28
	31.37	42.00		
	33.69	40.78		
30	29.25	35.28	26.13	37
	28.07	38.44		
	27.19	37.28		
40	22.74	32.18	24.09	31.2
	25.19	29.88		
	24.35	31.54		

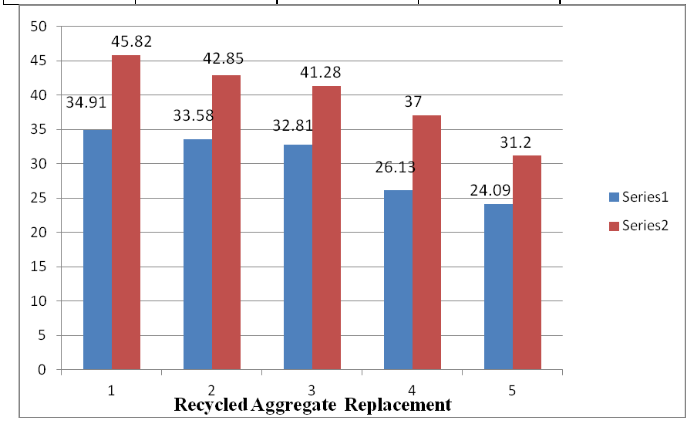

Chart-1: Recycle aggregate replacement Vs Compressive strength

Discussion: From above Figure it is noticed that the strength of concrete at the end of 7 days decreased with the increase in the % of RCA. The decrease in % of strength in concrete mixes with RCA 10%, RCA 20%, RCA 30% and RCA 40% was 3.80%, 6.01%, 25.15% and 30.99% when compared with concrete mix having RCA 0%.

It is noticed that the strength of concrete at the end of 28 days decreased with the increase in the % of RCA. The decrease in % of strength in concrete mixes with RCA 10%, RCA 20%, RCA 30% and RCA 40% was 6.48%, 9.90%, 19.24% and 31.90% when compared with concrete mix having RCA 0%. Decrease in strength of 10% in case of concrete with 20% RCA can be used for producing conventional concrete.

Table-3: Split tensile strength results

RCA (%)	Split tensile strength (N/mm²) 28 days	Average Split Tensile Strength (N/mm²)
0	4.25	4.36
	3.98	
	4.85	
10	4.01	4.08
	4.29	
	3.96	
20	3.98	3.98
	4.00	
	3.96	
30	3.07	3.07
	3.23	
	2.91	
40	2.23	2.77
	2.92	
	3.16	

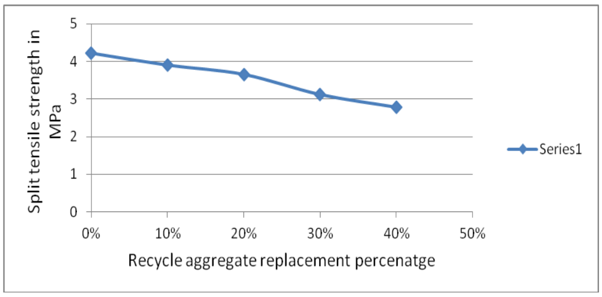

Chart-2: Recycle aggregate replacement Vs Split tensile strength for 28 days

Discussion: It is noticed that the strength of concrete at the end of 28 days decreased with the increase in the % of RCA. The decrease in % of strength in concrete mixes with RCA 10%, RCA 20%, RCA 30% and RCA 40% was 6.42%, 8.71%, 29.58% and 36.46% when compared with concrete mix having RCA 0%.

Table-4: Flexural strength results

RCA (%)	Flexural Strength(N/mm²) 28 Days	Average flexural Strength (N/mm²)
	6.32	6. 44
	6.06	
	6.95	
0	6.10	6. 11
	6.29	
	5.96	
0	6.18	5. 99
	5.95	
	5.86	
0	5.90	5. 44
	5.32	
	5.11	
0	4.62	4. 72
	5.01	
	4.54	

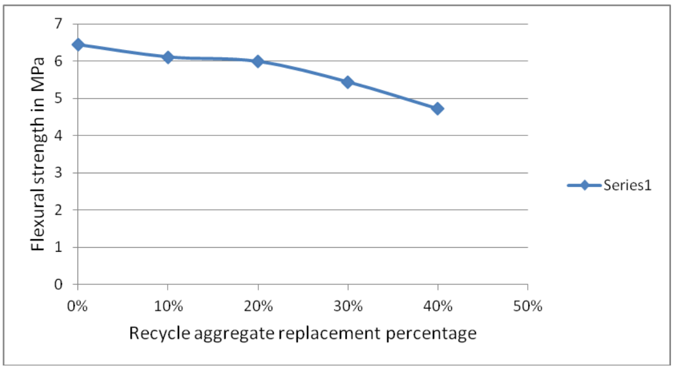

Chart-3: Recycle aggregate replacement Vs Flexural strength for 28 days

Discussion: It is noticed that the strength of concrete at the end of 28 days decreased with the increase in the % of RCA. The decrease in % of strength in concrete mixes with RCA 10%, RCA 20%, RCA 30% and RCA 40% was 5.12%, 6.98%, 15.52% and 26.70% when compared with concrete mix having RCA 0%.

.2 DURABILITY

4.2.1 Saturated Water Absorption Test

Table-5: shows the percentage saturated water absorption for RCA 0% and RCA 20% after 28 days curing

Specimen No	Percentage water absorption (NSC40)	Percentage water absorption (RCA20%)

1	4.920	5.342
2	4.305	5.425
3	5.106	4.368
4	4.782	5.135
5	4.603	5.312
6	4.194	5.124
Average	**4.65**	**5.17**

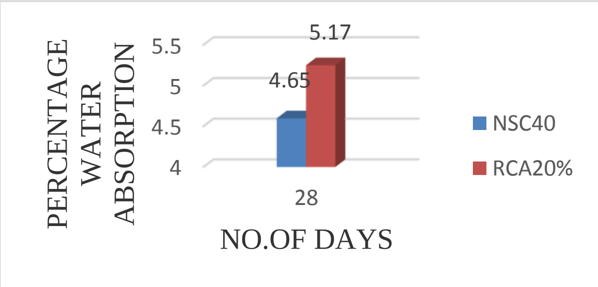

Chart-4: Percentage water absorption Vs number of days

4.2.2 Hydrochloric Acid Resistance Test

Table-6: Shows results of NSC40 and RCA20% cubes when subjected for 8 weeks of HCl

Specimen Type	**Weight Loss**		**Compressive strength in MPa**	
	28 Days	**56 Days**	**28 Days**	**58 Days**
NSC40	2.32	0.90	39.44	37.074
RCA 20%	2.404	1.072	35.079	32.623

Table-7: Shows results of NSC40 and RCA20% cubes when subjected for 8 weeks of $MgSO_4$

Specimen Type	**Weight Gain**		**Compressive strength in MPa**	
	28 Days	**56 Days**	**28 Days**	**56 Days**
NSC40	0.88	0.153	42.42	41.041
RCA20 %	0.513	0.212	37.225	35.563

Table-8: Shows results of NSC40 and RCA20% cubes when subjected for 8 weeks of NaCl

Specimen Type	**Weight Gain**		**Compressive strength in MPa**	
	28 Days	**56 Days**	**28 Days**	**56 Days**
NSC40	0.419	0.259	41.74	40.128
RCA20 %	0.735	0.341	36.32	33.959

CONCLUSIONS

- Quality of recycled aggregate plays vital role in the production of RCA concrete.
- RCA exhibits similar behaviour to fresh aggregate; therefore, RCA could be incorporated into many concrete structures. However, RCA that has an unknown origin should be tested to ensure that the RCA was not from a structure that was suffering from alkali-silica reaction, alkali-aggregate reaction, sulphate attack, or some other harmful reaction. Such RCA could affect the strength and durability of the concrete and may be harmful.
- Compressive strength of concrete with RCA 0%, 10%, 20%, 30% and 40% was 45.82, 42.85, 41.28, 37 and 31.2Mpa respectively which shows that obtained compressive strengths less than the target

strength 48.25MPa. Approximately linear decrease in strength can be seen.

- Tensile strength of concrete with RCA 0%, 10%, 20%, 30% and 40% was 4.36, 4.08, 3.98, 3.07 and 2.78 respectively.

- Flexural strength of concrete with RCA 0%, 10%, 20%, 30% and 40% was 6.44, 6.11, 5.99, 5.44 and 4.72 respectively.

- Water absorption of recycled coarse aggregate (RCA 20%) concrete was higher than the natural aggregate (RCA 0%).

- In case of acid test the average weight loss of cubes in RCA 0% (NSC40) concrete was found to be 2.32 whereas in RCA 20% concrete the average weigth loss was 2.404, varying marginally same.

- In chloride test, it is observed that concrete with RCA 20% gained more weight compared to RCA 0% concrete mix indicating disability to withstand chloride attack.

- Average weight gain of RCA 0% and RCA 20% concrete cubes immersed in $MgSO_4$ solution was 0.45 and 0.716 at the end of 56 days.

- From the observed strength and durability results, optimum level of replacement of RCA is about 20-25% of natural coarse aggregate.

REFERENCES

1. A.K.Padmini, K.Ramamurthy, M.S.Mathews (2009), "**Influence of parent concrete on the properties of recycled aggregate concrete**". *Construction and Building Materials,* 23, 829-836.
2. Ashraf M. Wagih , Hossam Z. El-Karmoty , Magda Ebid , Samir H. Okba (2013), "**Recycled construction and demolition concrete waste as aggregate for structural concrete**", *HBRC Journal* , 9, 193–200.
3. Fernando López Gayarre, Carlos López-Colina Pérez, Miguel A. Serrano López, Alberto Domingo Cabo (2014), "**The effects of curing conditions on the compressive strength of recycled aggregate concrete**", *Construction and Building Materials,* 53, 269-266.
4. Hisham Qasrawi (2014), "**The use of steel slag aggregate to enhance the mechanical properties of recycled aggregate concrete and retain the environment**", *Construction and Building Materials, 54*, 298–304.
5. Isabel Martínez-Lage , Fernando Martínez-Abella, Cristina Vázquez-Herrero, Juan Luis Pérez-Ordóñez(2012), "**Properties of plain concrete made with mixed recycled coarse aggregate**" , *Construction and Building Materials* ,37 ,171–176.
6. Khaldoun Rahal (2007), "**Mechanical properties of concrete with recycled coarse aggregate**", *Building and Environment*, 42, 407–415.
7. M. Chakradhara Rao , S.K. Bhattacharyya , S.V. Barai(2011), "**Behaviour of recycled aggregate concrete under drop weight impact load**", *Construction and Building Materials*, 25 ,69–80.
8. Revathi Purushothaman and Sasikala Mani (2013), "**Studies on Fresh and Hardened Properties of recycled Aggregate Concrete with Quarry Dust**", *ACI Materials Journal*, 111,283-289.
9. Sami W. Tabsh , Akmal S. Abdelfatah (2009), "**Influence of recycled aggregate concrete on strength properties of concrete**", *Construction and Building Materials* ,23, 1163–1167.
10. IS 456:2000, [Reaffirmed 2005], ***"Plain and Reinforced Concrete – Code of Practice",*** Fourth Revision, Bureau of Indian Standards, New Delhi, India.

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