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STUDY ON RECYCLED AGGREGATE CONCRETE WITH BLENDED 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 analyse 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.

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 tonnes 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 tonnes annually and these figures are likely to double fold in the next 7 years. 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.

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The management of construction and demolition waste is a major concern due to increased quantity of demolition rubble, continuing shortage of dumping sites, increase in cost of disposal and transportation and above all the concern about environment degradation. Although a substantial portion of construction materials could be substituted by re-processed construction waste material, these options are not exercised in developing countries due to lack of knowledge and insufficient regulatory frameworks resulting in waste getting piled up causing disposal problems. The increasing problems associated with construction and demolition waste have led to a rethinking in developed countries and many of these countries have started viewing this waste as a resource and presently have fulfilled a part of their demand for raw material. Since concrete composes 35% of the waste as per the survey conducted by Municipal Corporation of Delhi, India may also have to seriously think of reusing demolished rubble and concrete for production of recycled construction material. Such recycling operations have the added benefit of reducing landfill disposal, while conserving primary resources and reducing transport costs.

Though utilization of recycled coarse aggregates (RCA) in concrete has become more common practice all over the world, it is generally used for lower-grade applications. Higher-grade activities are rarely reported, because of its effects on workability, strength and durability. Work on recycled concrete has been carried out at few places in India but waste and quality of raw material produced being site specific, several inputs are necessary if recycled material has to be used in construction for producing high grade concrete.

1.2 C&D Waste

Construction and demolition waste is generated whenever any 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 needs to be focused upon in view of
- The potential to save natural resources
- its bulk which is carried over long distances for just dumping
- its occupying significant space at landfill sites
- its presence spoils processing of biodegradable as well as recyclable waste

Many developed countries have been recycling C&D waste and using it for construction works. In Scotland about 63% of the C&D waste was recycled in 2000. The Government there is working out specifications and code of practice for recycling of C&D waste. U.K uses 49-52% of the C&D wastes and Australia reuses 54% of the wastes generated. Belgium has a higher

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recycling rate (87%) and uses majority of C&D for recycling purposes. Japan is one of the pioneer countries that recycle C&D waste.85 million tonnes of C&D waste was generated in 2000, of which 95% of concrete was crushed and reused.

In India, there is not much development in this field. In the international experiences sited above, there is considerable emphasis on recycling of C&D in India.

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 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 in MSRIT campus 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-Super flow. CAC-Super flow is a superplastic sing admixture to produce flow able or pump able 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.

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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: Tensile Test

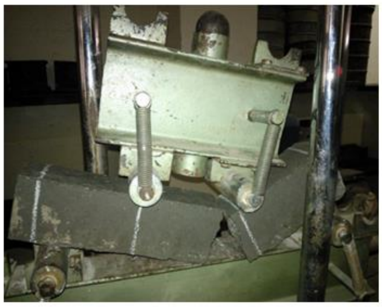

Fig 3: Flexural Test

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 demoulde done 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 sulphate solution are shown in Figure 3, 4 and 5.

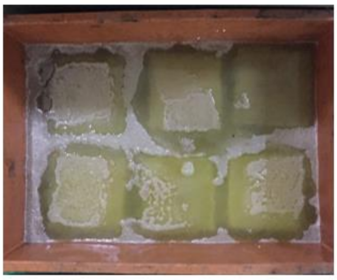

Fig 4: Cubes in acid solution

Fig 5: Cubes in chloride solution

Fig 6: Cubes in $MgSO_4$

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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: Strength results for all mix

% of Recycled aggregate replacement	Compressive strength in MPa		Tensile Strength in MPa	Flexural Strength in MPa
	7 Days	28 Days	28 Days	28 Days
0%	34.93	45.86	4.23	6.43
10%	32.84	42.64	3.91	6.07
20%	31.08	41.27	3.66	5.71
30%	28.03	37.14	3.12	5.43
40%	22.15	31.8	2.78	4.87

The results obtained in Table 2 are graphically represented in Fig 7, 8 & 9 and explained.

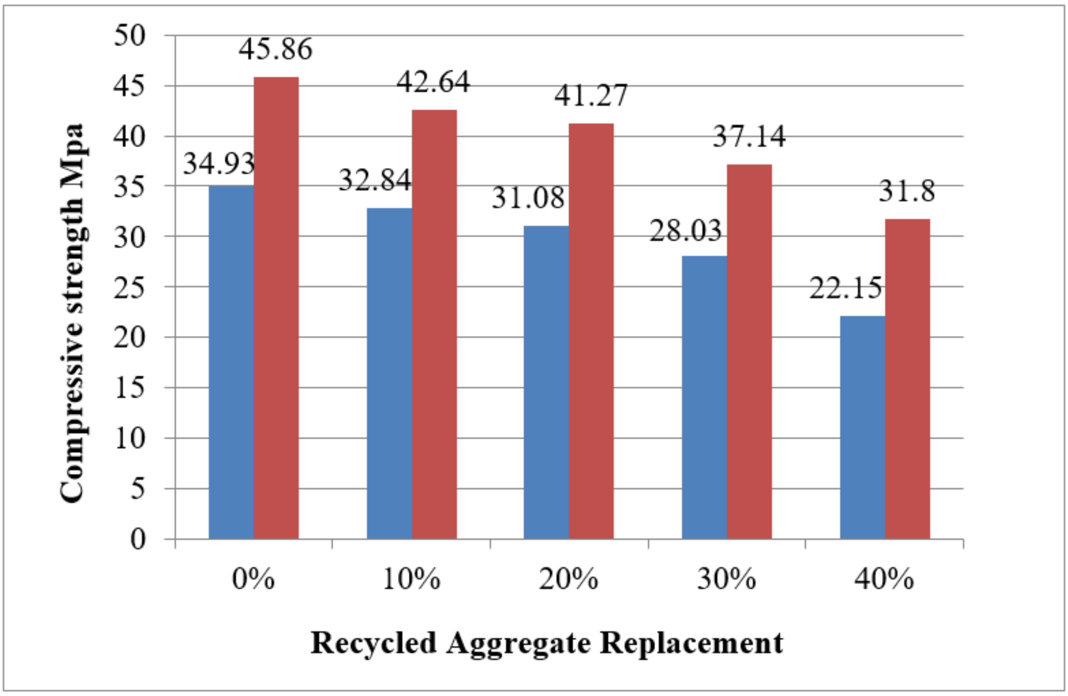

Fig 7: 7 Days and 28 days Compressive Strength Comparison for Concrete mixes

From Fig.4 it is noticed that the compressive strength of concrete with 20% RCA didn't deviate much from the strength results of concrete with RCA 0%. In the sense strength was within the acceptable limit. But for concrete with 40% RCA strength differed by 35% and 30% at 7 days & 28 days respectively.

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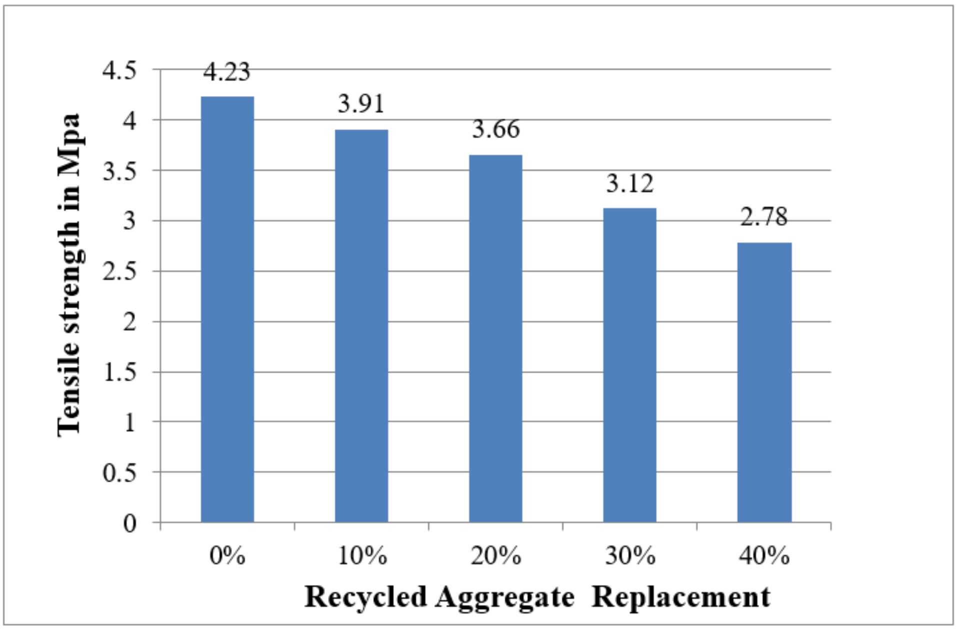

Fig 8: Tensile strength for concrete with different % of RCA

With the increase in % of RCA, linear decrease in the tensile strength can be see from above fig. For 40% RCA used, tensile strength decreased was 35% when compared with tensile strength of concrete with 0% RCA.

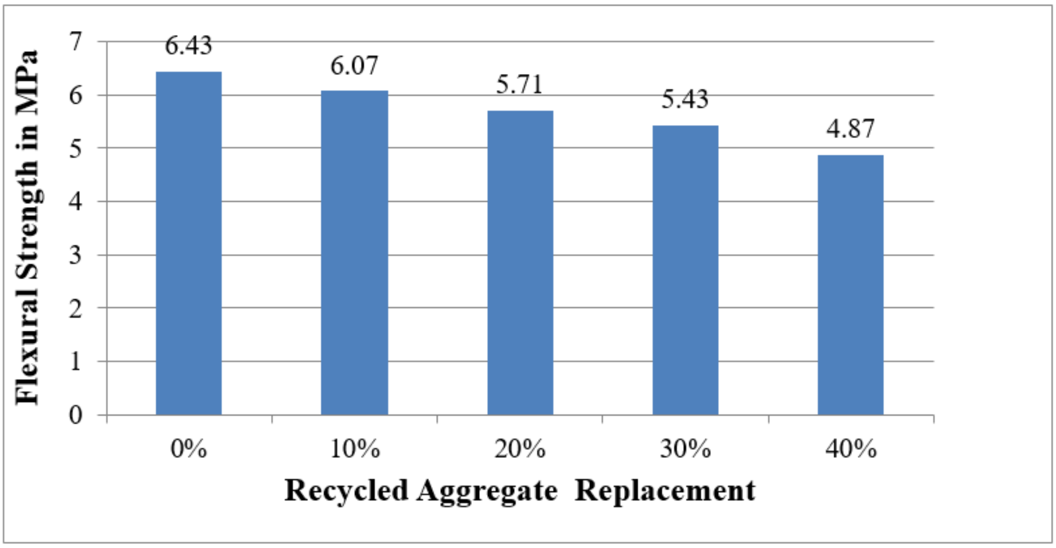

Fig 9: Flexural strength for concrete with different % of RCA

Flexural strength decreased by 5.6%, 11.2%, 15.5% and 24.26% for concrete with RCA 10%, 20%, 30% and 40% respectively when compared with concrete mix with 0% RCA.

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From the strength results it is seen that, for concrete mix with 20% RCA compressive, tensile and flexural strength changed very moderately. Hence durability characteristics are attempted for the concrete mix with 20% RCA and the results are compared with concrete mix with 0% RCA

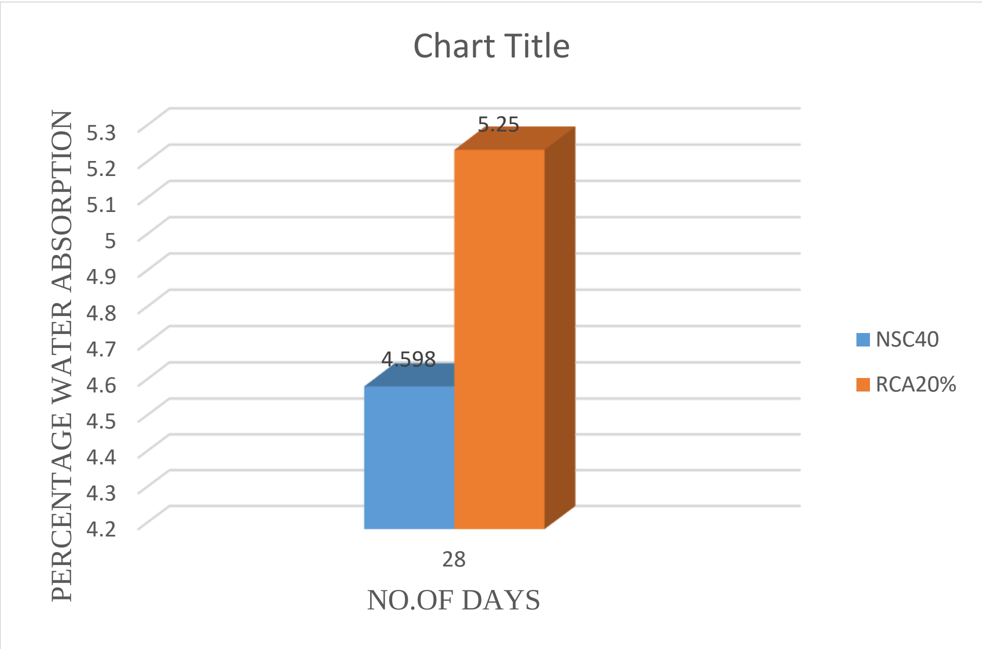
4.2 Durability

4.2.1 Saturated Water Absorption Test

Table 3: 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	4.950	5.94
2	4.505	5.45
3	5.06	4.38
4	4.78	5.35
5	4.203	5.12
6	4.094	5.24
Average	**4.598**	**5.25**

The results in Table 3 are graphically represented below



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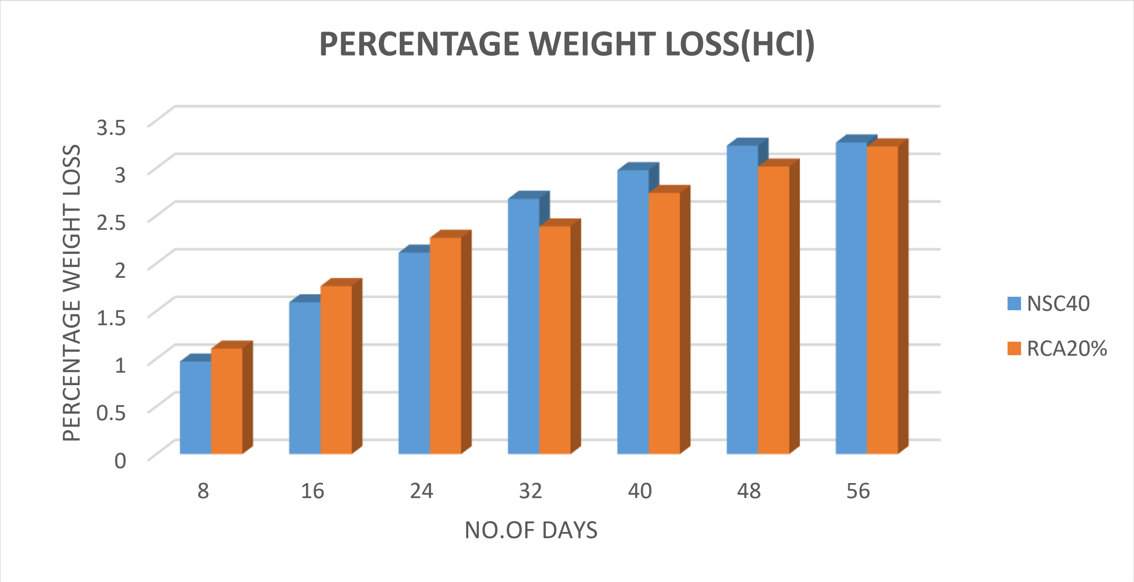
4.2.2 Hydrochloric Acid Resistance Test

Table 4: Acid resistance test values

No. of days of curing in acid (HCl)	Average weight loss (%) For NSC40	Average weight loss (%) For RCA 20%
8	0.97	1.106
16	1.592	1.761
24	2.113	2.268
32	2.677	2.387
40	2.977	2.738
48	3.234	3.015
56	3.268	3.226

The results in Table 4 are graphically represented below



5. 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, 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 45.86, 42.64, 41.27, 37.14 and 31.80 respectively. Approximately linear decrease in strength can be seen.
- Tensile strength of concrete with RCA 0%, 10%, 20%, 30% and 40% was4.23, 3.91, 3.66,

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3.12 and 2.78respectively.

- Flexural strength of concrete with RCA 0%, 10%, 20%, 30% and 40% was 6.43, 6.07, 5.71, 5.43 and 4.87 respectively.
- Water absorption of recycled coarse aggregate (RCA 20%) concrete was higher than the natural aggregate (RCA 0%).
- From the observed strength and durability results, optimum level of replacement of RCA is about 20-25% of natural coarse aggregate.

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