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Replacement of Recycled Construction and Demolition Waste Coarse Aggregates in Pavement Quality Concrete

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Abstract

In the present study, a coarse aggregate replacement scheme in concrete is investigated with five different replacement ratios including 20%, 40%, 60% and 80%, & 100%. The beneficiation process is carried out by acid treatment to reduce water absorption potential. After beneficiation the water absorption capacity got reduced by 28.78% and improved impact test value by 24.74%, Los Angeles Abrasion value by 17.42%, soundness value by 39.31% and specific gravity increased by 5%. After beneficiation, recycled materials were replaced for coarse aggregates in M30 and M40 grade of concrete. Results indicate construction and demolition waste as a conceivable practicable natural coarse aggregate supplanting material with insignificant changes in mechanical properties. The change in the strength properties were contrasted with conventional mix. From the study, it is found that an effective replacement of 45.75 % and 23.35% of Recycled coarse Aggregate for M30 & M40 grade respectively. The compressive strength is found to be for M30 – 40.45N/mm^2 & M40 – 51.33N/mm^2, the flexural strength is found to be for M30 – 11.55N/mm^2& M40 – 15.60N/mm^2 and the fatigue strength with respect to stress ratio 0.75 for M30 – 6540 no. of cycles & M40 – 10806 no. of cycles.

Keywords: Construction and demolition(C&D) waste, Compressive strength, Fatigue strength, Flexural strength, Pavement Quality Concrete (PQC).

INTRODUCTION

In developing countries, Construction and Demolition (C&D) waste involves a major portion of solid waste production. Research by engineers has clearly suggested that the possibility of appropriately treating and reusing such waste as aggregate in new concrete, especially in lower level applications[1]. Recycled aggregates (RA) are the main components of the old concrete. The recycling operations have the added benefit of reducing landfill disposal which in turn is eco-friendly. The use of recycled aggregates for the production of concrete involves breaking, removing, and crushing existing concrete into a material with specified size and quality [2]. Recycled aggregates normally have higher water absorption and lower specific gravity. The density of recycled aggregates used is lower than the density of normal aggregates and the porosity of recycled aggregates is also much higher than those of natural aggregates The properties of Recycled-concrete Fine Aggregates (RFA) and the effects of their incorporation in concrete received the attention of several researchers, this material, despite the obvious environmental advantages, presents distinct properties from those of Natural Aggregates (NA), which have prevented their use on a regular basis [3]. Regarding the influence of the recycling process, the number of processing stages is an aspect to be taken into account, since the density of C&D waste aggregates depends on the amount of adhered mortar. To remove the adhered mortar the various beneficiation processes have been carried out such as Thermal, mechanical and acid treatment process in many researches. From the studies researchers concluded that, acid treatment is found to be effective and economical. The ordinary portland cement is major binding agent in the concrete, higher usage of cement is causing an environmental issue since it consumes various natural resources. So there is an essential need for reducing the usage of cement in concrete. So many studies were conducted by replacing cement with silica for the concrete.

This research mainly emphasizes on the determination of the optimum strength of concrete in fresh and hardened states using varying proportion of Recycled Concrete Coarse Aggregates (RCCA). Therefore, this research is focused on the effectiveness of using treated or recycled aggregates as a replacement for common aggregates to produce a pavement quality concrete structure as there is a lack of research done in regard to the properties of treated recycled aggregates.

Physical properties of aggregates for Pavement Quality Concrete (PQC)

As per the Indian Road congress specification the materials used in PQC should confirm to the following requirements:

Table 1: Aggregate properties as per IRC Specification

Properties	As per IS 383 – 2016 & IRC 15-2017
Aggregate Impact Value, %	24
Crushing Value, %	24
Combined Index, %	35
Specific Gravity	
Coarse aggregate	2.65
Water Absorption, %	
Coarse aggregate	3
Fine aggregate	3
Soundness by, %	
Sodium Sulphate (after 5 cycles)	12

Recycled Aggregates (RA)

The C&D materials were collected from various locations such as Building demolition site, dumping yards, Ready mix concrete plant etc… Further the materials were categorized into the following by conducting sieve analysis:

- Recycled Concrete Fine Aggregates(RCFA)- Cement concrete/mortar waste
- Recycled Concrete Coarse Aggregates(RCCA) - Cement concrete/mortar waste

METHODOLOGY

The Following methodology is adopted for the present work:

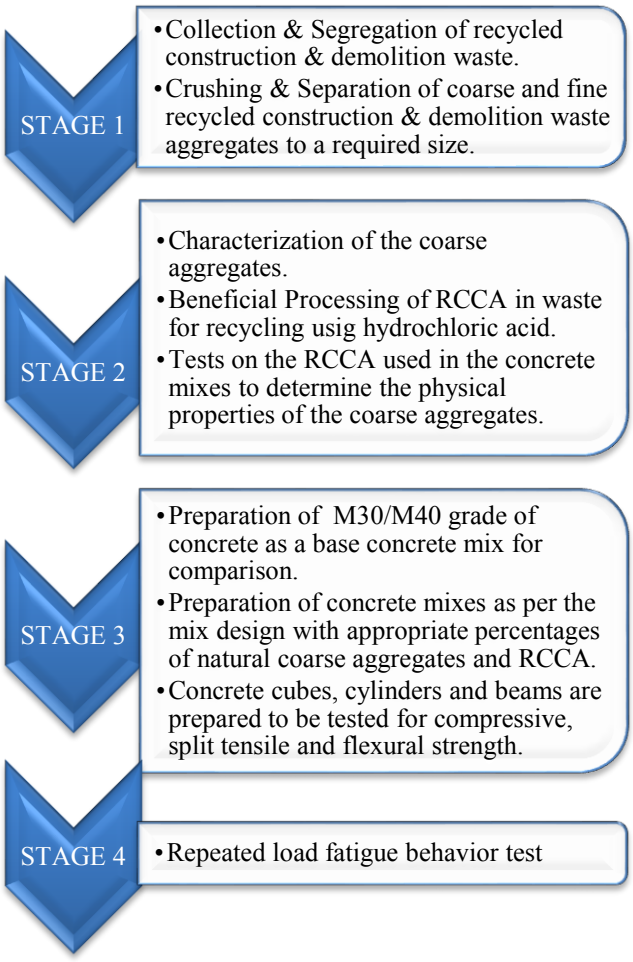

Figure 1: Methodology Flowchart

Table 2: Physical properties of aggregates

Sl. No.	Physical properties	Avg. Specific gravity	Avg. Water absorption	Avg. Crushing test value	Avg. Impact test value	Avg. Los Angeles Abrasion value	Avg. soundness test value In %	Grade of aggregates
Natural aggregates								
1	Fine aggregates (M-sand)	2.62	2.56	-	-	-	8.0	Grading Zone II as per IRC 44-2017 & 15-2017
2	Coarse aggregates	2.65	1.64	23.16	23.07	21.94	7.36	Satisfying table 1 of IRC 44-2017 , for Graded Aggregate of Nominal Size 20mm
Re-cycled C&D waste								
1	RCFA	2.21	19.09	-	-	-	19.5	Grading Zone II as per IRC 44-2017 & 15-2017
2	RCCA	2.37	4.10	32.32	33.38	34.21	16.66	Satisfying table 1 of IRC 44-2008 , for Graded Aggregate of Nominal Size 20mm

Beneficiation of Recycled –concrete Coarse Aggregates (RCCA)

It is generally recognized that the use of additional crushing stage can considerably reduce the mortar content but decreases the overall yield of recycled C&D concrete aggregates, due to breaking of a significant portion of relatively weaker original natural aggregates. Therefore, efforts have been made to produce C&D concrete aggregates with lower mortar contents by acid treatment process with a volumetric ratio (V_{acid}/V_{RFA} = 2.5) [3]. The following were results obtained for the materials replaced in proportion by its weight

Table 3: Effective Characterization of aggregates

Sl. No.	Physical properties	Avg. Specific gravity	Avg. Water absorption	Avg. Crushing test value	Avg. Impact test value	Avg. Los Angeles Abrasion value	Avg. soundness test value	Grade of aggregates
RCCA Without beneficiation process								
a	**20% RCCA**	2.60	2.0	25.90	24.00	25.11	8.40	Satisfying table 1 of IRC 44-2017 & IS 383-2017, for Graded Aggregate of Nominal Size 20mm
b	**40% RCCA**	2.56	3.22	27.0	27.67	29.55	10.22	
c	**60% RCCA**	2.50	3.50	29.44	28.0	31.34	12.0	
d	**80% RCCA**	2.41	3.89	30.54	31.78	34.0	14.8	
e	**100% RCCA**	2.37	4.10	32.32	33.38	34.21	16.66	
RCCA With beneficiation process by Acid soaking (HCL)								
a	**20% RCCA**	2.64	1.90	23.84	25.62	23.68	8.00	Satisfying table 1 of IRC 44-2017 & IS 383-2017, for Graded Aggregate of Nominal Size 20mm
b	**40% RCCA**	2.60	2.42	25.89	25.70	25.26	8.95	
c	**60% RCCA**	2.55	2.84	27.23	28.40	28.96	10.56	
d	**80% RCCA**	2.52	3.0	27.31	28.80	30.0	12.89	
e	**100% RCCA**	2.49	2.92	28.0	25.12	28.25	10.11	

RESULTS AND DISCUSSIONS

The analysis results were presented in the form of tables and graphs in this part. The recycled aggregates were treated with Hydrochloric acid solution.

Fresh properties of Concrete

For fresh concrete, mainly the slump test was used to determine the flow of concrete mixing as presented in the below table. The values of the slump test falls within the

range of 25mm – 40mm [9]. The highest value recorded approximately 35mm for 0% and 20% replacement and the lowest slump value was 18mm for 100% replacement. Based on the trial and error the various proportions for M_{30} and M_{40} design mixes were prepared.

Compressive Strength

With reference to the results shown in Figure 2 & 3, the compressive strength of both M_{30} and M_{40} proportions shows significant increase in the strength for concrete prepared with aggregates after beneficiation process.

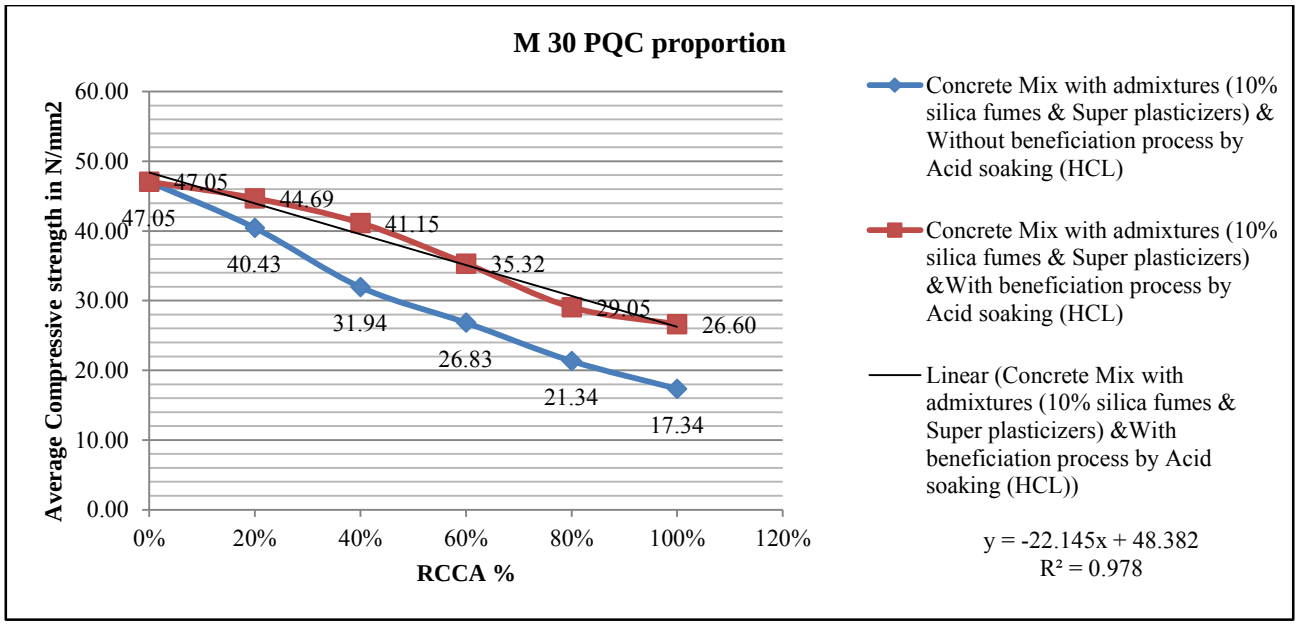

Figure 2: 28-days compressive strength of M_{30} concrete

Based on the statistical comparison with regression analysis the optimum dosage was evaluated and found to be:

- Optimum percentage of recycled concrete coarse aggregate (RCCA) for M_{30} obtained by the regression analysis is given by

y = -22.145X +48.382, since, the target strength of concrete is 38.25N/mm^2. We have y = 38.25N/mm^2.

- The optimum percentage of Recycled Fine aggregate = 45.75%

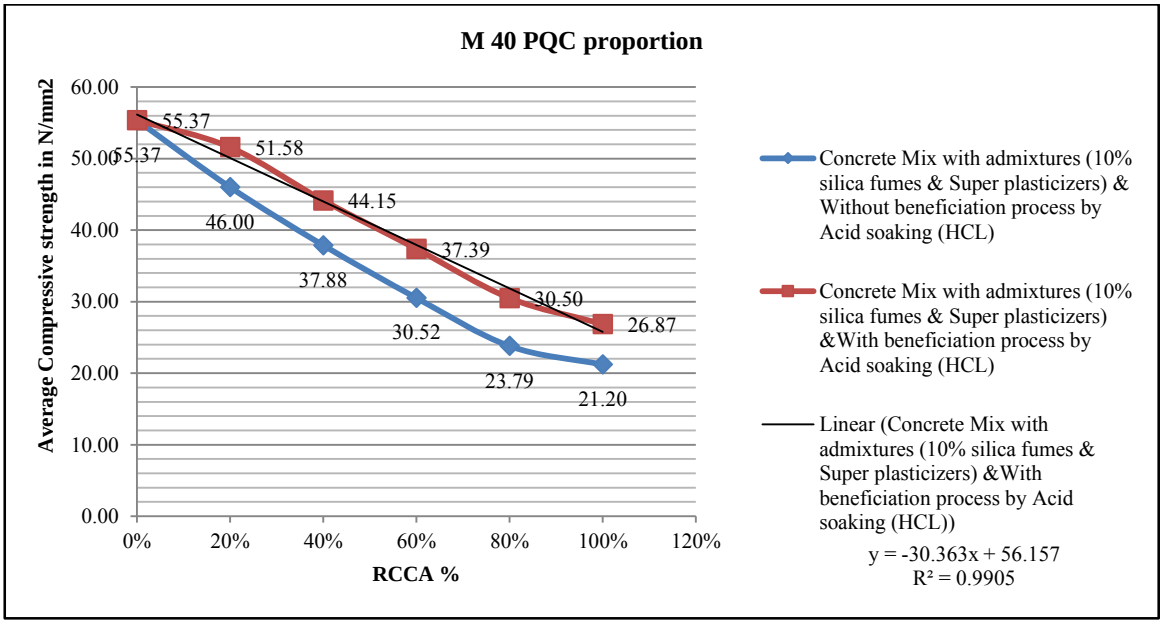

Figure 3: 28-days compressive strength of M_{40} concrete

- Optimum percentage of recycled fine aggregate (RFA) for M_{40} obtained by the regression analysis is given by: y = -30.363x + 55.34, since, the target strength of concrete is 48.25N/mm^2.
  - The optimum percentage of Recycled Fine aggregate = 23.35%

Using the above proportion compression cubes were prepared and the 28-days strength achieved is:

- M_{30} - 40.45N/mm^2
- M_{40} - 51.33N/mm^2

Flexural Strength

With reference to the results shown in Figure 4 & 5, the flexural strength of both M_{30} and M_{40} proportions shows significant increase in the strength for concrete prepared with aggregates after beneficiation process.

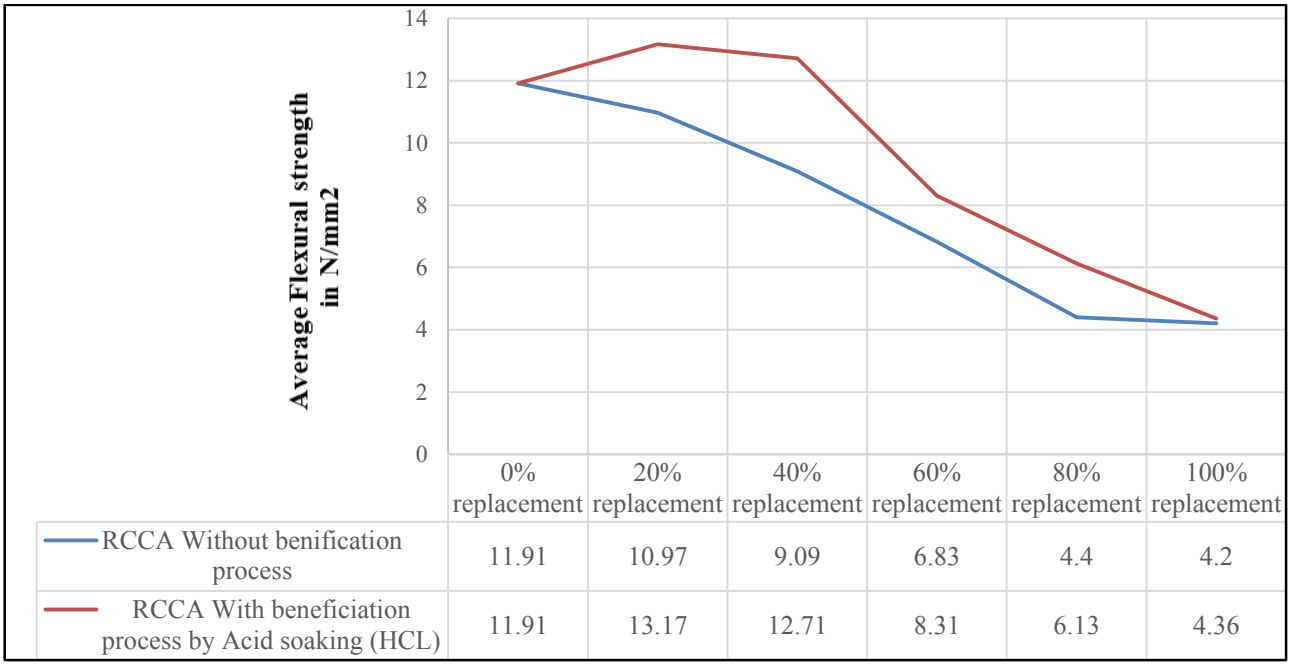

Figure 4: 28-days Flexural strength of M_{30} concrete

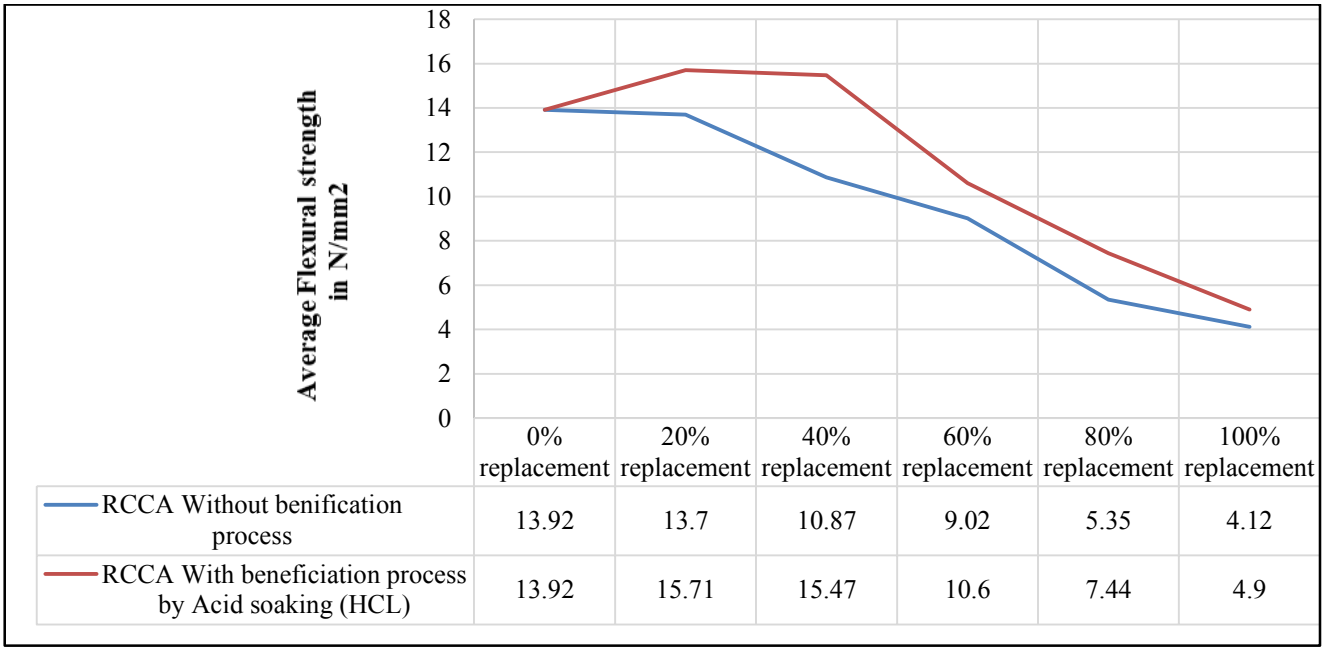

Figure 5: 28-days Flexural strength of M_{40} concrete

For the optimum dosage, the flexural specimen gives the following results:

- M_{30} - 11.55N/mm^2
- M_{40} – 15.60N/mm^2

Fatigue Strength

With reference to the results shown in Figure 6 & 7, the fatigue strength of both M_{30} and M_{40} proportions shows significant increase in the strength for concrete prepared with aggregates after beneficiation process.

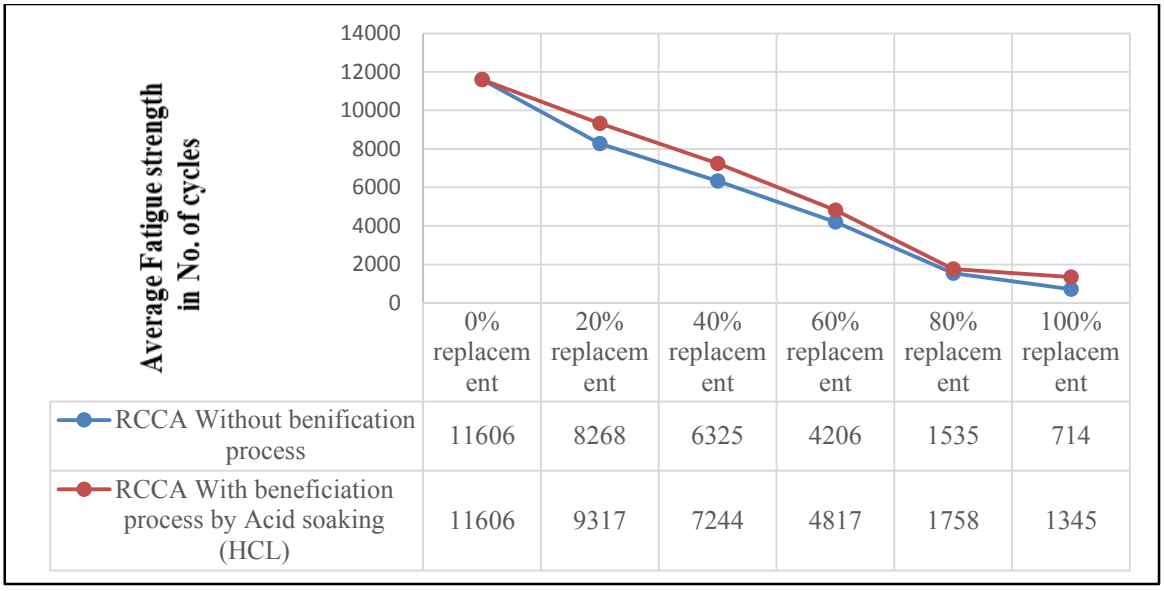

Figure 6: 28-days Fatigue strength of M_{30} concrete

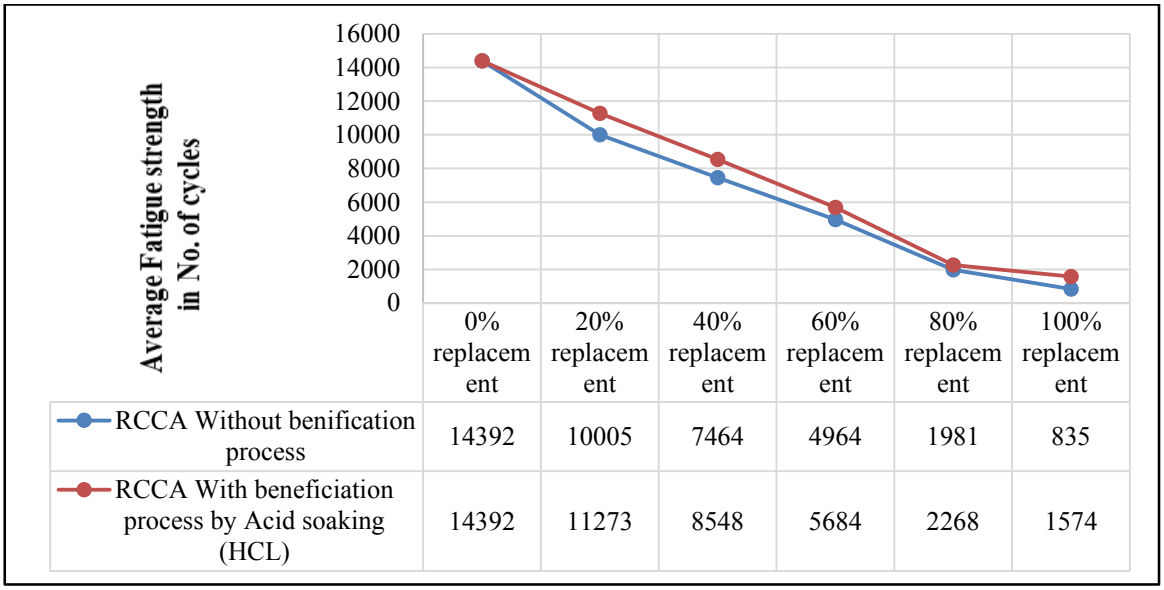

Figure 7: 28-days Fatigue strength of M_{40} concrete

For the optimum dosage, the fatigue specimen gives the following results

- M_{30} - 6540 no. of cycles
- M_{40} - 10806 no. of cycles

CONCLUSIONS

Based on the obtained results following conclusions can be drawn:

- From the compressive strength test results obtained, the mix proportions up to 20% replacement have achieved required target strength for M_{40} grade and up to 40% for M_{30} grade of concrete. Using the

above result the statistical analysis was performed and the optimum replacement is worked out as 45.75% for M_{30} and 23.35% for M_{40}

- From the flexural strength test results obtained, all the mix proportions with replacement have achieved required strength as per the IRC standards
- From the fatigue strength test results obtained, all the mix proportions with replacement have achieved required number of cycles as per the IRC standards
- Based on the above results it can be concluded that beneficiation process improves the quality of aggregates and the strength of the concrete
- By the replacement of C&D waste aggregates in the concrete and silica for the cement will leads to sustainable approach for construction

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