An Experimental Investigation on Treatment of Recycled Aggregate for Effective Use of Construction & Demolition Waste

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Abstract *:— Concrete is primarily a composition of cement, coarse aggregates, fine aggregates and water, further processed by addition of industrial products/ by products for enhancing the properties. Engineers are mainly dependent on nature for obtaining the Coarse and Fine aggregates as well as water for the chemical reaction with cement. Scarcity is there for all these naturally occurring materials and need is there to explore alternative sources. Even for the water with required properties, shift is towards the use of waste water after due treatment. One of the alternative sources of coarse aggregates is recycled concrete aggregates (RCA) which are obtained from the processed Construction and Demolition (C&D) waste. During and after the demolition of any concrete structure, the demolished concrete waste is taken to a recycling plant and there crushed into the required sizes which is called the Recycled concrete aggregate (RCA). Using manually recycled coarse aggregate obtained from waste concrete to manufacture fresh concrete is a highly sustainable option for the developing countries in order to beneficially dispose off old concrete structures, preserve the depleting stock of natural resources. The test results from the limited laboratory experiments on recycled coarse aggregate suggest that the quality of concrete made out of manually recycled coarse aggregate in terms of compressive, flexural and splitting tensile strength is comparable to that of concrete made out of natural coarse aggregate. The use of recycled aggregate weakens the quality of recycled aggregate concrete which limits its application. For improving the quality of recycled coarse aggregate suggest that various surface treatment methods such as washing the recycled aggregates with water and diluted acid & compare Strength properties of the treated and untreated course aggregate.*

Key words: *Recycled aggregate concrete, Normal water washing treatment, Nitric acid treatment, Compressive strength and Tensile strength.*

I. INTRODUCTION

With the growth of society on all the fronts, lot of construction activities are seen everywhere. Mega construction activities are increasing exponentially. Also, the demolition of existing structures, which have outlived its service life, is going on simultaneously. It is not essential that the structures need to be demolished only after their service life span is over, but also due to ongoing trend of reconstruction of even healthy structures just for creating more space in order to meet the present requirement. All such activities are generating huge amount of waste, called the Construction and Demolition (C&D) waste. Disposal of such debris in a sustainable manner is a big challenge for the builders, developers and owners. While the disposal of debris is a challenge, on the other hand there is an acute shortage of naturally available aggregates for construction of buildings. Reduction of this demand in a small way is possible with the reusing or recycling of construction and demolition waste generated from the construction activities. Hence, the construction sector must accept the use of C& D waste wherever feasible. To achieve sustainable issue in construction area, researchers and companies focus on using waste concrete as a new construction material. It is called recycled aggregate which can be produced by concrete crusher. The aggregates are categorized by size as coarse and fine aggregate. Although using recycled aggregates has great opportunity to preserve healthy environment, the properties and characteristics of recycled aggregates has not been fully investigated yet. Since it is hard to standardize the characteristic of recycled aggregates, all the researchers who study recycled aggregate should perform experiment of their concrete, which will be used for recycled aggregate, to gain the characteristics of their specimens. The characteristic of recycled aggregates could be different by its parent concrete because the parent concrete was designed for its purposes such as permeable, durable and high strength concrete. For example, water to cement ratio of parent concrete will give an

impact on water absorption capacity of recycled aggregates which is related to characteristics of concrete issue such as durability, permeability, strength and elastic modulus.

A. Recycle Aggregate:

RAs are extracted through the processing of the debris generated from the demolition of concrete structures and other construction debris such as waste concrete, rejected precast concrete members, broken masonry, concrete road beds and asphalt pavement, leftover concrete from ready mix concrete plant and the waste generated from different laboratories [1]. RAs may be of different types such as brick aggregate, glass aggregates, asphalt and bitumen aggregate, concrete aggregates, tiles and marbles recycled from flooring, finishes and ceramic products. Aggregate typically processed by the crushing of parent or old concrete such as demolished waste concrete is regarded as recycled concrete aggregate (RCA). Generally RCAs are mixed with bricks, tiles, metals and other miscellaneous such as glass, wood, paper, plastic and other debris [1,2]. The concept of use of RA from demolished concrete structures was introduced into practice dates back to the time of world war II in Europe [1,3]. Earlier it had been used as unbound sub base materials for pavement. Now-a-days it is being used for construction purposes also. The use of RA in concrete has generated interest in civil engineering construction regarding sustainable development as it is the means of achieving more environment friendly concrete. Concrete made up of RA in terms of fine or coarse or both, processed from C&D waste either as a partial or 100% replacement of conventional natural aggregates is known as RAC.

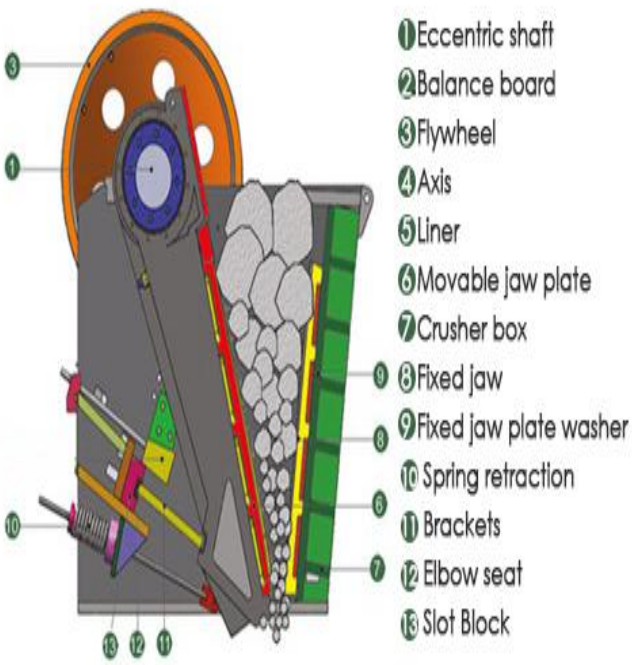
B. Recycling Process:

Recycling is the act of processing the used material for further use in developing new value added products. The integral technique behind recycling process includes the breaking of demolished concrete to produce smaller size fragments by subjecting to a series of performances such as removal of contaminants (reinforcement, wood, plastic etc.), different stages of screening, and sorting. Higher quality aggregates can also be processed in steps with time and effort involved in stock piling, crushing, pre- sizing, sorting (pre-crushing and post crushing), screening and contaminant elimination depending upon the level of contamination and the application for which the recycled materials will be used [1]. Demolition debris can be crushed by several crushers such as Jaw crusher, hammer mill, impact crusher, and cone crusher or manually by hammer [4]. Different crushers have different consequences on the physical and mechanical properties of RAs depending upon the effectiveness of crushing processes [5] and consequently it affects the concrete performance also. Jaw crushers are mainly used for primary crushing as it can crush oversized concrete pieces into comparable size for secondary crushing. Impact crushers are preferred for secondary crushing as they produce a better quality of aggregate with less adhered mortar content [6]. Desirable grading for RAs can be achieved by crushing through primary crushers successively through secondary crushers [7]. The selection of crushers at various stages depends on several factors such as maximum feed size, quality of output, desirable particle size and shape of the various fractions, and amount of finer produced. These days with the help of mobile crushing plants and some portable equipment, recycling facility can be established on site for immediate use of product and also the freight distance can be reduced [8]. Along with the above mentioned dry processes, wet processing technique for RA provides better quality aggregate with less organic and inorganic impurity. However, in some developed countries like Japan, China, USA and Netherland, the researchers have developed some advanced processing techniques to minimize the adverse effect of RA. By adopting these methods, high quality aggregates can be produced by removing the adhered mortar without losing the integrity of original coarse aggregate. Some of these techniques are freeze–thaw method [9], thermal expansion method [10], microwave heating method [11], heating and rubbing method [12–14], mechanical grinding method [15] and ultrasonic treatment method [16] etc.

C. Jaw Crusher:

Jaw Crusher is also called **Broken Jaw**. The Characteristics of this series of crushers are simple structure, reliable working condition, easy maintenance, low cost of the producing and maintaining. **Jaw Crusher machine** is widely used in mining, metallurgy, building material and chemical industry. Fig 1 shows the schematic diagram of jaw crusher.

Figure 1 : Schematic diagram of Jaw Crusher



D. Nitric Acid dissolution Method:

Nitric Acid Dissolution Method was adapted from the work of Movassaghi [3] and involves immersing the RCA in a 20% (by volume) nitric acid solution and heating it until the adhered mortar starts to dissolve (approximately two hours), leaving behind the original aggregate. However, after the test was completed significant amounts of adhered mortar remained attached to both RCA samples. In addition, the nitric acid dyed some of the aggregates a yellowish colour which may indicate the presence of limestone in the original aggregate. Although significant mass loss occurred, the remaining mortar was still firmly attached to the original aggregates for both the RCA-1 and RCA-2. In an attempt to remove the remaining cement mortar by mechanical friction, the samples were subjected to 15 minutes in the Micro-Deval apparatus. This process however, was unsuccessful at removing the remaining adhered mortar. This suggests that this method dissolved the outer layer or surface of the adhered mortar but failed to breakdown the mortar- aggregate bond. It is possible that longer exposure at higher concentrations of nitric acid could dissolve greater amounts of the remaining cement mortar, although this may also dissolve the original limestone aggregate if present. Although the test was unsuccessful at removing the total adhered mortar amounts it is important to note that significant mass losses of 20% and 32% were recorded for RCA-1 and RCA-2, respectively.

II. EXPERIMENTAL PROGRAM

Research Scope

- To study the strength properties of concrete made with recycled aggregate after incorporating water washing and pre-soaking treatments using nitric acid.

Materials Used

- *Cement*: The Portland Pozzolana Cement conforming will used for the preparation of test specimens.
- Fine Aggregate: The fine aggregate used in this experimental investigation will natural river sand.
- Natural Coarse Aggregate : Crushed granite aggregates particles passing through 20mm and retained on 4.75mm I.S sieve will used as natural aggregates
- Recycled Coarse Aggregate : Crushed concrete aggregate waste passing through 20mm and retained on 4.75mm I.S sieve will used as recycled coarse aggregate in some proportion (20%, 30%, & 40% of N.A.).
- Water: Portable water available in laboratory will use for mixing and curing the concrete specimens.
- Pre Soaking Treatments: The recycled aggregates will crushed and soaked in water for 24 hours for water treatment then kept for drying. Similarly the recycled aggregate soaked with diluted nitric acids separately and then those aggregates will used for casting of concrete cubes.
- Acid Properties: The acid which highly concentrated so 0.1ml of concentrated acid will mixed with 150 ml of water from bases of previous research paper [3] . Specifications of nitric acid are shown in table.1.

Table 1: Properties of Nitric Acid

Molecular formula	**Nitric Acid (HNO3)**
Appearance	Colourless
Density	1.512 g/cm3
Solubility in water	Miscible with water
Acidity	-1.64
Viscosity	2.6 at 68 F
Molecular weight	63.01g/mol

Table 2 : Details of Mix Design

Sr. No	Notation	W/C	Water	Cement	N.C.A. (Natural Coarse Ag.)	N.F.A. (Natural Fine Ag.)	Recycle Coarse Agg.)
1	N.A. (Natural Agg.)	0.50	186	372	1117	737	--------
2	R20 (20% Replacement of R.A.)	0.50	186	372	893.6	737	223.4
3	R30 (30% Replacement of R.A.)	0.50	186	372	781.9	737	335.1
4	R40 (40% Replacement of R.A.)	0.50	186	372	670.2	737	446.8
5	R20W (20% Replacement of R.A. With Water treatment)	0.50	186	372	893.6	737	223.4
6	R30W (30% Replacement of R.A. With Water treatment)	0.50	186	372	781.9	737	335.1
7	R40W (40% Replacement of R.A. With Water treatment)	0.50	186	372	670.2	737	446.8
8	R20N (20% Replacement of R.A. Treated With Nitric Acid)	0.50	186	372	893.6	737	223.4
9	R30N (30% Replacement of R.A. Treated With Nitric Acid)	0.50	186	372	781.9	737	335.1
10	R40N (40% Replacement of R.A. Treated With Nitric Acid)	0.50	186	372	670.2	737	446.8

Table 3 : Details of Mix Specimens

Sr.No	Notation	Cube (Nos)	Cylinder (Nos)
1	N.A. (Natural Agg.)	6	6
2	R20 (20% Replacement of R.A.)	6	6
3	R30 (30% Replacement of R.A.)	6	6
4	R40 (40% Replacement of R.A.)	6	6
5	R20W (20% Replacement of R.A. With Water treatment)	6	6
6	R30W (30% Replacement of R.A. With Water treatment)	6	6
7	R40W (40% Replacement of R.A. With Water treatment)	6	6
8	R20N (20% Replacement of R.A. Treated With Nitric Acid)	6	6
9	R30N (30% Replacement of R.A. Treated With Nitric Acid)	6	6
10	R40N (40% Replacement of R.A. Treated With Nitric Acid)	6	6

Table 4 : Initial Properties of N.A, R.A., & T.R.A.

Test	Result RA	Result TRA	Results NA
Specific Gravity	2.46	2.54	2.68
Apparent Specific Gravity	2.41	2.48	2.65
Water Absorption (%)	5.10	1.8	0.9
Bulk Density (kg/m3)	127	131	151
Flakiness Value (%)	24.25	24.25	13.5
Elongation Value (%)	22.20	22.20	16.2

Table 5 : Mechanical Properties of N.A, & R.A.

Test	Result RA	Results NA
Crushing Value	25.13%	15.5 %
Impact value	17.6 %	8.7 %
Abrasion Value	26.5 %	16.2 %
IS Limit for Road	30 %	
IS Limit for Building	45 %	

Table 6 : Average Test Result of Specimens

Sr. No	Notation	Compressive Strength	
		Compressive Strength	Split Tensile Strength
1	N.A. (Natural Agg.)	27.61	2.78
2	R20 (20% Replacement of R.A.)	22.24	2.27
3	R30 (30% Replacement of R.A.)	21.22	2.18
4	R40 (40% Replacement of R.A.)	20.35	2.08
5	R20W (20% Replacement of R.A. With Water treatment)	22.82	2.45
6	R30W (30% Replacement of R.A. With Water treatment)	21.65	2.31
7	R40W (40% Replacement of R.A. With Water treatment)	20.93	2.27
8	R20N (20% Replacement of R.A. Treated With Nitric Acid)	26.60	2.50
9	R30N (30% Replacement of R.A. Treated With Nitric Acid)	25.14	2.41
10	R40N (40% Replacement of R.A. Treated With Nitric Acid)	24.71	2.31

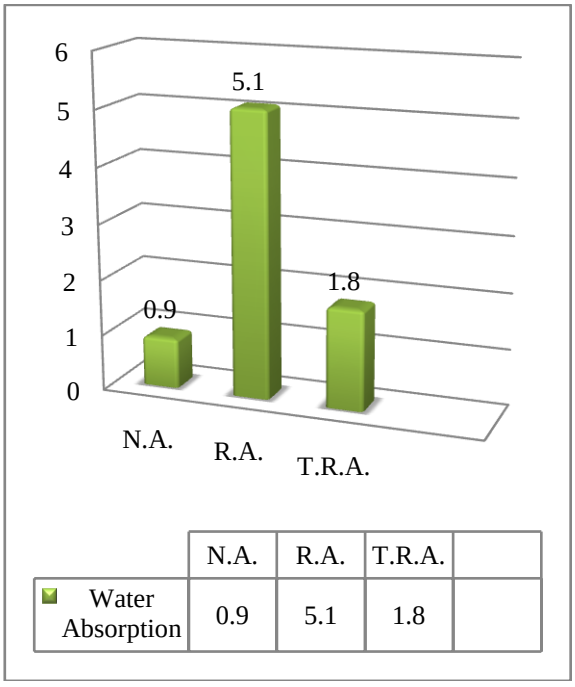


Figure 2 : Variations in Water Absorption

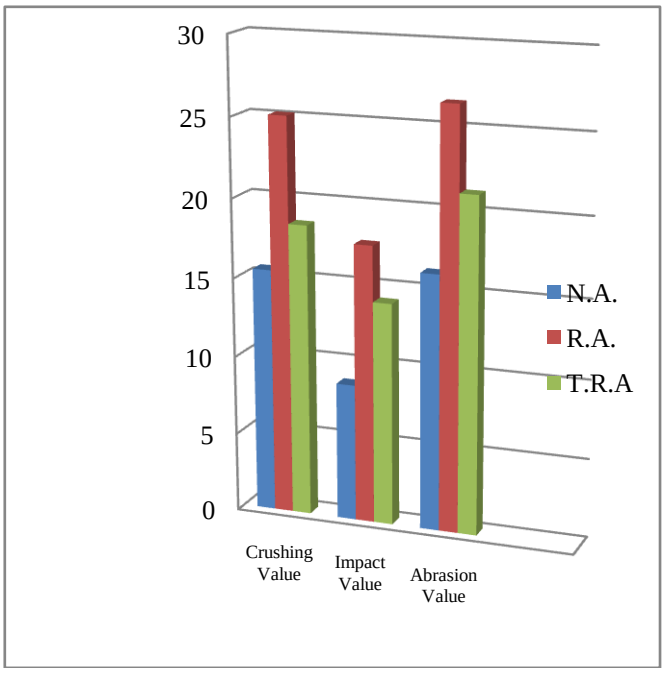


Figure 3 : Mechanical Properties Vs Types of aggregate

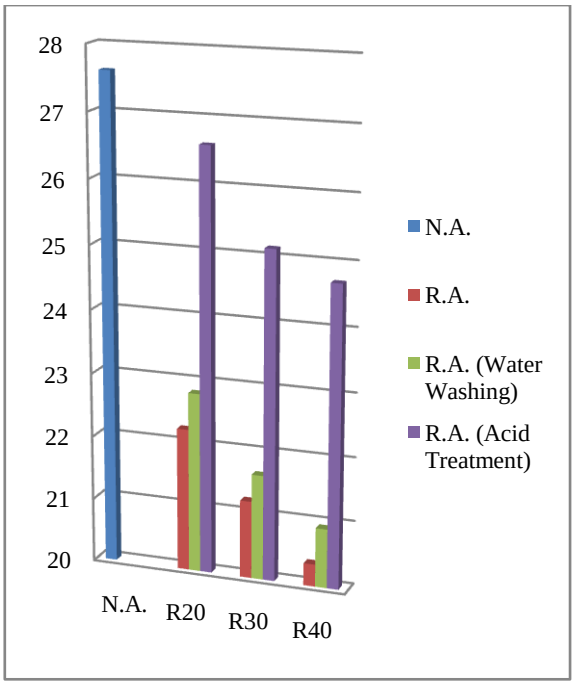


Figure 4 : Compressive Strength of Concrete Vs Type of aggregate

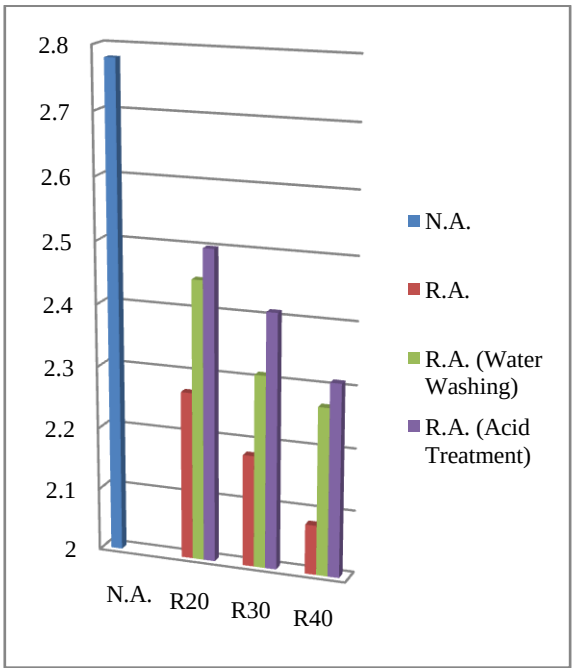


Figure 5 : Split Tensile Strength of Concrete Vs Type of aggregate

III. CONCLUSION

Based on the results obtained from the experiment the following conclusions are drawn

- The test results showed that the water absorption, impact value, crushing value, abrasion value are decreased by nitric acid treatment.
- The test results showed that the compressive and split tensile strength of the recycled aggregate concrete is found to be lower than the natural aggregate. However the strength of recycled aggregate concrete can be improved by the water and acid treatments.
- Furthermore Recycled aggregate treated with nitric acid displayed the decent result compared to water treatment. Water treated recycled aggregates can be used in place of natural aggregates for temporary structures.
- From the above results, Compressive and split tensile strength of 20% replacement recycled aggregate is found to be higher than the 30% replacement as well as 40% replacement.
- The test results showed that the compressive and split tensile strength of the recycled aggregate concrete is decreased with increase replacement percentage.
- From the above results, R20N (20% replacement recycled aggregate with nitric acid treatment) group gives the maximum strength results compare to other group.

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