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MECHANICAL PROPERTIES OF NORMAL CONCRETE USING TREATED RECYCLED CONCRETE AGGREGATE

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ABSTRACT
This research includes a practical study to investigate the mechanical characteristics of normal concrete using recycled concrete aggregate in both states (cured and untreated conditions). The laboratory work involves the process of recycling concrete aggregate by crushing it to the required size, then the treatment process for recycled aggregates is carried out by soaking in dilute hydrochloric acid for (24) hours, then soak it in water for another (24) hours, then it is air-dried to be ready for treatment with (sodium metasilicate pentahydrate) solution for one hour. After that casting control samples (standard cubes 15 * 15 cm, standard prism 10 * 10 * 50 cm, standard cylinders 15 * 30 cm). The experimental results show that the treatment effect for recycled aggregates improves compression strength by (5.4 %) and splitting tensile strength by (5.3 %) and modulus of rupture by (8.3 %) and modulus of elasticity by (0.7 %) compared to the normal aggregate.

KEYWORDS: mechanical properties, mechanical characteristics, treated recycled concrete aggregate.

INTRODUCTION
{1} one of the sustainable solutions to the problem of increasing construction waste as well as the problem of depletion of non-compensable natural sources of aggregates is the recycling of concrete construction waste.
There are several benefits to reusing the Construction and Demolition wastes can be summarized in several points:
1) Used for on-site and pre-cast casting for parking gutters and crips.
2) Saving costs.
3) Environment's conservation.
4) Time saving, no waiting with regard to material availability.

There are several disadvantages to the process of recycling the construction wastes can be summarized in several points:
1) Less quality.
2) The quality of the materials might impact the project's lifecycle.
3) Special equipment and land are needed.
4) The water absorption will be high.

Many techniques to improve RCA's properties include reducing attached mortar content and strengthening the adhered mortar. Mechanical grinding {2}, selective heat grinding {3} in addition to the heat grinding {4} have been typical techniques with regard to the mechanical grinding. A study conducted by {5} used ultrasonic water cleaning repeatedly for the purpose of removing weak adhered mortar till the water becomes clear. {6} using acidic solution for removing adhered mortar efficiently as well as enhancing RCA's quality. A study conducted by {7} applied silane-based polymers for treating RCA. {8} replaced 2% regarding needed cement by the silica fume in the premixing process. {9} used the method of bio-deposition for RCA's treatment with the use of bacteria referred to as S. pasteurii, that have been inoculated with certain liquid culture medium that has been obtained from urea. {10} utilized sodium silicate solution for

soaking RCA for a period of 1 hour, 5 hours, in addition to 24 hours. {11} Utilizing CO2 for the pretreatment regarding RCA has been not just effective approach to enhance RCA's properties. In this research, hydrochloric acid solution (HCL) was used as a first stage to reduce and remove weak mortar on the recycled aggregate and then use a polymeric solution (sodium metasilicate pentahydrate) to improve adhered mortar on recycled aggregates.

EXPERIMENTAL WORK

The work involved the use of three different mixtures (NA, RA, TRA), where it was casting three Standard cubes(15 * 15 * 15)cm and three standard cylinders(15 d * 30 h)cm in addition to prisms (10 * 10 * 50)cm for each mixture. Table 1 showing a mix proportion for each mixture.

Table 1. Mix Proportion (in Weight) Used in Concrete Beams Mixtures

Group Name	Cement	Sand	Coarse aggregate	Water
NA	1	2	3 Normal Aggregate(100%)	0.45
RA	1	2	3 Recycled Aggregate(100%)	0.45
TRA	1	2	3 Treated Recycled Aggregate(100%)	0.45

MATERIALS

1. Cement

Tasluoja Ordinary Portland cement (Type1) has been utilized in the presented study. The chemical properties, the main cement compounds (Bogue's Equation), and the physical properties have been listed in tables 2, 3 and 4 respectively; confirm with the specification limit of Iraqi specification Iraqi Standard Specification {12}.

Table 2. Cement Chemical Composition

Oxide Composition	Abbreviation	Content by Weight (%)	Limit of Iraqi Specification No.5/1984[38]
Loss on ignition	L.O.I	2.72	4 (Max)
Silica	SiO_2	20.37	-
Alumina	Al_2O_3	5.15	-
Iron oxide	Fe_2O_3	4.39	-
Sulfate	SO_3	2.57	2.8 (Max)
Lime	CaO	63.11	-
Magnesia	MgO	1.68	5 (Max)
-	Total	99.99	-
Free lime	Free Lime	1.12	-
Lime saturation factor	L.S.F	0.92	0.66-1.02
Insoluble	I.R	0.69	1.5 (Max)

Table 3. Major Compounds regarding Cement (Bogue's Equation)

Compounds of Cement	Abbreviation	Content
Tri.calcium Aluminate	C3A	6.22
Tri.calcium Silicate	C_3S	49.23
Di.calcium Silicate	C_2S	21.5
Tetra.calcium Aluminoferrite	C_4AF	13.34

Table 4. Cement's Physical Properties

Physical Properties	Test Results	Limits of Iraqi Specification No.5/ 1984 [38]
Specific surface area(Blaine method), (cm2 /g).	4426	≥ 2300
Setting time (vicar's apparatus): • Initial setting time (hrs: min: sec.) • Final setting time (hrs: min.).	 0:3:10 5:00	 ≥ 0:0:45 < 10:00
Compressive strength, (MPa) 3 days 7 days	 24 32	 ≥ 15 ≥ 23

2.Fine Aggregate

In Iraq, specifically in the AL-Ukhaider region/Karbala, the natural sand has been applied as a fine aggregate in the presented work, which has 2.6 as Fineness Modulus (F.M). Fine aggregate's grading has been subjected to checking based on Iraqi Standard Specifications {12}. Table 5 is showing sieve analysis related to the fine aggregate. Table 6 indicates the fine aggregate's physical characteristics that have been conducted through the lab of construction materials in AL-Mustansiriya University/ college of engineering.

Table 5. Fine Aggregate Sieve Analysis

Sieve size mm	% passing by weight	Limits of Iraqi standard specification No. 45:1984 (Zone 2)
9.5	100	100
4.75	100	90-100
2.36	90.3	75-100
1.18	78.3	55-90
0.6	55.2	35-59
0.3	21.5	8-30
0.15	6	0-10
Pan	0	-

Table 6. Physical Characteristics of Fine Aggregate

Physical properties	Test result	Limit of Iraqi specification No.5:1984
Specific gravity	2.63	-
Absorption	4%	-

COARSE AGGREGATE

a) Natural Coarse Aggregate (NCA)

Angular gravel (crushed gravel) of 20mm as maximal size which has been taken from the region of AL-Niba´ee (in the Iraqi governorate of AL-Anbar,) has been utilized in the presented work. Table 7 is showing sieve analysis related to NCA, which is bound by Iraqi Standard Specification {12}. Table 8 indicates such aggregate's physical properties.

Table 7. NCA Sieve Analysis

Sieve size mm	% passing by weight	Limits of Iraqi standard specification No. 45:1984
20	100	95-100
14	----	----
10	60	30-60
5	10	0-10
2.36	0	----

Table 8. Physical Characteristics of NCA

Physical properties	Test result	Limit of Iraqi specification No.5:1984
Specific gravity	2.67	----
Absorption	1.4 %	----

Recycled Coarse Aggregate (RCA)

With regard to the presented work, the crushed coarse aggregate utilized is considered to be caused by breaking concrete wastes from construction laboratory waste. Table 9 show the sieve analysis of RCA based on Iraqi Standard Specifications No45: 1984, table 10 indicates the physical characteristics which are related to RCA.

Table 9. Sieve Analysis regarding RCA

Sieve size mm	% passing by weight	Limits of Iraqi standard specification No. 45:1984
20	100	95-100
14	----	----
10	60	30-60
5	10	0-10
2.36	0	----

Table 10. Physical Characteristics of the RCA

Physical properties	Test result
Specific gravity	2.594
Absorption	5.22 %

WATER

Tap water at the laboratory is utilized for the mixing, as well as the curing of the concrete.

HYDROCHLORIC ACID (HCL)

HCL can be defined as one of the colorless inorganic chemical systems that have the formula of (H2O: HCL). Furthermore, it has a characteristic pungent odor. Pre-soaking recycled aggregate with HCL enhanced the RCA's mechanical properties through eliminating loose or weak mortar, and this will enhance the efficiency regarding recycled aggregate; {13} suggested that the concentrations regarding the applied solution must be low, also the best concentration has been (0.5M). Thus, with regard to the presented work, RCA is going to be immersed in HCL at 0.5 mol (M) concentration as shown in figure 1.

Fig. 1: Immersed RCA in Hydrochloric Acid (HCL)

SODIUM METASILICATE PENTAHYDRATE($Na_2Sio_3.5H_2O$)

Sodium metasilicate has been created through the fusion regarding sodium carbonate (soda ash) with silica sand or SiO2 in proper stoichiometric ratios. This will take place at a temperature of 1400 Celsius. The sodium metasilicate pentahydrate can be considered as one of the alkaline cleaning agents which is extensively utilized in industrial sectors and household. Tables 11 and 12 are showing physical and chemical composition. Sodium metasilicate will be providing alkalinity as well as silica in a molar ratio (1:1) between the sodium oxide as well as silica, that will make it appropriate for hard surface cleaning in addition to the characterization to have: (1) high ratio of dissolution; (2) increased mechanical strength; (3) reduced dust content; in addition to (4) insignificant insoluble {14}. The sodium metasilicate pentahydrate has been utilized via {15} to fill RCA porous network with no hydrophobic impacts to obtain reduced water absorption as well as excellent fragmentation resistance.

The solution of sodium metasilicate pentahydrate has been applied in the presented work as can be seen in figure 2 for coating RCA's surfaces for the purpose of filling cracks and pores throughout the physical surface, also it has been suggested for improving the bond strength between the aggregate as well as the cement matrix due to the fact that it is functioning as filler with cement hydration's product.Table 11.Physical Composition of Sodium Metasilicate Pentahydrate

Property	Information
Physical State	white, free-flowing granules
Melting Point (o C)	72.2
Density (g/cm3)	1.75
Specific gravity (g/cm3)	0.90

Table 12. Chemical Composition of Sodium Metasilicate Pentahydrate

Property	Information
SiO2	28.5
Al2O3	----
Fe2O3	----
CaO	----
Na2O	28.5
H2O	45.5
pH	12.5

Fig. 2: Presoaking RCA in Sodium Metasilicate Pentahydrate Solution

RESULTS AND DISCUSSIONS

There have been four essential characteristics of the hardened Concrete; which are, compressive strength (f′c), elasticity modulus (E_c), splitting tensile strength (f_t), and rupture modulus (f_r). Each value of these properties was the average of three control specimens obtained at the age 28 days and the result summarized in table 13. Figures (3, 4, 5, and 6) show the effect of the use recycled aggregate in both states (treated and untreated) on mechanical properties of hardened concrete.Table 13.Mechanical Properties Results for all Mixtures at the Age of 28 DaysGroup Name	f′c (MPa)	f_t (MPa)	fr (MPa)	Ec (MPa)
NA	27.3	2.616	2.616	2.616
RA	24.5	2.262	2.262	2.262
TRA	26.0	2.404	2.404	2.404

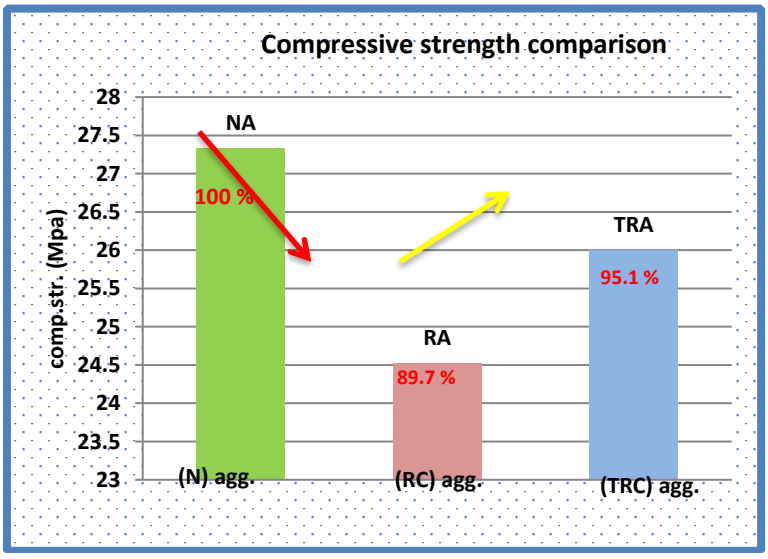

Fig. 3: Comparison of Compressive Strength when Using Treated & Untreated (RCA) aggregates

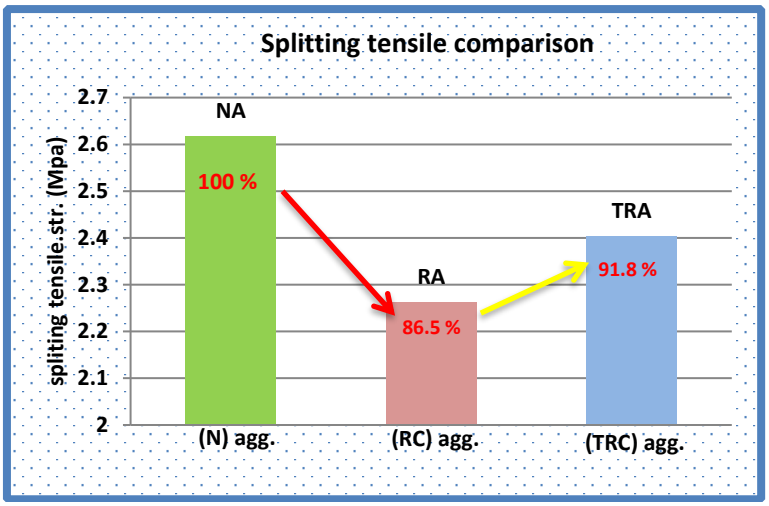

Fig. 4: Comparison of Splitting Tensile Strength when Using Treated & Untreated (RCA) aggregates

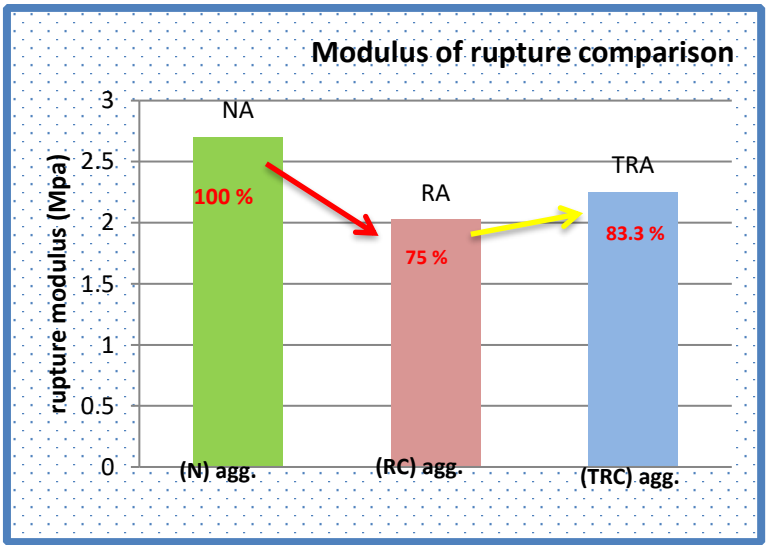

Fig. 5: Comparison of Rupture Modulus Strength when Using Treated & Untreated (RCA) aggregates

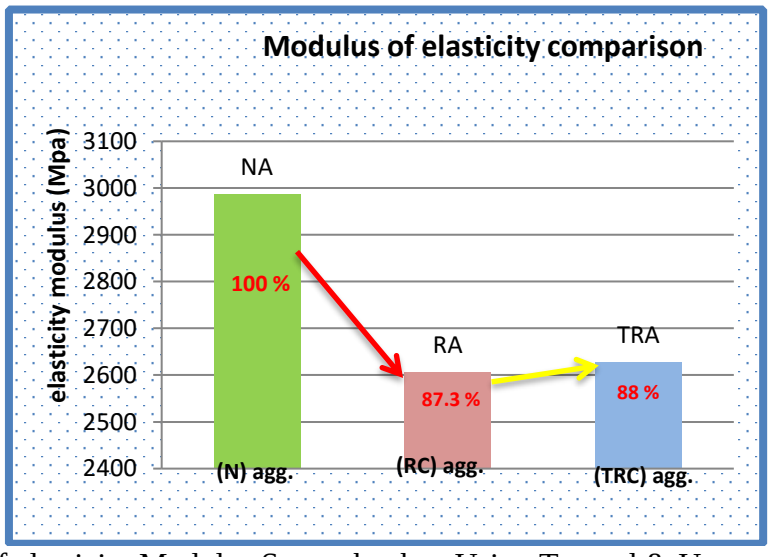

Fig. 6: Comparison of elasticity Modulus Strength when Using Treated & Untreated (RCA) aggregates

CONCLOUSION

1) The compression strength before treatment is (89.7%) of the compression strength of the reference mixture and becomes (95.1%) after treatment.
2) The splitting tensile strength before treatment is (86.5%) of splitting tensile strength that is related to reference mixture and becomes (91.8%) after treatment.
3) The modulus of rupture before treatment is (75%) of modulus of rupture for the reference mixture and becomes (83.3%) after treatment.
4) The modulus of elasticity before treatment is (87.3%) of modulus of elasticity for the reference mixture and becomes (88%) after treatment.

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