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PROPERTIES OF NORMAL STRENGTH CONCRETE WITH TREATED CRUSHED BRICK AND RECYCLED CONCRETE AS COARSE AGGREGATE

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Abstract: The results of a research program conducted at the University of Mustansiriayah in Iraq to analyze the qualities of concrete created with crushed bricks and crush concrete are presented in this paper. To make a suitable aggregate, these materials were crushed. Some aggregates were treated, while others were not. The properties investigated were the workability and the density of fresh the aggregates of crushed bricks and crush concrete were treated in some mixtures and others were not treated. The properties investigated were the workability and the density of fresh concrete, and the compressive strength and tensile splitting strength behavior of hardened concrete. Different replacement ratios (0, 50%, and 100%) were investigated. The concrete rustles produced with recycled aggregates were compared with a reference concrete produced with natural coarse aggregates currently used in Iraq. Using surface treatment with silicate solution, when comparison to RCA50 and RCA100 samples, TRCA50 and TRCA100 compressive strength improved by roughly 5.05 percent and 5.9 percent after 28 days, respectively. And came closer to concrete with natural aggregate R, and improved 3.25% and 4.6% in TBR100 and TBR50, respectively compared. With the BR100 and BR50 respectively, they added a cross resistance of R for TRAC100% when silica fume was added, approaching R at TBR100%. Aggregates indicate that this type of concrete can be used in various precast applications.

Keywords: *recycled concrete aggregates, crush brick, mechanical properties, normal concrete*

1. Introduction:

Concrete is the most widely used building material in the world, and demand for construction is increasing as the world's population expands. To satisfy this need, natural resources used as construction materials in concrete structures are growing. As just a result, it has a severe detrimental impact on the ecosystem and decreases the availability of natural resources. More significant, the huge quantities of waste concrete generated by demolished concrete structures pose significant sustainability concerns in terms of processing and transport. These ramifications highlight the importance of developing efficient environmentally friendly tools and establishing the basic principle of using recycled coarse aggregates (RCA) in construction [1]. Studies on the use of RCA for concrete applications and pavement stabilization schemes have recently been conducted [2–4]. RCA will surely reduce the carbon footprint caused by rapid construction development, which will benefit the concrete sector. [5]

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However, due to military activity in those countries, the amount of demolition waste is expanding at an alarming rate throughout Iraq and the Middle East. Furthermore, in those states, there really is no record of the amount of demolition wastes produced, and there are insufficient financial resources to dispose of the wastes, resulting in a significant detrimental environmental impact, public health, and safety. As a result, using such wastes in concrete projects would help both the economy and the environment.

2. Behavior of RCA

The material behavior of RCA (fresh and hardened concrete behavior containing RCA) is not as expressively influenced by RCA integration as the structural behavior of reinforced concrete containing RCA. The tensile-splitting action of compound concrete was studied by Wu et al. (2018) [4]. Two sets of experiments were carried out. DCLs were applied to both series of collapsed concrete lumps. They discovered that: (1) the adverse effect of the DCLs on the compound concrete's combined tensile-splitting strength did not increase significantly as the disparity between the compressive strengths of the fresh and demolished concrete grew; (2) The ratio of the combined tensile-splitting strength to the combined compressive strength for compound concrete containing normal-strength FC I (41 - 43 MPa) was usually similar to that for traditional normal-strength concrete, but for compound concrete containing high-strength FC II (53 - 65 MPa), the ratio was roughly 1.1 times that for conventional high-strength concrete. Ozbakkaloglu et al. (2018) [5] published a report on concretes' mechanical and longevity properties made from various sizes and contents of recycled aggregates. Their findings indicate that as the recycled aggregate replacement ratio increases, the compressive strength of RAC decreases for a given w/c ratio. In addition, as the RCA percent was increased, the flexural and separating tensile strengths of both NSC and HSC blends decreased. Because of the old cement mortar added to RCA, it has a greater ability to trap water than normal aggregates (NA). This property would reduce RCA's workability, strength, and longevity, which would limit its use in SCC [22]. The impact of RCA integration on the mechanical and toughened properties of SCC is influenced by a number of factors, including the mix proportion and RCA substitution percent, RCA sources, crushing technique, RCA size and quality, and extra materials. According to Revathi, Selvi [6], the compressive strength of SCC containing RCA with substitution percentages of 50% and 100% decreased by 4.1 percent and 16.3 percent, respectively. Etxeberria and Mari claim that [7], compressive strength reduced by 20–25 percent when coarse RCA was replaced entirely, but there was no noticeable change when only 25% of the RCA was replaced. Furthermore, Tensile strength was discovered to be reduced by integrating RCA with a value of 16.8 to 58.5 percent and increasing the substitution percentage from 25 to 100 percent [8]. It is critical to find a suitable solution to overcome the undesirable properties caused by the use of RCA in concrete. Several studies [9,10–12] RCA quality has been achieved by removing attached mortar or stretching adherent mortar. In the first way to remove the previous adhering mortar, RCA is frequently pre-soaked in different acids such as HCl, H2SO4, or H3PO4. On the other hand, when a hazardous acidic solvent is used, disposal waste is produced [13]. The second method comprises improving RCA quality without removing the adherent cement mortar by utilizing a surface modification, such as coating [14]. Polyvinyl Alcohol [16], Alkaline organosilicon modifiers [22], silicate-based solutions [17], Microbial carbonate precipitation [15], silane-based water repellent [30], Polyvinyl Alcohol [16], Alkaline organosilicon modifiers [22], Carbonation [19], silicate-based solutions [17], pozzolanic composites [18], and silicate-based solutions [17],are all coating materials that have been used to increase the efficiency of RCA to varying degrees of success. While the approaches discussed above may improve RCA qualities, they also have significant environmental repercussions, limiting their application. Pozzolanic additives have recently attracted increasing attention as useful admixtures for preventing alkali-silica reaction events. Ca(OH)2 is consumed in the pozzolanic process, resulting in hydrated calcium silicates with a low C/S ratio [20]. To enhance the RCA's structure, Katz [21] recommended impregnating it with a silica fume solution, particular the interfacial transition zone (ITZ) between both the RCA as well as the cement paste, to improve the structure of the RCA section. According to Spaeth and Djerbi Tegguer [28], a silicon-based polymer surface coating considerably reduced the water absorption of RCA aggregates. The mechanical parameters of RCA, including as compressive strength, split tensile strength, and modulus of elasticity, were checked to determine the effect of the treatment solution presented in this work. The purpose of this investigation was to see how the RCA substitution level, as well as surface treatment with sodium metasilicate pentahydrate for brick debris and HCL and sodium metasilicate pentahydrate for broken concrete, affected the behavior of hardened samples.

3. Experimental Program

3.1. Materials

Ordinary Portland cement and natural fine aggregate were used as the building materials (sand). Natural coarse aggregate was mixed with RCA replacement ratios of varying degrees. Both NA RCA and BR have the same gradation zone and meet the specifications of (Iraqi specification No.45/1984) [23]. Manual grinding of concrete cubes from previous laboratory research was used to create the recycled aggregates and brick Iraqi Republican. Using sieves, the crushed concrete was divided into two sizes (10 to 14 mm and 5 to 10 mm), and these two fractions were combined in proportions to achieve scores comparable to natural aggregates (see Tables 1 and 2).

Table 1. Mix design Proportion ratios.

Material	Content (kg/m3)
Cement	430
Coarse Aggregate	990
Fine Aggregate	166
Water/cement ratio	0.45

3.2. Concrete Mixes

The NA and RCA suppliers each received a 14 mm rating. A reference concrete (NAC) and twelve combinations combining RCA plus BR, as well as treated RCA (TRCA) and treated brick (TBR), were made according to Table 1. Furthermore, the water to cement material (cement) ratio was 0.45. To see how percentage substitution for RCA and BR affected the results, the NA was substituted with 50% and 100% (by weight) of RCA. TRCA50, TRCA100, TBR50, and TBR100 blends indicated mixtures with TRCA with 50 percent and 100 percent substitution, respectively. RCA50, RCA100, BR50, and BR100 samples were referred with 50 percent and 100 percent replacement, respectively, and TRCA50, TRCA100, TBR50, and TBR100 blends indicated mixtures with TRCA with 50 percent and 100 percent substitution, respectively. Moreover, the treated mixture was compared with a mixture of silica fume added in different proportions (10%,20%).

3.3. Treatment Procedure for RCA

The treatment process was done by soaking the aggregates resulting from the cracking process of concrete in hydrochloric acid for a period of 24 hours, it was washed well with water, after that it was placed in sodium metasilicate pentahydrate for one hour, as well as the crushed bricks were placed into the same material to reduce porosity as well as reduce water absorption, then it was left exposed. To air until its surface is not moist as shown in figure (1).

Figure 1. Treatment Procedure for RCA

3.4. Physical and Mechanical Tests

3.4.1. Slump Test

The importance of fresh concrete research in this project can be summarized as follows: The slump test is used to assess the fresh characteristics of standard concrete in this analysis. The slump test is the most commonly used method for determining the workability, consistency, and filling ability of fresh concrete on construction sites and in laboratories.

3.4.2. Testing of Hardened Concrete Specimens

3.4.2.1. Compressive Strength Test

The test specimens' failure stress under uniaxial compression was determined using a compressive strength test. According (BS 1881:part116) [24], for this study, three 150 mm cube specimens each batch of concrete mix were constructed. Testing 28 days of age were used to monitor the development of compressive power.

Figure 2. Cube before Compressive strength test.

3.4.2.2. Tensile Splitting Strength Test

Laboratory analysis of a concrete cylinder (150mm*300mm) was conducted based on these results (BS 1881: part 117) [25]. After 28 days, a cylinder was moist cured in water and placed to the test with the compressive load. The test was conducted by placing the cylinder sample horizontally between the loading surface on the compression test unit and applying the load before the cylinder fails vertically.

Figure 3. Tensile splitting strength test

3.4.2.3. Flexural Strength Test

The aim of this test was to determine the flexural strength of hardened concrete using simple prisms and four -point loading. After 28 days, each batch of concrete has one prism specimen

(100*100*500 mm) examined in accordance with (ASTM C78-02) [26] (3-21).

Figure 4. Flexural strength test

4. Test Results and Discussion

4.1. Slump Test

Every batch of concrete was subjected to a slump test, which was documented and displayed in Table 3. The control mix had a 170 mm slump displacement, while the URCA100 replacements had a 150 mm slump. URAC50 percent had a slump of 160 mm, which was 6% lower than the reference mix. The lowest slump, 150mm, was reported with URAC 100 mixture. The control mix had a slump measurement of 170 mm, while the UBR100 replacement had a slump measurement of 100 mm. When compared to the control mix, the slump for URAC50 percent was 120 mm, which was 30% lower. The UBR100 mixture had the lowest slump, measuring 100mm. The porosity of RCA contributes to this, as it absorbs more water and lowers workability. It was revealed that treating RCA with silicate solution resulted in an increase in a slump due to a reduction in water absorption when compared to untreated RCA samples. As a result of the findings, it can be concluded that as the RCA mixing ratio grew, the slump reduced. Only as result, most of the free water has evaporated, and the degree of cement hydration has decreased. Compaction and surface finish on the UBR100 percent concrete proved tough due to its limited workability and dry character.

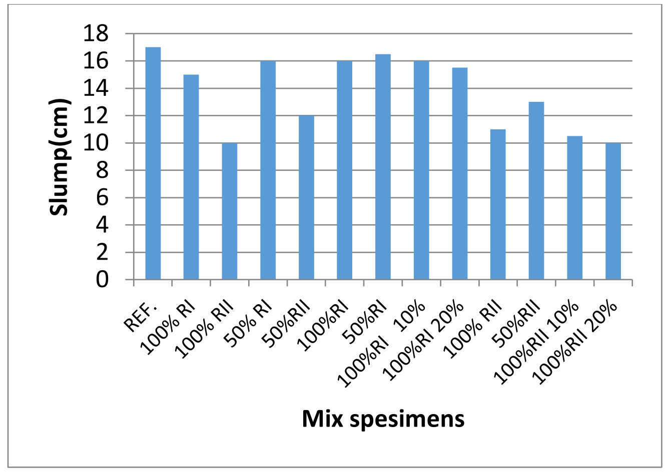

Figure 5. Slump results

Table 2. Slump and density Test Value

Group no.	Replacement amount of RCA(%)	Admixtures for concrete(%)	Slump test value(cm)	Oven Dry Density(kg/m	S.S.D Density (kg/m3)
Without treatment					
R	0%	----	17	2900	2770
URAC100 %	100% RI	----	15	2781	2680
UBR100%	100% RII	----	10	2302	2250
URAC50%	50% RI	----	16	2877	2755
UBR5**0%**	50%RII	----	12	2564	2421
Treatment With (HCL & Na2SiO3.5H2O)					
TRAC100 %	100%RI	----	16	2777	2680
TRAC50%	50%RI	----	16. 5	2876	2733
RAC S10%	100%RI	10%	16	2787	2688
RAC S20%	100%RI	20%	15. 5	2799	2713
Treatment With (Na2SiO3.5H2O) Only					
TBR100%	100% RII	----	11	2400	2240
TBR50%	50%RII	----	13	2560	2420
BR S10%	100%RII	10%	10. 5	2412	2250
BR S20%	100%RII	20%	10	2430	2267

I: the source of RCA from concrete masse
II: the source of RCA from s. the brick crash

4.2. Density

As a result of the test, the particulate density of RCA and BR at saturated surface dry conditions was found to be 2781 and 2302 kg/ m3, respectively. Because ancient mortar adheres to original aggregate particles or the brick itself with a low density, it was somewhat lower than NA's density of 2900kg/m3. Furthermore, there was a difference of about 4% and 17% between the two groups. When RCA and BR were dried in the oven, they had a higher density than NA. All mixes have densities ranging from 2781 to 2095 kg/m3, with the RCA&BR samples having a lower density compared to the control sample (NAC). As a result, the RCA&BR and TRAC&TBR mixes' overall average density did not change significantly. Furthermore, with the inclusion of RCA % and RCA treatment, a relationship between overall density and the slump may be observed, and the slump and density patterns are comparable.

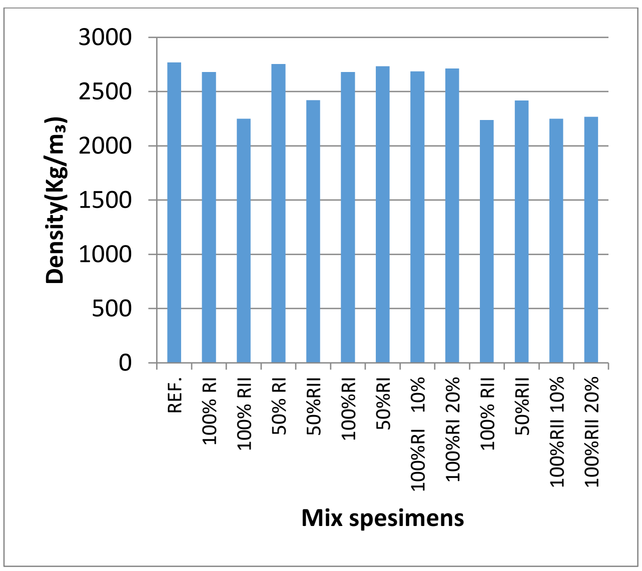

Figure 6. Density results

4.3. Compressive Strength Test

Table 9 shows the compressive strength test results for four different mixtures at 28 days from the same w/c ratio. It demonstrates that NA generated stronger concrete than RCA or/and BR concrete. The compressive strength was found to diminish as the BR substitution levels rose. The control mix's design strength was 35 N/mm2, as specified throughout the mix design computations. After 28 days, all of the mixes were determined to satisfy the design strength expectations. At 28 days, compressive strength dropped 10% and 38% from R to RC-100 and BR-100, respectively. At 7 days, compressive strength dropped 7% and 33% from R to RAC-50 and BR-50, respectively. When compared to the reference sample, RAC 50 and RCA100 fell by roughly 7% & 10%, respectively (NAC). This is consistent with recent studies that found that adding RCA to concrete affected its mechanical qualities [19, 20]. When compared to RCA50 and RCA100 samples, the surface treatment with silicate solution improved the 28-day compressive strength of TRCA50 and TRCA100 by around 5.05 percent and 5.9 percent, respectively. TBR100 and TBR50, respectively, improve 3.25 percent and 4.6 percent when comparing to BR100 and BR50, respectively. This was due to the reduction in RCA porosity following treatment. By filling the RCA and BR surface pores with silicate, the moisture content of RCA is reduced, and the old and new cement pastes in RAC are reinforced, resulting in stronger results. The surface treatment, on the other hand, revealed just a minor improvement in the TRCA100-TBR100 sample at both ages of 28 days.

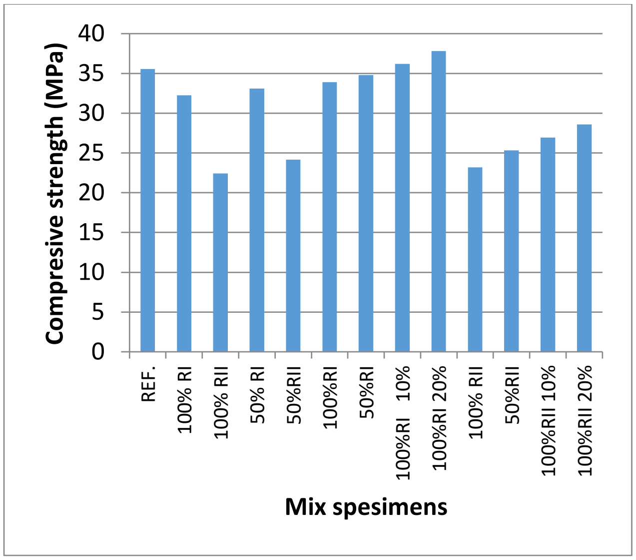

Figure 7. Compressive strength results

4.4. Tensile Splitting Strength Test

Table 3 shows the tensile splitting strength data. As the substitution content of the RCA's material or BR elements in the mixture increased, the cylinder splitting strength decreased. This strength trend in relation to substitution ratio was

Table 3. Mechanical properties

Group no.	Replacement amount of RCA(%)	Admixtures for concrete (%)	Compressive strength	Tensile splitting strength)	Flexural strength
Without treatment					
R	0%	----	35.5	3.25	3.88
URAC100 %	100% RI	----	32.2	3.11	3.67
UBR100%	100% RII	----	22.4	2.63	3.06
URAC50%	50% RI	----	33.8	3.29	3.78
UBR50%	50%RI I	----	24.1	2.72	3.17
Treatment With (HCL & Na2SiO3.5H2O)					
TRAC100 %	100% RI	----	33.8	3.15	3.77
TRAC50%	50%RI	----	34.7	3.29	3.83
RAC S10%	100% RI	10%	36.1	3.35	3.88
RAC S20%	100% RI	20%	37.8	3.43	3.94
Treatment With (Na2SiO3.5H2O) Only					
TBR100%	100% RII	----	23.1	2.68	3.11
TBR50%	50%RI I	----	25.3	2.81	3.27
BR S10%	100% RII	10%	26.3	2.88	3.33
BR S20%	100% RII	20%	28.8	2.97	3.43

I: the source of RCA from concrete masse
II: the source of RCA from s. the brick crash

quite similar to Evangelista and Brito's [37] published pattern, who argued that the recycled coarse aggregate's porous structure was to blame for the lower strength. The evolution of cylinder splitting strength as a function of curing time seemed to be less pronounced for 100 percent and 50 percent BR replacement levels, since the strength gain was minimal beyond 28 days. As shown in Table 10, the strength reduction from R mix to RAC100 and RAC50 was 5% and 3.27 percent, respectively, while the reduction for TRAC-100 and TRAC-50 mixture was only 2.11 percent and 0.8 percent, respectively; whereas the relative 28-day strength reduction was 20% and 17% for BR100 and BR 50, respectively. In addition, the tensile results for TBR100 and TBR50 indicated a rise of 19% and 15% MPs, respectively. Treatment with sodium-meta-silicate pentahydrate TRCA50's splitting tensile strength was comparable to that of NAC, as shown. It's worth noting that the proposed treatment approach increased the splitting tensile strength of RAC& BR by about 5-10%. When compared to the one that has not been treated.

4.5. Flexural Strength

In Table 3, the results of the flexural strength test were tabulated. The 28-day flexural strength of recycled concrete containing RCA100 and BR100 content was found to be only 5% and 20% lower, respectively. The flexural strength of the RAC50 and BR50 mixes was roughly 94 percent and 81 percent of the control mix, respectively, according to the data. As a result, concrete mixes having various BR replacement ratios had no significant effect on the flexural strength of recycled concrete, and they were allowed to be used up to 50% for recycled concrete fabrication. A research [36] reported nearly identical findings, however their research utilized tiles as an aggregate material. TBR100 and TBR50 were treated with sodium-meta-silicate pentahydrate and compared to untreated samples. TRCA50's splitting tensile strength being comparable to that of NAC, as shown. It's worth noting that the proposed treatment procedure increased the splitting tensile strength of RAC& BR by about 5-10% when compared to untreated one.

5. Summary

Using mix designs with the same w/c ratio and coarse aggregates composition, the impacts of RCA and BR aggregates on the physical and mechanical properties of fresh and cured concrete were examined but varied course aggregate compositions. The following are the findings reached as a result of this research:

1. Even after being cleaned properly in the recycled aggregate treatment plant, a limited quantity of waste impurities remains.
2. When the ratio of RAC & BR is increased, the density decreases, especially when the percentage of crushed bricks is increased, weakening the combination.
3. Compressive and cylinder splitting strengths would only be affected by changing the RAC material (0–50%–100%). Their effects on flexural intensity are negligible.
4. Only compressive and cylinder splitting strengths will be affected by changing the BR content (0–50 percent –100 percent). Their effects on flexural strength are minimal, although the treatment resulted in a significant rise.
5. The RCA change resulted in a significant decrease of workability, according to slump flow tests done on new mixtures. The slump of TRCA-containing mixes (TRCA50 and TRCA100 mixes) was higher than the slump of untreated RCA and the reference sample, and the slump of TBR-containing mixes (TBR50 and TBR100 mixes) was higher than the slump of untreated RCA and the reference sample.

Conflict of interest

The authors confirm that the publication of this article cause no conflict of interest**.**

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