Investigation on Fresh Properties of Concrete Made with Recycled Lightweight Aggregates from Demolished Bricks

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Abstract: Nowadays, research on the usability of recycled aggregate (RA) in concrete is gaining popularity in all over the world due to the preservation of the environment and sustainable development. RA can be obtained after crushing and screening of the construction rubble obtained from demolished structures. In this work, comparative analysis of the experimental results of the properties of fresh concrete with different replacement ratios of natural with recycled lightweight brick aggregate (RBA) is presented. It is found that the workability decrease as the RBA percentage increases, but it was improved by adding superplasticizer. The density of RBA concrete was decreased 13% maximum.

Keywords: Recycled Lightweight Aggregate, Recycled Brick Aggregate, Concrete Fresh Properties

1. Introduction

The problem of waste accumulation exists worldwide. Most of waste materials are left as a landfill material or illegally dumped. Environmental impact can be reduced by making more sustainable use of this waste. Waste management is one of the priorities of every community and it has become evident that good waste management can enhance the quality of life.

The main principle of a quality waste management is in lowering the mass production of new ways to recycle and reuse existing, and safe and ecologically acceptable depositing of unused waste. Recycling is the reprocessing of old materials into the new products, prevent the waste of potentially useful materials, reducing the consumption of raw materials. Recycling or re-using of bricks is an environmentally friendly way of eliminating it from the waste stream. Recycled brick aggregates recovered from demolished masonry structures can be utilized in the manufacture of new concrete mixtures. The special attention in this work is the use of aggregate from demolished lightweight bricks. A lightweight aggregate concrete from recycling is produced.

2. Literature Review

De Venny and Khalaf (1999) performed experimental and theoretical studies into the effects of using recycled aggregates to produce concrete instead of virgin aggregates. The aggregates used have been recycled from construction and demolition waste. The recycled aggregates were predominately made up of crushed bricks, but the aggregates did contain impurities such as timber and mortar. New test methods were presented in this investigation to determine brick porosity and water absorption. This involved the testing of broken brick fragments under vacuum, rather than the testing of whole brick units by 5hrs boiling or 24hrs submersion in cold water. The new test methods proved to be easy to perform and provided accurate results.

Sagoe-Crentsil, Brown, and Taylor (2001) carried out tests for fresh and hardened properties of concrete made with commercially produced coarse recycled concrete aggregate and natural fine sand.

Test results indicate that the difference between the characteristics of fresh and hardened recycled aggregate concrete and natural aggregate concrete is perhaps relatively narrower than reported for laboratory-crushed recycled aggregate concrete mixtures.

Rao, Jha and Misra.(2007) discussed different aspects of the problem beginning with a brief review of the international scenario in terms of construction and demolished (C&D) waste generated, recycled aggregates (RA) produced from construction and demolished (C&D) waste and their utilization in concrete and governmental initiatives towards recycling of construction and demolished (C&D) waste. Along with a brief overview of the engineering properties of recycled aggregates, the paper also gives a summary of the effect of use of recycled aggregate on the properties of fresh and hardened concrete.

Yang, Du and Bao (2010) addressed the problem of concrete rubble, which is inevitably mixed with other wastes such as crushed clay bricks (CCB). The level of inclusion varies depending on the original construction materials of demolished buildings. The differing properties of CCB from RCA will affect the mix design as well as the physical and mechanical properties of the resulting new concrete when the inclusion level exceeds a certain limit. Separating CCB from RCA presents an operational difficulty in practice and also has huge cost implications. Therefore, it is important to study the effect of CCB with various inclusion levels on the properties of fresh and hardened concrete. This paper reports on a study conducted to investigate the physical and mechanical properties of recycled concrete with high inclusion levels of RCA and CCB and to explore the potential or the limitation of this type of mixed recycled aggregate in primary concrete structures.

Zhang and Zong.(2013) performed experiments to design mix proportions of concrete made with recycled coarse aggregate from waste brick, and the workability, mechanical performance, and durability of the concrete with different contents of recycled coarse aggregate have also been investigated. Waste brick was used to replace natural aggregate after being treated, called recycled coarse aggregate (RA). Furthermore, fly ash was used as 0, 10%, 15%, and 20% by weight replacements of cement. Workability was evaluated through slump and cohesiveness testing, and results implied that the concrete samples showed good workability except the mix containing 40% RA. Mechanical performance testing indicated that addition of RA decreased compressive strength and replacing up to 30% of natural aggregate with RA produced concrete samples which met the requirements of strength standards. Concrete with RA presented a little higher chloride ion penetration coefficient and carbonation depth than normal concrete due to the higher porosity. Pore structure testing also indicated that recycled aggregate from waste brick can increase the porosity of the concrete.

3. Experimental Work and Methodology

3.1 General

The experimental program consists of casting and testing of fresh concrete having natural aggregates NA in the reference mix design, with recycled brick aggregate RBA at different percentages by weight and adding S.P admixture. The main variables in this study include the replacement percentage of RBA with NA and effect of adding S.P on density and slump. A summary of the mixes and replacement proportions is shown in Table 1.

Table 1: Concrete Batch Parameters

Mix NO.	Percent coarse RBA Substitution	S.P ml/m^3
1	0%	0
2	20%	0
3	40%	0
4	60%	0
5	100%	0
6	0%	440
7	20%	440
8	40%	440
9	60%	440
10	100%	440

3.2 Material Properties

Cement: The cement which was used in this study was Portland limestone cement CEM II/A-L 42.5R. Its properties are conformed to the industrial standard no.3868 by Iraqi Central Organization for Standardization & Quality Control.

Fine Aggregate: Natural sand was used for concrete mixes in this study. The fine aggregate has 4.75mm maximum size with rounded-shape particles and smooth texture. The specific gravity, water absorption and density were 2.63, 1.07% and 1755 kg/$\boldsymbol{m^3}$, respectively.

Coarse Aggregate (Gravel): The coarse aggregate was natural aggregate with maximum size of 25mm. The specific gravity, water absorption and density were 2.65, 0.713%and 1695 kg/$\boldsymbol{m^3}$, respectively.

Recycled Coarse Aggregate: The recycled brick was collected from bricks that are damaged during unloading, storage and cutting on the site, with maximum size of 25mm. The specific gravity, water absorption and density were 1.91, 14.2%and 1308 kg/m^3, respectively.

Water: Ordinary drinking water was used for mixing and curing of concert.

Superplasticizer: A superplasticizer as a chemical admixture was used in this investigation to study its effects on fresh properties of RBA concrete. Sika Viscocrete Super E4-S was used.

Chemical Base: Modified polycarboxylates based polymer, Density: 1.065 +/- 0.01 kg/l at 20°C, pH Value: 6 – 8, Freezing Point: -6 Co, Total Chloride Ion Content: Max. 0.01%, Chloride-free. Approval standard Confirms to requirements of ASTM C494-Type G.

3.3 Mix Proportions and Methodology

The design of concrete mix is described in Table (2).

Table 2: Proportions of mix design

Mix NO	Replacement %	Water kg/m^3	Cement kg/m^3	N Aggregate kg/m^3	RBA kg/m^3	E Aggregate kg/m^3	SP ml/m^3
1	0	150	340	1000	0	650	0
2	20	150	340	800	200	650	0
3	40	150	340	600	400	650	0
4	60	150	340	400	600	650	0
5	100	150	340	0	1000	650	0
6	0	102	340	1000	0	650	440
7	20	102	340	800	200	650	440
8	40	102	340	600	400	650	440
9	60	102	340	400	600	650	440
10	100	102	340	0	1000	650	440

From Table (2) the methodology of this work is shown through the variables: RBA, natural aggregate, and superplasticizer on the slump and density of concrete. It was necessary to produce two series/10 mixtures of RBA replacements corresponding to superplasticizer inclusion. The variation in RBA % is made as close as 20% increments in order to see whether the effect is steady or a certain RBA % may give a difference in workability behavior.

3.4 Mixing Procedure and casting

The objective of mixing is to obtain a uniform and consistent mixture of cement, water, aggregate, sand and any admixtures used in the concrete and also to meet the requirement of the standard.

Mixing Procedure:

1. Crushing of bricks using a hammer after that washing it with water to remove dust from the crushed brick.
2. Preparing the mixture by mixing coarse, sand aggregate with cement then adding water.
3. Preparing molds and prisms by oiling the inside of the cubes and prisms
4. Take the slump test
5. Pouring concrete mixture inside the cubes and prisms by three layers and tamping each layer with (35) strokes using a tamper, square in cross-section with 2.54 cm side and 38.1 cm length, weighing 1.818 kg.

4. Results and Discussion

Workability and density of RBA concrete were measured and studied in this work.

4.1 Workability

Table (3a) shows the slump results as the RBA percentage increases from 0 to 100%. Fig (1) shows this variation of RBA % against the concrete slump. Slump from control specimen to 100% RBA was ranged (80mm-20mm) respectively, so with increasing the percentage of RBA the slump decreases which is expected because RBA has high water absorption, so the workability of the mixture decreases with increasing RBA percentage. The % decrease reached 75% for 100% RBA replacement. In Fig (1) the slump decreased from 80mm at ordinary concrete (0 % RBA) to only 20mm at (100 % RBA) concrete. Equation (1) is a fitting equation resulted from the figure:

$$\text{Slump (mm)} = 21(RBA\%)^2 - 82(RBA) + 81 \quad [1]$$

which indicates a considerable decrease in slump with RBA%.

The slump was improved to about 60% when SP was applied at 100% RBA. By adding superplasticizer slump increases 10-25 mm giving a higher workability especially for RBA concrete which has low workability. The obtained fresh test results are shown in Table (3b), and Fig. (2). Fig (2) shows better workability performance when superplasticizer was added to the mixture. The slump decreased from 90mm at ordinary concrete (0 % RBA) to only 35 mm at (100 % RBA) concrete (compared to 80 to 20 mm for concrete without superplasticizer, respectively). Equation (2) is a fitting equation resulted from Fig. (2):

$$\text{Slump (mm)} = 19(RBA\%)^2 - 76(RBA) + 92 \quad [2]$$

All over the work, the slump was decreased steadily following a 2nd degree polynomial.

Table 3a: Results of slump test without superplasticizer.

RBA %	Sump*(mm)
0	80
20	65
40	55
60	35
100	20

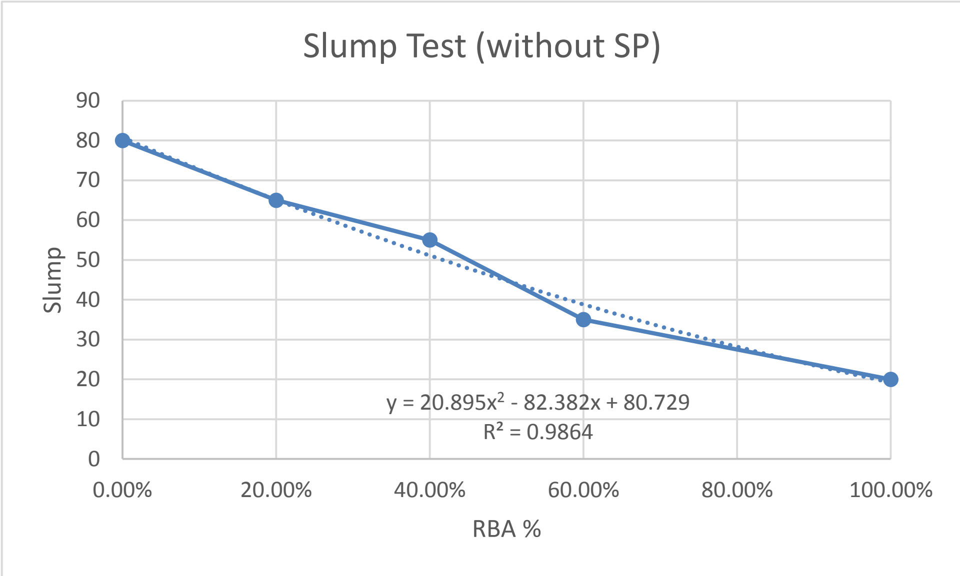

Figure 1: Slump Test (without SP)

Table 3b: Results of slump test with superplasticizer

RBA %	Sump*(mm)
0	90
20	80
40	65
60	50
100	35

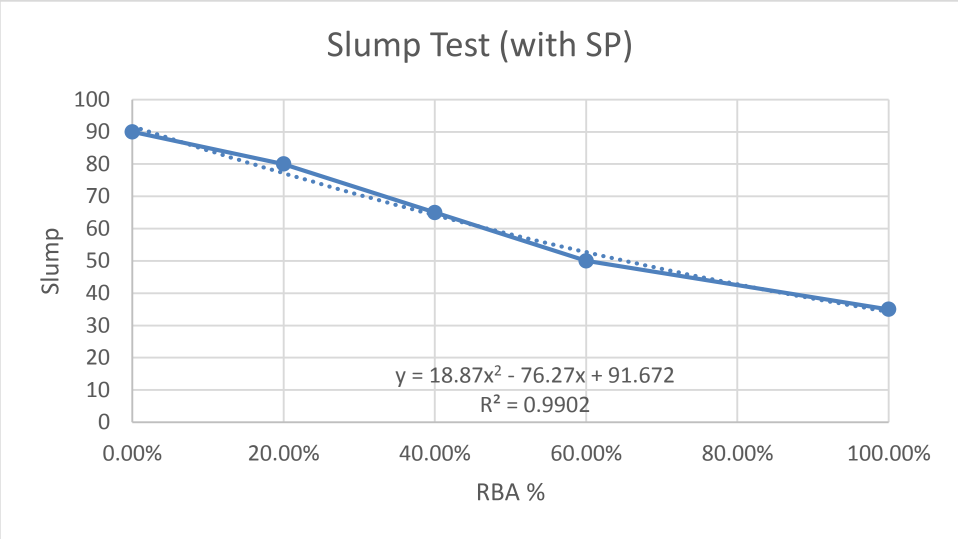

Figure 2: Slump Test (With SP)

4.2 Density

The use of RBA in concrete will decrease the concrete density because of the lower density of RBA (1300 kg/m^3) compared to the ordinary aggregate (1700 kg/m^3). The obtained test results are shown in Table 4 and Fig 3. The density has reduced from 2444 to 2134 kg/m3 for RBA% 0% to 100% respectively, i.e., a 12.7% reduction in the density. From Fig (3), a fitting equation can be set as follows:

$$\text{Density } (kg/m^3) = 83(RBA\%)^2 - 384(RBA) + 2439 \quad [3]$$

This reduction in density is favorable especially when the RBA concrete has the acceptable structural strength recommended by the building codes.

Table 4: Density of RBA concrete

%RBA	Density(kg/m^3)
0.00%	2444.445
20.00%	2370.37
40.00%	2251.85
60.00%	2289.335
80.00%	2171.85
100.00%	2134.075

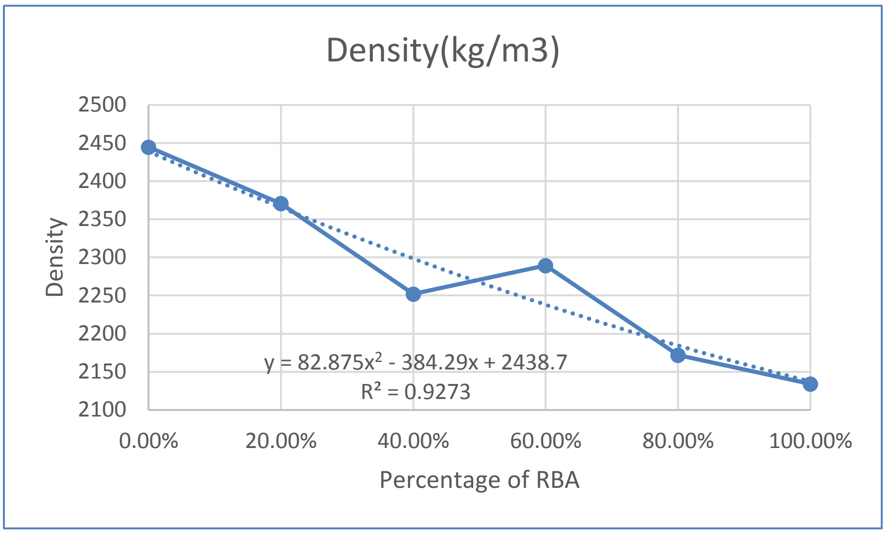

Figure.3: Density of RBA concrete

5. Conclusion

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. This work clearly suggested the possibility of appropriately treating and reusing lightweight brick waste as aggregate in new concrete, especially in lower level applications. The following conclusions can be drawn.

1. The workability of fresh concrete decreases with increasing the percentage of RBA due to high absorption of water of recycled brick aggregate.
2. The percentage decreases in slump reached 75% for mixes without superplasticizer and improved to 60% when superplasticizer was applied.
3. The density decreases by increasing the percentage of RBA concrete. The percentage decrease was about 13% for 100% RBA replacement.

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