ISSN 2712-0554
Original Research

Heritage and Sustainable Development
Vol. 5, No. 2, August 2023, pp.175-182
https://doi.org/10.37868/hsd.v5i2.238

Using recycled bricks to improve the compressive strength of concrete and produce lightweight concrete

Hajer Satih Abbas [1], Shaima Sabri Ali[2] , Alaa Hassoon[3]

[1] Civil Engineering Department, University of Al-Qadisiyah, Diwaniyah, Iraq
[2] Civil Engineering Department, Ministry of Education, Baghdad, Iraq
[3] Civil Engineering Department, University of Al-Qadisiyah, Diwaniyah, Iraq

*Corresponding author E-mail: Hajer.alsalman@qu.edu.iq

Received Dec. 3, 2022
Revised Mar. 29, 2023
Accepted May 16, 2023

Abstract

This research presents the aim of using sustainable materials like crushed bricks from the demolition of old buildings as additives to preserve the environment, reduce energy consumption, reduce the cost of concrete, improve the properties of concrete, and obtain lightweight concrete for high buildings with more fluidity for narrow places. Also, it discusses the best replacement ratios because the knowledge about them is still lake. Three mixes of concrete were used and tested. Mix-1was the standard, where the replacement of coarse aggregate with crushed brick aggregate has been used in mix-2, the mix-3 was to study the replacement of fine aggregate by powder brick. In this analysis, only two factors were taken into account: the percentage of coarse aggregate replaced by brick aggregate (from 0 to 50%) and the percentage of fine aggregate replaced by brick aggregate (from 0 to 75%). Compressive strength was tested after curing at ages (7, and 28) days. The results showed that concrete with crushed brick aggregate reduces unit weight and increases compressive strength of concrete. Using mix-2 increased the compressive strength by about 9.7%, and 7% at ages (7, 28) days respectively, and reduced the weight by 11%. Also, using mix-3 increased the compressive strength with high percentages of about 59%, and 61% at ages (7, and 28) days respectively, with a little percentage of reducing the weight by 2%.

Keywords: concrete mixtures, sustainable material, crushed and dust brick, compressive strength, lightweight concrete

1. Introduction

The most significant material used in construction during the past century has been concrete. It is a composite material made of cement, coarse aggregate like gravel, fine aggregate like sand, and cement. Water is used to mix them all together. Building materials are usually selected through functional, technical, and financial requirements. Employing sustainable resources will help minimize the number of raw materials used to make concrete, protect the environment, increase efficiency, and reduce cost. The population in Iraq is increasing, so it requires an increase in residential buildings for that is preferable to use sustainable materials. Thus, the use of eco-friendly materials with superior properties to conventional building materials should be the first step in the design of green structures. Building materials have a significant impact on a building's environmental footprint and energy usage. Ecologically sustainable development (ESD) has been a major topic of discussion since the 1970s, when environmental economics and sustainable development first emerged. Sustainability is the study of natural systems and how they function, preserve biodiversity, and supply all the resources necessary for an ecosystem to remain in equilibrium.

There has been some progress in lowering construction waste since the green building concept was introduced, but more people still need to learn about the benefits of recycling and reusing demolition debris. especially in places like the developing world where there is so much construction going on. Sustainability and sustainable development aim to strike a balance between two seemingly incompatible goals: the push for economic and technical progress, on the one hand, and the protection of the natural environment, on the other. Therefore, the purpose of this study is to examine what happens when fine and coarse aggregate are switched out for crushed bricks [5,8,9].

2. Literature review

A number of researchers have used sustainable materials in the mixing of concrete as: Brick aggregate was used in 21 tests conducted by Gopinandan et al. To determine if brick aggregate concrete is fire resistant, an experimental investigation was done. According to observations, conventional concrete that uses crushed brick aggregate has excellent heat resistance [1]. Instead of disposing of it as trash, Ranjodh degraded the environment by using brick dust and marble powder as fine aggregate [2].

The aggregate qualities and their impact on the characteristics of both fresh and hardened concrete were the focus of Derick's investigation into the use of coarse recycled concrete aggregate as a component in structural concrete [3]. Riaz et al. (2017) used bricks as coarse aggregate. Compressive strength, dynamic modulus of elasticity, total weight, and moisture content are measured on concrete cubes made from recycled bricks using both destructive and nondestructive methods [4]. Bansal elaborated on the recycling possibilities of C&D trash, the challenges of processing and using C&D trash, and finally, recommendations for the sustainable use of C&D trash [5].

A study by Hiremath on the use of crushed brick aggregate in place of coarse aggregate. In this investigation, the volumetric replacement of aggregate by brick aggregate was considered (0, 25, 50, 75, and 100 percent) [6]. The origins, quantity, and categorization of waste concrete were all described and examined by Xiao. Concrete waste reduction techniques had been introduced. Additionally, the recovery of waste concrete was explained and examined, along with recycling philosophy and technology [7,8].

The purpose of this article is to ascertain whether or not brick waste is acceptable as an alternative coarse and fine aggregate in concrete, which is important for reassuring the public that brick waste material may be reused in the construction process. The tests are necessary to demonstrate whether brick waste can meet the compression strength test's minimum and even higher standards. When replacing coarse aggregate with crushed brick and replacing fine aggregate with powder brick, the tests determine the compressive strength and the weight of the concrete. Therefore, it is known how many percentages of brick waste are required to produce concrete mixes with adequate strength.

3. Materials

Gravel served as the coarse aggregate, while sand served as the fine aggregate; both were combined with a binding ingredient (such as cement) that filled the voids between the aggregate particles and bound them together. Finding out how much of each material goes into making concrete is crucial.

Cement: Aggregates can be held together in one mass thanks to its cohesive and adhesive capabilities. Ordinary Portland cement (OPC) of 43 grades meeting IS: 8112-1989 specifications was utilized.

Coarse aggregate: One of the essential components of the concrete mix is coarse aggregate. It considerably impacts how well concrete performs by altering its flowability, resistance to segregation, and strength. In this project, we increased the concrete's strength by using crushed gravel with a particle size of (9.5-37.5) mm in the concrete ix.

Fine aggregate: In the present work's concrete mixture, natural sand was utilized. When applied in a reasonable amount, it improves the flowing ability and segregation resistance. When employed in different ratios, it also alters the strength of concrete. Concrete's compressive strength and water needed for mixing are influenced by the shape, texture, and number of voids in the particles as well as the surface area. According to Indian standards, the fine aggregate (the lowest grading zone) was subjected to a sieve analysis according to IS: 383-1970. The sand's specific gravity was 2.43 and its fineness modulus was measured at 1.97. The fine aggregate has a 2% silt and clay component.

Recycled brick: The dimensions of clay bricks used in this work were (240x115x70) mm with the compressive strength of the bricks being 12MPa. The efflorescence test was done to brick and was within the acceptable limit of 28% as shown in figure (1). The recycled bricks came from the structure's original demolition. Crushing aggregate brick that as coarse aggregate passes through a range between (9.5-37.5) mm and crushing aggregate brick used as a fine aggregate pass through a range between (2.5-3.5) mm, as determined by sieve analysis tests performed in accordance with IS:2386-1963.

Figure 1. Brick

Mixing water: In this experiment, both the mixing and curing processes make use of potable water.

4. Methodology

The experimental program was completed to examine the qualities of concrete using brick as aggregate substitute at varying percentages. In the current study, we conducted the following experiment:

- Compressive strength at the ages of (7 and 28) days by replacing fine aggregate with brick dust at 75% replacement levels.
- Compressive strength at the ages of (7 and 28) days by replacing coarse aggregate with brick crushed at 50% replacement levels.

Bricks were broken into pieces approximately 80 mm in size by using a hummer and ground into rubble by the Laos Angelus device as shown in figure 2. Where put several blocks after breaking them into small parts in the device that contains iron balls, they start to rotate when turned on and the balls grind the brick parts, this process takes 30 minutes to take it out, and get a mixed specimen of gravel and sand. Finally, it was separate the sand from the gravel by means of sieves by placing the specimen in a vibrating device that contains graduated sieves (from 0.15 mm up to 10 mm), where the sand separated from the gravel.

Figure 2. Laos angelus device

The precipitation was checked by the cone to ensure that a similar operation was obtained for all concrete models. The result of the slump test was equal to 5 cm

5. Mix design

Concrete mix designs were primarily based on the Indian code IS 10262-2009. Saturated and surface dry (SSD) aggregates are employed in accordance with the code guideline, and aggregate is either wet or dry adjusted as necessary.

Wooden molds cubes used for casting with (150x150x150) mm dimensions for the compressive strength test, moreover, three cubes with the same dimensions for the test of strength with the replacement of 50% of gravel with crushed brick pass through the sieve with a (9.5-37.5) gradient as shown in figure 3, where its grading is similar to that of the gravel used in the concrete mix. The other three cubes were prepared with the replacement of 75% of the sand with dust brick as shown in figure (4).

Table 1. Quantities by weight of materials adopted in this study

Mixes	Cement (kg)	Sand (kg)	Gravel (kg)	Crushed Brick (kg)	w/c
Mix-1	12	32	48	0	0.5
Mix-2	12	32	24	24	0.65
Mix-3	12	8	48	24	0.6

The different values of w/c ratios are used because the blocks are more water absorbent than sand and gravel, and to maintain their operation similar to concrete all models need to add more water to mix-2 and mix-3 more than conventional concrete.

Figure 3. Crushed brick

Figure 4. Dust brick

The procedure of mixing that followed in this experimental work are:

- Washing the hand mixer to prevent it from absorbing the water of the concrete mixture.
- Mixing the sand and gravel gradually mixed to make them homogeneous.
- Adding the cement was mixed into the mix.
- Then the water was gradually added.

The time that needs for the mixing process to continue was (4-5) minutes.

During the mixing time, the molds have been prepared to be ready for use. Pouring the molds and putting them for a minute on the vibrator for the purpose of homogenizing their components and preventing air from entering them. At last, the molds were covered with a nylon sheet to stop water evaporation from the surface for 24 hours. The molds were opened, and the models were placed in water for curing for (7,28) days for the purpose of preventing cracking and gaining the required strength. After removing all samples from the curing tank and washing off the surfaces, a compression testing machine with a 2000 KN capacity was used to conduct the requisite test for uniaxial compressive strength.

7. Results and discussion

The experiment followed the guidelines laid down in IS 516-1959. At the end of 7 days and 28 days of curing, samples were removed from the water and examined promptly. The water from the roof was left to slowly drip down. The testing position of the cube was perpendicular to the casting position. Without any sudden changes, the stress was applied and raised by 14 N/mm2 per minute until the specimen broke. Figure 5 depicts the results of the compression test performed on the sample.

Figure 5. Compression testing machine

The following Table 2 gives the compressive strength test results of all types of mixed concrete for 7 days and 28 days.

Table 2. Test results of compressive strength

Mix	Weight (g)	ave	Decreasing %	$f_{cu\ 7}$ (MPa)	ave	Increasing%	$f_{cu\ 28}$ (MPa)	ave	Increasing%	Notes
Mix-1	7570	7583	0	14.6	14.2	0	18.9	18.3	0	standard
	7680			14.2			17.8			
	7500			13.7			18.03			
Mix-2	6740	6728	11.3	15.1	15.57	9.65	18.88	19.66	7.43	replacement gravel with crushed brick
	6690			16			19.5			
	6755			15.6			20.6			
Mix-3	7330	7417	2.2	21.5	22.6	59.3	27.7	29.5	61.4	replacement sand with dust brick
	7450			24			31.8			
	7470			22.4			29.1			

The increasing compressive strength of mixes s shown in Figure 6 below.

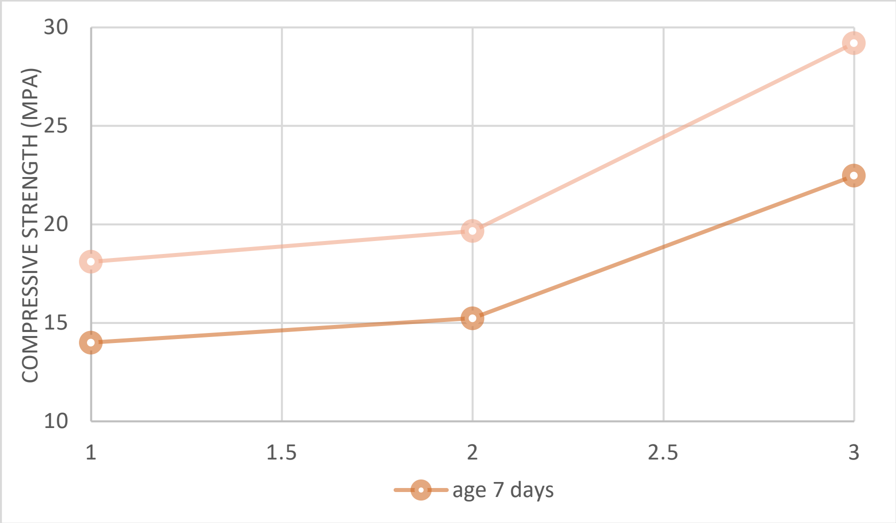

Figure 6. Increasing compressive strength

8. Conclusion

The testing was done for all mixes by using cubes of (7, 28) days of curing. The results of the experimental work were shown:

- When replacing 50% of gravel with crushed bricks (mix-2) that's increasing the compressive strength of ages (7,28) days by about 9.65% and 7.4% respectively. This increase is considered very little according to mix-1.
- The result of the compressive strength of mix-3 that replaced the sand with 75% of brick, showed that an increase is very high in the values of compressive strength at ages (7,28) days about 59.15%, 61.4% respectively according to mix-1 (standard).
- Results showed both mix-3 and mix-2 give higher compressive strength than mix-1.
- The increase of compressive strength values of mix-2 is a little according to mix-1, but mix-3 gives very higher values.
- The amount of gravel 48 Kg that is used in mix-3 which uses 24 Kg in mix-2. That explains the reason for increasing the compressive strength of mix-3 more than mix-2 because the gravel has higher strength than sand which gives the mixture high strength, and it gives better cohesion with gravel than sand.
- The construction of high-strength concrete contributes to the achievement of the structure's lowest volume and lightest weight. High-rise buildings are high-strength concrete's most significant applications.
- Mix-3 is considered very good and safe to use because of its high values of compressive strength.
- Using mix-2 decreases the self-weight of concrete by about 11%, whereas using mix-3 that decreasing the weight by 2.2% only.
- Self-weight decreased when using mix-2 (11%) more than mix-3 (2%) according to mix-1 because mix-2 replaced 50% of gravel (heavyweight) with crushed brick (less weight).
- Lightweight concrete is used to reduce the self-weight of the structure. So, using mix-2 is suitable for this purpose.
- Lightweight concrete has the benefit of reducing the structure's weight, the amount of reinforcing necessary, and the size of the foundations. Additionally, it has excellent thermal insulation properties and uses less energy for heating and cooling.
- Recycling brick aggregate has advantages: it is good for the environment because it helps to reduce pollution, and it is good for the economy since it lowers costs.
- Finally, using crushed bricks as an alternative to gravel gives good results in compressive strength, whereas using powder brick instead of sand gives acceptable values of compressive strength with a weight reduction percentage of concrete.

Declaration of competing interest

The authors declare that they have no any known financial or non-financial competing interests in any material discussed in this paper.

Funding information

No funding was received from any financial organization to conduct this research.

References

[1] G. Dey, "Use of Brick Aggregate in Standard Concrete and Its Performance in Elevated Temperature"," *International Journal of Engineering and Technology*, vol.*5*, no.4, p.523. 2013.

[2] E. Singh, E. Kaushik, and E. G. Singh, "Study of Self Compacting Concrete Using Brick Dust and Marble Powder"," *International Journal of Engineering Research and Applications*, vol.*3*, no.3, pp.1283-1286, 2013.

[3] D. Wade Immelman, "The influence of percentage replacement on the aggregate and concrete properties from commercially produced coarse recycled concrete aggregate"," in *Structural Engineering, Mechanics and Computation - Proceedings of the 5th International Conference on Structural Engineering, Mechanics and Computation*, 2013.

[4] R. Bhanbhro, I. Memon, A. Ansari, and A. Shah, *Bashir Ahmed Memon, "Properties Evaluation of Concrete Using Local Used Bricks as Coarse Aggregate*. Scientific Research Publishing, 2014.

[5] A. Bansal, G. Mishra, and S. Bishnoi, "Recycling and Reuse of Construction and Demolition Waste: Sustainable Approach"," in *The 7th International Conference on Sustainable Built Environment, Earl's Regency Hotel*, Kandy, Sri Lanka, 2016.

[6] M. N. Dr and S. Sanjay, "Replacement of Coarse Aggregate by Demolished Brick Waste in Concrete"," *JSTE-International Journal of Science Technology & Engineering, vol., pp.31-36, 2017*.

[7] J. Xiao, *Springer Tracts in Civil Engineering*. Springer, 2018.

[8] M. F. Usman Aminu Umar and H. Khamidi, "Sustainable Building Material for Green Building construction", *Conservation and Refurbishing*, 2014.

This page intentionally left blank.