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The Effect of Replacement of Natural Gravel with Recycled Aggregate on Concrete Compressive Strength

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Abstract: The increasing demand for natural aggregates in concrete production has raised concerns about the shortage of natural resources and environmental pollution. This research explores the possibility of replacing natural gravel with recycled aggregate obtained from crushed mosaic tiles in concrete mixtures. The study aims to evaluate the use of construction and building waste in concrete production as an eco-friendly alternative to conventional aggregates.

Four experimental concrete mixtures were designed to examine the effect of replacing natural gravel with crushed mosaic tiles. The first mixture served as a reference mix, containing 100% natural gravel. The second mixture included 25% crushed tiles and 75% natural gravel. The third mixture consisted of equal amounts of both materials (50% each), while the fourth mixture completely replaced natural gravel with 100% crushed tiles.

The main goal of this study is to find the best replacement ratio that ensures good concrete properties while helping the environment. By using recycled materials, this research helps reduce environmental impact, decrease construction waste, and save natural resources. The results are expected to provide useful information on the possibility of using alternative materials in concrete production, supporting eco-friendly building practices.

Keywords: Recycled aggregate, compressive strength, density, replacement ratio, concrete properties.

1. Introduction

Concrete is the most widely used construction material worldwide due to its availability, strength, durability, and adaptability to various structural forms. It consists primarily of cement, water, fine aggregate (sand), and coarse aggregate (gravel), with the coarse aggregate typically comprising 60–75% of the total volume (1). Natural aggregates, however, are non-renewable resources, and their continuous exploitation has raised serious environmental and ecological concerns (2) .

With rapid urbanization and increasing construction activities, the demand for concrete has grown substantially, further escalating the depletion of natural aggregate reserves. Simultaneously, the construction industry is a major contributor to solid waste generation, particularly from the demolition of old buildings and structures (3). These dual challenges—scarcity of natural aggregates and increasing construction waste—have led researchers to explore sustainable alternatives such as recycled aggregates (4) .

Recycled coarse aggregates are primarily obtained by crushing construction and demolition (C&D) debris, including waste concrete, ceramics, bricks, and tiles. Among these, waste mosaic

tiles—typically made from hard and dense ceramic materials—are readily available from demolished residential and commercial structures. Rather than disposing of them in landfills, these tiles can be reused as coarse aggregates, contributing to a more sustainable construction practice (5),(6) .

Several studies have shown that replacing natural coarse aggregate with recycled materials may affect the physical and mechanical properties of concrete. Recycled aggregates tend to have higher porosity, lower density, and greater water absorption, which can lead to reduced compressive strength and increased variability in performance (7),(8) . However, at specific replacement ratios, acceptable strength and durability can still be achieved, especially for non-structural or low-load-bearing applications (9),(10) .

This study investigates the effects of partially or fully replacing natural gravel with crushed ceramic (mosaic) waste tiles on the compressive strength and density of concrete. The goal is to assess the viability of using tile waste as a sustainable coarse aggregate substitute. This research aligns with global sustainability goals, as it reduces landfill waste and preserves natural resources, promoting a circular economy in the construction sector (11),(12) .

The findings of this study may provide insights into optimizing concrete mix designs using recycled materials while ensuring adequate performance and environmental benefits. Through this, the research contributes to expanding the knowledge on alternative construction materials in line with sustainable development practices (13),(14) ,(15) .

2. Literature Review

The concept of incorporating recycled materials into concrete has been widely studied over the past decades. Researchers have explored various waste materials, including crushed concrete, bricks, glass, and ceramic tiles, as partial or full substitutes for natural aggregates. The main aim is to reduce environmental degradation and achieve sustainable construction without significantly compromising concrete performance (4) .

Rafat Siddique (2013) investigated the use of waste ceramic tiles as coarse aggregate in concrete and concluded that up to 30% replacement did not significantly affect compressive strength (5). Similarly, Medina et al. (2012) examined the mechanical behavior of concrete containing ceramic waste and reported satisfactory results for compressive and flexural strength at moderate replacement levels (6).

Evangelista and de Brito (2007) analyzed the properties of concrete using recycled fine aggregates and observed a reduction in workability and density, but mechanical properties remained within acceptable limits at lower replacement levels (7). Poon et al. (2004) emphasized that the interfacial transition zone (ITZ) is often weaker in recycled aggregate concrete due to the porous nature of the RA, which affects strength development (8).

Kou and Poon (2009) studied the performance of recycled glass aggregates in self-compacting concrete and found that recycled aggregates influenced flow properties but could maintain strength with proper mix adjustments (10) . Silva et al. (2014) further categorized recycled aggregates from different C&D sources and highlighted the variability in physical properties depending on the source and processing method (11) .

Some studies focused specifically on ceramic and mosaic waste. Batayneh et al. (2007) used ceramic sanitary waste in concrete and found acceptable results in terms of compressive and tensile strength. They also noted that ceramic aggregates improve durability due to their dense microstructure (12). Tuncan et al. (2000) concluded that tile aggregates exhibit good resistance to abrasion, making them suitable for concrete in medium-traffic applications (13)

Moreover, investigations by Limbachiya et al. (2000) demonstrated that recycled aggregate concrete could attain compressive strengths similar to conventional concrete with appropriate mix design and curing practices (14). Recent works by Pedro et al. (2014) stressed that the

performance of structural concrete using recycled aggregates varies depending on aggregate quality, replacement percentage, and curing conditions (15)

From these studies, it is evident that the performance of concrete with recycled ceramic or tile aggregates depends heavily on particle size, replacement level, and mix design. Most researchers agree that up to 30% replacement typically results in acceptable mechanical behavior, while higher levels may compromise strength and workability unless modified through admixtures or optimized proportioning. Hence, there is a pressing need to examine the balance between environmental sustainability and structural performance in using recycled aggregates.

3. Aim of Work

This study aimed to experimentally investigate the effect of replacement of natural gravel with recycled aggregate (crushed mosaic tiles) on concrete properties , especially compressive strength.

4. Experimental work

In this study, several concrete cubes have been made by using natural coarse aggregate as well as recycled coarse aggregate, cured and tested in order to investigate the effects of recycled aggregate on concrete compressive strength.

4.1 Materials

A. Cement : ordinary portland cement (type karasta) used in this study as shown in fig (1)

Fig (1)

B. Fine aggregate: local fine aggregate from Karbala' region in Iraq is used throughout the experimental work in this study as shown in fig (2)

Fig (2)

C. Coarse aggregate: natural crushed aggregate from Nibaa'i region in Iraq is used throughout the experimental work in this study as shown in fig (3)

Fig (3)

D. Recycled Coarse Aggregate : mosaic tiles from demolition buildings sites collected, crushed to produce several smaller sizes as shown in Fig. (4)

Fig (4)

4.2 Specimen preparation

In this study, several concrete cubes with (150) mm have been made with concrete mix ratio 1:2:4. These cubes have been divided into four groups according to recycled aggregate percentage, the replacement percentage of recycled aggregate studied in this work are 0%,25%, 50% and 100%, . The four groups can be described as follows:

i) Group A: Concrete mix made with 0% replacement percentage of recycled aggregate (100% natural aggregate). Fig (5)

ii) Group B: Concrete mix made with 25% replacement percentage of recycled aggregate. Fig (6)

iii) Group C: Concrete mix made with 50% replacement percentage of recycled aggregate. Fig (7)

iv) Group D: Concrete mix made with 100% replacement percentage of recycled aggregate . Fig (8)

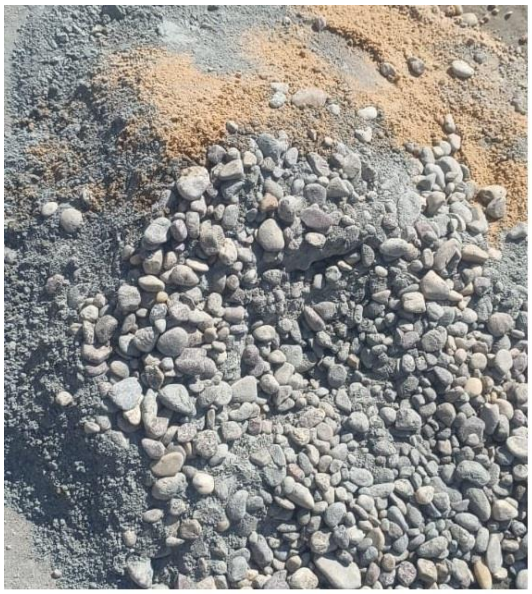

Fig (5)

Fig (6)

Fig (7)

Fig (8)

4.3 Tests of concrete specimens

All concrete cubes specimens have been tested for compressive strength at 28 days. Hydraulic test machine (SERVOTRONIC) as shown in Figure (9) , and the results as shown in table (1)

Fig (9)

Table (1) : Test results of concrete specimens

Mix sign	A (0%)			B (25%)			C (50%)			D (100%)		
Symbol sign	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3
Compressive strength (28 days) (N/mm2)	26.65	24.57	25.35	18.85	21.32	22.62	17.16	16.9	17.55	12.74	11.57	14.3
Weight (kg)	7.798	7.780	7.769	7.684	7.708	7.737	7.373	7.387	7.402	7.310	7.291	7.358
Density (Kg/cm3)	2310	2305	2302	2277	2284	2292	2184	2189	2193	2166	2160	2180

5. Results and discussion

The main aim of this study is to determine the compressive strength of concrete specimens with different percentage of recycled aggregate . The use recycled aggregate as an aggregate cause a reduction in the compressive strength of concrete in comparison with concrete made with natural aggregate only as shown in Fig (10) , and that is due to the following reasons :

- Recycled aggregate is less dense than natural aggregate.
- Recycled aggregate has more porous than natural aggregate.
- Recycled aggregate has a higher water absorption capacity than natural aggregate.

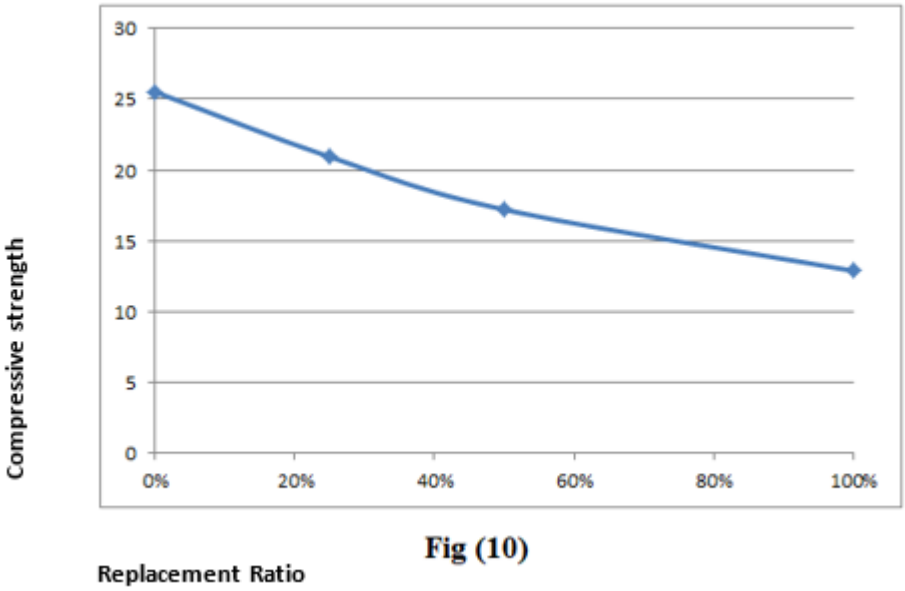

Fig (10)

6. Conclusions

1. Replacing natural gravel with recycled aggregate decreases compressive strength due to higher porosity and water absorption.
2. Concrete density decreases as the recycled aggregate percentage increases.
3. Using recycled aggregate reduces construction waste and conserves natural resources.
4. The best replacement ratio is 25%, balancing strength and environmental benefits.

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