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EXPERIMENTAL STUDY ON THE INFLUENCE OF RECYCLED AGGREGATES DERIVED FROM CONSTRUCTION AND DEMOLITION WASTE ON THE FRESH–STATE PROPERTIES OF ECO–FRIENDLY CONCRETE

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Abstract: Construction and demolition waste represents an important source of recyclable materials that can be reused in the construction industry, contributing to the reduction of natural resource consumption and environmental protection. The aim of this study is to demonstrate the feasibility of producing eco–friendly concrete using recycled aggregates derived from construction and demolition waste and to evaluate their influence on concrete properties. Two concrete mixtures of strength class C8/10 were prepared, one containing natural aggregates and the other containing recycled aggregates, and the properties of fresh concrete were investigated. The results showed that the use of recycled aggregates leads to minor changes in the workability and density of concrete without significantly affecting its overall performance. The observed reductions in workability and density remained within acceptable limits for the investigated concrete class, confirming the technical feasibility of incorporating recycled aggregates into eco–friendly concrete mixtures. The study confirms that recycled aggregates can represent a sustainable alternative to natural aggregates in the production of eco–friendly concrete.
Keywords: construction and demolition waste, waste management, recycling, reuse, circular economy, sustainable development

INTRODUCTION

The construction industry plays a crucial role in economic and social development; however, it is also one of the largest consumers of natural resources and generators of waste worldwide [1]. In the context of increasing concerns regarding environmental protection and the efficient use of resources, the development of sustainable construction materials has become a priority for both researchers and practitioners [2-4]. The implementation of circular economy principles in the construction sector involves reducing the consumption of raw materials, promoting material reuse, and recovering waste generated from construction and demolition activities [5,6].

Construction and demolition waste (CDW) constitutes one of the most significant categories of waste generated globally. The rapid pace of urbanization and infrastructure development has led to a substantial increase in the quantities of waste resulting from the renovation, rehabilitation, and demolition of existing structures [7]. Improper management of this waste can have adverse environmental impacts, including the occupation of landfill areas and the increased consumption of natural resources required for the production of new construction materials [6-9]. For this reason, the recovery and recycling of construction and demolition waste have become key strategies for promoting sustainable practices within the construction industry [5,9].

Among the solutions proposed to reduce environmental impact is the use of recycled aggregates obtained through the processing of construction and demolition waste. Numerous studies have demonstrated that these materials can be successfully employed in various engineering applications, such as road base layers, backfilling materials, and concrete production, thereby reducing the demand for natural aggregates and minimizing the amount of waste sent to landfills [9,10]. Furthermore, Life Cycle Assessment (LCA) studies have shown that the use of recycled aggregates can contribute to reducing both the environmental impact and the carbon footprint associated with the production of concrete and other construction materials [11]. In addition to environmental benefits, the use of recycled aggregates may contribute to increasing resource efficiency and reducing the dependency of the construction sector on virgin raw materials, which is becoming increasingly important in the context of global resource scarcity.

Concrete is the most widely used construction material in the world, and aggregates account for approximately 60-80% of its total volume. Consequently, replacing natural aggregates with recycled aggregates represents one of the most effective approaches to reducing the consumption of mineral resources [12,13]. Recent research has demonstrated that recycled aggregates can be incorporated into both conventional and high-performance concrete, provided that proper characterization of the aggregates and appropriate mix design procedures are applied [12,14].

However, the properties of recycled aggregates differ from those of natural aggregates due to the presence of adhered mortar on the particle surfaces and their more porous internal structure. These characteristics generally result in lower bulk density and higher water absorption capacity compared to natural aggregates [15,16]. As a consequence, the use of recycled aggregates may influence the properties of fresh concrete, particularly workability, density, and behavior during placement and compaction [12,13,16].

Concrete density is an important property because it affects the self-weight of structural elements and serves as an indirect indicator of the compactness and composition of the concrete mixture. Studies reported in the literature have shown that the incorporation of recycled aggregates frequently leads to a moderate reduction in concrete density, a phenomenon attributed to the lower density and higher porosity of aggregates derived from construction and demolition waste [12,13,17]. At the same time, the higher water absorption capacity of recycled aggregates may alter the workability of the mixture, influencing slump values and the overall behavior of fresh concrete [14,16].

Although the scientific literature provides extensive information regarding the use of recycled aggregates in structural concrete and the evaluation of their mechanical properties, most studies focus on medium- and high-strength concrete classes and on the performance of hardened concrete [12,14], [17]. Comparatively, fewer studies have investigated the influence of recycled aggregates on fresh concrete properties, particularly in low-strength concretes used for non-structural applications and local infrastructure projects [18]. Furthermore, the effects of recycled aggregates on fresh concrete density and the relationship between density and workability require further investigation, considering the variability of the characteristics of aggregates obtained from construction and demolition waste [15], [16].

In this context, additional experimental studies are needed to expand the existing knowledge base and assess the feasibility of using recycled aggregates in eco-friendly concrete with moderate performance requirements. Moreover, the variability of recycled aggregate characteristics depending on the origin of construction and demolition waste remains a significant challenge, requiring further experimental validation under different production and application conditions.

Accordingly, the present study aims to investigate the influence of recycled aggregates on the properties of eco-friendly concrete of strength class C8/10, with particular emphasis on the density of fresh concrete.

Two concrete mixtures were produced: one containing natural aggregates and the other containing recycled aggregates. The investigated properties included slump, temperature, and density. The comparison of the obtained results allows the evaluation of the effects generated by replacing natural aggregates with recycled aggregates and the assessment of their potential for use in eco-friendly concrete production, thereby contributing to the promotion of circular economy principles and the development of sustainable solutions for the construction sector.

MATERIALS AND METHODS USED

Within this study, two concrete mixtures of strength class C8/10 were produced to evaluate the influence of recycled aggregates derived from construction and demolition waste on concrete properties. The first mixture was prepared using natural aggregates, while the second incorporated recycled aggregates obtained through the processing of construction and demolition waste.

The preparation of the concrete mixtures and the experimental testing were carried out under laboratory conditions. The constituent materials were proportioned and mixed using a concrete mixer to ensure the production of homogeneous mixtures. Aggregate properties were verified through sieve analysis using a sieving apparatus, while the quantities of the constituent materials were determined using a precision balance and an electronic scale.

To evaluate the properties of fresh concrete, consistency, temperature, and density were determined. Concrete consistency was assessed using the slump test method, employing a standard slump cone in accordance with standardized testing procedures. The temperature of the fresh concrete was measured using a thermometer, while density was determined by relating the measured mass to the known volume of the test container.

After hardening, the mechanical properties of the concrete were evaluated through compressive strength testing using a hydraulic testing machine. The obtained results were comparatively analyzed in order to highlight the influence of recycled aggregate incorporation on concrete performance and to assess the feasibility of using such aggregates in the production of eco-friendly concrete.

The adopted experimental methodology was designed to ensure a direct comparison between conventional concrete and recycled aggregate concrete under identical production and testing conditions, thereby allowing the influence of aggregate type to be isolated and evaluated.

RESULTS AND DISCUSSION

Fresh Concrete Properties

To evaluate the influence of recycled aggregates on the behavior of fresh concrete, two C8/10 concrete mixtures were produced: one containing natural aggregates and the other containing recycled aggregates. In both cases, the main fresh concrete properties were determined, namely slump, temperature, and density.

Concrete Produced with Natural Aggregates

The results obtained for the concrete containing natural aggregates are presented in Table 1. It can be observed that the slump value measured after 10 minutes was 150 mm, corresponding to the recommended consistency for the concrete mixture. After 30 minutes, the slump decreased to 90 mm, a phenomenon that can be explained by the gradual loss of workability resulting from cement hydration and the evaporation of part of the mixing water.

Table 1. Results of Fresh Concrete Tests for Concrete Produced with Natural Aggregates – Strength Class C8/10

PARAMETER	AFTER 10 min	AFTER 30 min	PERMISSIBLE / RECOMMENDED VALUES
Slump	150 mm	90 mm	150 mm
Temperature	21.1 °C	21.4 °C	–5 / +30 °C
Density	2.31 t/m^3	2.31 t/m^3	±30 kg/m^3

The temperature of the fresh concrete remained within the limits specified by the technical standards, recording a value of 21.1°C immediately after mixing and 21.4°C after 30 minutes. This slight increase is insignificant and indicates the normal progression of cement hydration.

Regarding density, the measured values remained constant throughout the monitoring period, with a value of 2.31 t/m^3 recorded both after 10 and 30 minutes. This behavior confirms the homogeneity of the mixture and the stability of the fresh concrete composition. The obtained results are consistent with those commonly reported for conventional low-strength concrete mixtures and indicate an adequate level of fresh-state stability.

Concrete Produced with Recycled Aggregates

The results obtained for the concrete incorporating recycled aggregates are presented in Table 2.

Table 2. Results of Fresh Concrete Tests for Concrete Produced with Recycled Aggregates – Strength Class C8/10

PARAMETER	AFTER 10 min	AFTER 30 min	PERMISSIBLE / RECOMMENDED VALUES
Slump	140 mm	100 mm	150 mm
Temperature	25.7 °C	25.7 °C	–5 / +30 °C
Density	2.25 t/m^3	2.25 t/m^3	±30 kg/m^3

The temperature of the fresh concrete remained constant throughout the monitoring period, with a measured value of 25.7°C recorded both after 10 and 30 minutes.

The measured temperature falls within the range permitted by current regulations and demonstrates that the use of recycled aggregates does not adversely affect the thermal behavior of fresh concrete.

In terms of slump, values of 140 mm after 10 minutes and 100 mm after 30 minutes were recorded. Although the initial value was slightly lower than the recommended value of 150 mm, it remained within acceptable limits and indicated good workability of the mixture. The reduction in slump over time was similar to that observed for concrete containing natural aggregates. The reduction in density is consistent with the lower specific gravity typically associated with recycled aggregates and confirms the influence of aggregate composition on fresh concrete characteristics.

The density of the concrete produced with recycled aggregates was 2.25 t/m^3 both after 10 and 30 minutes, representing a lower value compared to that obtained for concrete produced with natural aggregates.

Comparative Analysis of Results

A comparison of the results obtained for the two concrete mixtures indicates that the use of recycled aggregates leads to a slight reduction in the workability of fresh concrete.

Table 2. Comparative analysis

PARAMETER	NATURAL AGGREGATES	RECYCLED AGGREGATES	DIFFERENCE
Slump after 10 min	150 mm	140 mm	–6.7%
Temperature after 10 min	21.1 °C	25.7 °C	+21.8%
Density	2.31 t/m^3	2.25 t/m^3	–2.6%

Although differences between the two mixtures were observed, the magnitude of these variations remained relatively small. This suggests that recycled aggregates can be incorporated into low-strength concrete mixtures without requiring substantial modifications to conventional production practices.

The initial slump decreased from 150 mm for concrete containing natural aggregates to 140 mm for concrete containing recycled aggregates, representing a reduction of approximately 6.7%. This behavior can be attributed to the higher porosity and greater water absorption capacity of recycled aggregates, which reduce the amount of free water available for mixture lubrication.

Similarly, the density of the concrete produced with recycled aggregates was lower than that of the concrete produced with natural aggregates, namely 2.25 t/m^3 compared to 2.31 t/m^3. The difference of approximately 2.6% can be associated with the presence of adhered mortar on the surface of recycled aggregate particles, resulting in a lower apparent density. With regard to fresh concrete temperature, both mixtures remained within the permissible limits. However, the concrete containing recycled aggregates exhibited a higher temperature (25.7°C) compared to the concrete containing natural aggregates (21.1-21.4°C), without negatively affecting placement conditions.

The comparative analysis indicates that the use of recycled aggregates results in a slight reduction in both workability and density of fresh concrete. Nevertheless, the obtained values remain within acceptable limits for concrete of strength class C8/10, demonstrating the feasibility of using recycled aggregates in eco-friendly concrete production. The reduction in slump can be attributed to the higher water absorption capacity characteristic of recycled aggregates, while the lower density is associated with the presence of adhered mortar on their surfaces. These findings are in agreement with previous studies reported in the literature, which have identified higher porosity, residual mortar content, and increased water absorption as the primary factors influencing the fresh-state behavior of recycled aggregate concrete [19].

From a practical perspective, the observed reductions in workability and density are unlikely to represent significant limitations for non-structural applications, where moderate performance requirements are generally acceptable.

The results obtained demonstrate that recycled aggregates derived from construction and demolition waste can be effectively utilized in eco-friendly concrete production without compromising the essential fresh-state properties required for practical applications. Their use may contribute to reducing extraction pressures on natural aggregate resources while simultaneously promoting waste valorization within the framework of the circular economy. Consequently, recycled aggregate concrete may represent a viable solution for non-structural concrete elements, road infrastructure works, and other applications where moderate mechanical performance is sufficient [20].

Future research should focus on the long-term durability, mechanical performance, and life-cycle environmental impacts of recycled aggregate concrete, as well as on the optimization of mix design procedures aimed at maximizing recycled aggregate utilization while maintaining the required engineering performance.

CONCLUSION

The results of this study demonstrate that recycled aggregates derived from construction and demolition waste can be successfully incorporated into eco-friendly concrete of strength class C8/10. Although the use of recycled aggregates led to a slight reduction in workability and density, all measured values remained within the acceptable limits specified for the investigated concrete class.

The experimental results showed that concrete containing recycled aggregates exhibited fresh-state properties comparable to those of conventional concrete. The observed reduction in slump can be attributed to the higher water absorption capacity of recycled aggregates, while the lower density is associated with the presence of adhered mortar and the more porous structure of the recycled material. However, these differences did not significantly affect the practical performance of the concrete.

The findings confirm that recycled aggregates represent a technically feasible and environmentally sustainable alternative to natural aggregates. Their use contributes to the recovery of construction and demolition waste, the conservation of natural resources, and the promotion of circular economy principles within the construction sector.

Future research should focus on evaluating the long-term mechanical performance and durability of recycled aggregate concrete, as well as on optimizing mix design procedures to increase the proportion of recycled materials while maintaining the required engineering properties.

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