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# Recycled Glass-Fiber Reinforced Cement (RGFRC) Waste as a Substitute in Concrete Production

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**Abstract.** Nowadays, a large amount of glass fiber reinforced cement (GFRC) waste from construction industries and demolition activities presents a significant source of major environmental and economic problems. In order to protect the environment, many studies have been conducted to recycle and reuse these wastes in concrete production. The present work also aims to reach this objective and to show technically the possibility of recycling glass fiber reinforced cement waste (RGFRC) as a partial substitution in concrete production. Three concrete mix variations were formulated: one comprising solely natural aggregate (NC) serving as the control, and two others incorporating a blend of natural and recycled glass fiber reinforced cement (RGFRC) with 20% and 40% replacement of recycled aggregate, respectively. The test of compressive strength behavior was performed on the mixes. The results showed that concrete containing 20% RGFRC has the best mechanical properties compared with the control concrete and that using more RGFRC would have a harmful impact on the mechanical characteristics of concrete.

## Introduction

The consequent increase in the construction sector is reflected in an ever-increasing need for raw materials [1,2]. The natural deposits of potentially exploitable aggregates are becoming scarcer. Many studies have been published on the development of new materials using waste from demolition and construction sites [3–5].

In recent times, there has been a noticeable trend in using recycled aggregates from industrial or demolition waste in the concrete production [6–10]. This approach not only facilitates waste recycling in modern society but also enables the formulation of more cost-effective concretes with enhanced properties [11].

Many previous studies have reported results on testing the properties of Recycled Glass Fiber Reinforced Concrete (RGFRC) and on examining the effects of its partial or total incorporation in the production of concrete. *In a study carried out by Olorunsogo and Padayachee*, [12], emphasis was placed on the sustainability of concrete produced with different proportions of recycled concrete aggregates. Results indicated a decrease in durability as the quantities of recycled aggregates increased, while durability improved with aging. This phenomenon has been attributed to cracks and fissures the RA during processing, making the aggregate more susceptible to permeation, diffusion and absorption.

*Tabsh and Abdelfatah* [13] studied the strength of concrete from coarse aggregates of recycled concrete, taking into account both the source of the recycled concrete and the targeted strength of the concrete. Their results revealed that the strength of concrete could be 10 to 25% lower than conventional concrete using coarse natural aggregates, whatever its origin. In a study conducted by *Malešev et al.* [14], the properties of fresh and hardened concrete were examined with three amount of recycled coarse aggregates (0%, 50%, and 100%). The results indicated that concrete incorporating recycled aggregate performed satisfactorily, showing no significant deviation from the performance of natural concrete, irrespective of the replacement ratio. The researchers explained that achieving concrete with good mechanical properties containing recycled concrete aggregate requires the use of large aggregates of high recycled concrete and compliance with specific guidelines for the design and production of this new type of concrete.

*Thomas et al.* [15] conducted another study to assess the concrete strength and durability properties of crushed concrete aggregates. The test results revealed that replacing natural aggregates with up to 25% CCA had no negative impact on the strength properties of concrete. However, the durability investigation indicated that an increase in CCA percentage leads to a reduction in CCA concrete durability.

This is related to a higher water absorption of the CCA and to the presence of porous mortar on the surface, both influencing the durability of the concrete. The study demonstrated that augmenting the cement content in the mix increases CCA concrete durability by enhancing either the density and the quality of the hydrated cement paste.

Major part of the literature review indicates that employing 50% or more Recycled Concrete Aggregate (RCA) would have a negative impact on the mechanical properties of concrete [16,17].

In Morocco, the acceleration of urbanization and rapid population growth have caused a generation of construction and demolition waste (CDW). Total of CDW production is approximately 30 million tons per year including concrete waste. *The exhaustion of natural resources and the largest demand for natural building materials face Morocco to develop the reuse of RCA as alternative source of concrete production according to the standards regulations* [18]. For this purpose, the aim of this study is to contribute to the valorization of concrete waste in the concrete production; in order to reduce waste, to well manage natural resources, and finally to prevent the environmental pollution. The experimental study consists to examine the influence of the partial substitution (20% - 40%) by concrete waste on the mechanical behavior of the studied concrete.

## Material and Methods

*Preparation of materials*

The used materials in this study are: natural concrete aggregates composed of two fractions (NA 8/16 and NA 14/20), natural fine sand (NS) with fraction 0/5, Portland cement CPJ 45, Water (Drinking water of the network, free of impurities) and the recycled glass fiber reinforced cement (RGFRC). The RGFRC is a concrete waste, collected from a building demolition site, crushed in the laboratory and ground to produce gravel of granular class 0/20.

20% and 40% of this RGFRC waste was utilized to substitute the natural aggregate in concrete production.

In this study, at first, we were tested the properties of the four kinds aggregates prior to mix proportion design. The preliminary tests, namely the particle size analysis test, the Methylene blue test, the sand equivalent, the surface cleanliness, the Los Angeles test, the coefficient of flattening, the water absorption coefficient, real density and the bulk density of the aggregates, were carried out according to international and national standards. The results of the different tests are presented in Table 1.

*Table 1: Aggregates properties.*

| Name of Test | Reference Standard | Aggregate | | | |
|---|---|---|---|---|---|
| | | NS 0/5 | NA 8/16 | NA 14/20 | RCA 0/20 |
| **d/D (mm)** | EN 933-1 [19] | 0/5 | 8/16 | 14/20 | 0/20 |
| **Sand equivalent test (%)** | EN 933-08 [20] | 70 | *** | *** | 71 |
| **Surface cleanliness (%)** | NM 10.1.169 [21] | *** | 0,5 | 0,3 | 3,0 |
| **Methylene blue test (g/Kg)** | EN 933-09 [22] | 0,7 | *** | *** | 0,9 |
| **Water Absorption (%)** | EN 1097-6 [23] | 0,19 | 1,37 | 1,05 | 0,42 |
| **Bulk density mg/m3** | NM 10.1.707 [24] | 1,76 | 1,40 | 1,40 | 1,42 |
| **Real density (t/m3)** | EN 1097-6 [23] | 2,74 | 2,71 | 2,71 | 2,69 |
| **Coefficient of flattening (%)** | NM 10.1.155 [25] | *** | 5 | 6 | 20 |
| **LOS ANGLES(%)** | EN 1097-2 [26] | *** | 20 | 19 | 23 |

*Mix proportions*

The teste on the Aggregates were followed by incorporating RGFRC waste in the concrete mixture as a fraction substitution of natural aggregates. The proportions of the concrete mixture were calculated using the most widely used method in the industry: **DREUX GORISSE's method** [27].

Three mix compositions were designed. The first mix M0 (reference concrete) was made only of natural aggregates, the second mix M20 was made with 20% substitution of natural aggregates by recycled glass fiber reinforced cement and the third mixture M40 is with 40% RGFRC replacement. Mix design is shown in Table 2.

*Table 2: Mix proportion of concretes (kg/m3).*

| | Composition of natural aggregate (kg/m) | | | Composition of recycled aggregate (kg/m) | Water (L) | Cement (kg) |
|---|---|---|---|---|---|---|
| | 0/5 | 8/16 | 14/20 | | | |
| M0 | 876 | 464 | 520 | 0 | 9,450 | 17,500 |
| M20 | 700,8 | 371,2 | 416,0 | 372 | 9,450 | 17,500 |
| M40 | 525,6 | 278,4 | 312,0 | 744 | 9,450 | 17,500 |

For each mix design, three samples were prepared to increase the reliability of the tests.

*Testing*

At age of 7 and 28 days, the densities of all concrete samples were calculated according to *EN 12390-7 standard* [28].

Compressive strength tests were carried out conforming to *EN 12390-3 standard* [29]. The cylindrical specimens tested are loaded under compression until failure and fracture according to *EN 12390-4 standard* [30]. The strength properties were measured after 7 and 28 days of curing.

***Fig. 1.*** *Concrete specimens prepared for compressive strength test.*

**Results and discussion**

*Relative density*

The relative density for the tow experimental phases of curing with 7 and 28 days of age respectively is presented in Figure 2.

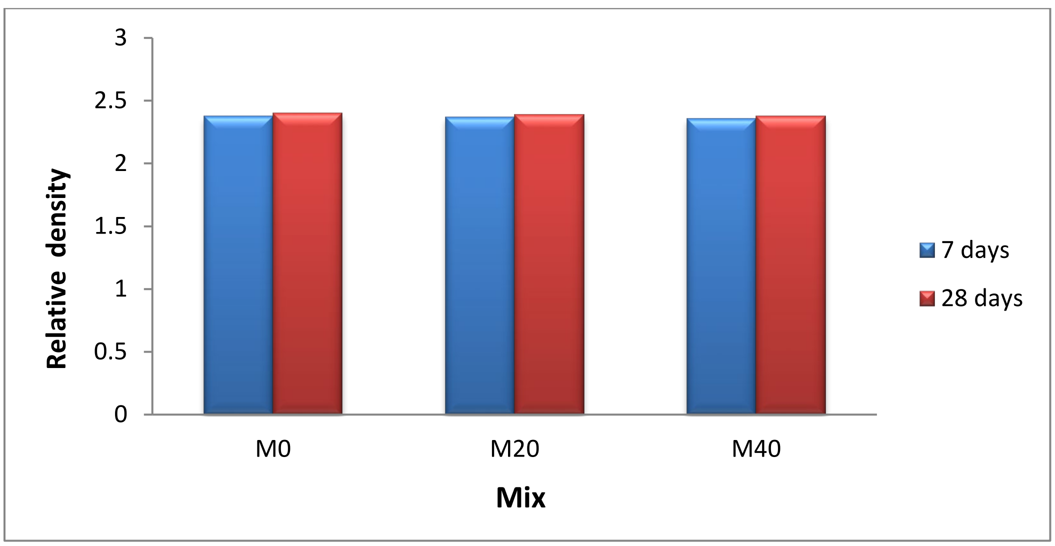


*Figure 2: Average density of concretes.*

According to the graph, the control concrete M0 (reference formulation based on natural aggregates) has a density of 2.38 in 7 days of curing and 2.40 in 28 days. The average density of the concrete containing 20% RGFRC M20 was about 2.37 in 7 days of curing and 2.39 in 28 days. The concrete based on 40% waste M40 had an average density of 2.36 in 7 days of curing and 2.38 in 28 days. These results show that all the tested mixes present exhibit similar behavior to the density of the reference formulation.

The evolution of the samples density at the age of 28-day is low and similar to the initial values. *This is mainly due to the high quality of recycled aggregate* [31].

*Compressive strength Tests*

The results of the compressive strength tests on concrete with different substitution degrees and ages, are shown on Figure 3

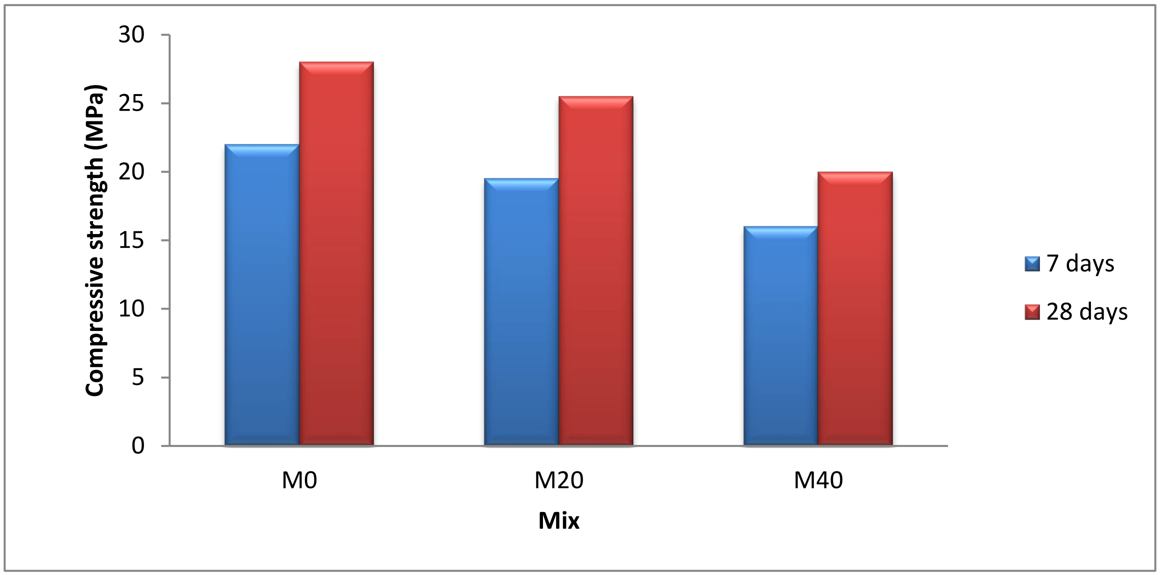


*Figure 3: Compressive strength tests of Mix (MPa).*

At the age of 7 and 28 days, the value of the compressive strength of the concrete containing RGFRC is less than that of the natural concrete. This might due to the presence of the old mortar attached to the recycled aggregates. *This mortar causes increased porosity of the concrete which diminish the mechanical performances of the new concrete* [19].

Exceeding 28 days of curing, the resistance is more influenced by the incorporation of recycled aggregates than the mixes tested after 7 days. *This observation is explained by the long-term self-cementing effects of the old cement mortar and the interaction of the new cement paste and the old cement mortar* [12,20].

At 7 and 28 days of curing, the compressive strength of concrete containing 20% RGFRC was greater than that containing 40% of RGFRC. *It clearly show that the compressive strength reduces with increasing the amount of recycled aggregates* [12,15]. The use of RGFRC exceeds than 20% has a significant loss of compressive strength.

Based on *the Moroccan Standard NM 10.1.008* [32], the result obtained from the M20 (20% of RGFRC) is acceptable for a concrete class B25.

## Conclusion

The experimental work was conducted to study the use of recycled glass fiber reinforced cement as partial substitution of natural aggregates in the concrete production . Properties as grind size distribution, bulk density, water absorption and surface cleanliness were evaluated. These tests were followed by design different mixtures with RGFRC substitution. The most important conclusions can be stated as follows.

- The densities of concrete mixes made with recycled aggregates are the same as the density of the control concrete at a given curing age. This is probably due to the high quality of the recycled aggregates.
- The compressive strength decreases as the percentage of recycled aggregates in the mix increases and, as expected, improves with age due to long-term.
- The substitution of natural aggregates beyond 20% of recycled aggregates decreases the compressive strength.
- The concrete with 20% replacement of natural aggregates is acceptable for a concrete class B25 in the sense of *Moroccan standard NM 10.1.008*.

## Compliance with Ethical Standard Conflict of Interest

The authors declare that they have no conflict of interest.

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