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# Influence of the ceramic recycled agreggates in the masonry mortars properties

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## HIGHLIGHTS

- Influence of ceramic recycled aggregates in the masonry mortars properties.
- Masonry mortars made with 6 dosages of ceramic recycled aggregates (CRA).
- Strength of the mortar improves when the proportion of CRA is increased.
- The shrinkage of mortars reaches similar values with replacements up to 50%.

## ARTICLE INFO

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## ABSTRACT

In this study the influence of the utilization of ceramic recycled aggregates in the properties of masonry mortars is analyzed. The mortars were made with an initial relation cement–sand of 1: 6. The recycled aggregate used was added to the mixture in percentages of replacement of 20%, 35%, 50%, 70% and 100% of natural aggregate. The substitutions were made in volume. All manufactured specimens were cured for 28 days under standard conditions. Once the curing period was completed the physical and mechanical properties were analyzed.

After analyzing the results obtained in the tests a reduction in the density is observed as the percentage of substitution increases. Also, its behavior to flexion improves, the compressive strength is increased and the coefficient of water absorption is reduced. The shrinkage can be considered acceptable up to percentages of replacement of 50%.



## 1. Introduction

The reutilization and the recycling of the construction and demolition waste (C&DW) is one of the principal problems that, worldwide, the construction industry is trying to solve [1,2].The shortage of natural aggregates in some parts of the world and current environmental policies have made the reuse and recycling of C&DW a very attractive solution. On a European level the aim for the year 2020 is the reutilization of 70% of C&DW. Many studies have been carried out on the employment of recycled aggregates proceeding from concrete waste in the manufacture of new concretes [3–6]. In all of them the influence on concrete properties of recycled aggregates used in their manufacture has been analyzed. A reduction has been observed in its mechanical characteristics as the percentage of recycled aggregates in its dosage is increased. Other studies using ceramic and mixed recycled aggregates have detected similar problems [7–9]. It is necessary to emphasize that substitutions of 20% of the natural aggregate coarse granulometric fraction for recycled aggregate do not cause a reduction in the properties of the concrete and that the above mentioned limit is established in some current procedures [10–13].

On the other hand, the C&DW manufactured in recycling plants generate, approximately, between 40% and 50% of particles of 0–4 mm. Due to the high absorption that they present and to the quantity of fine particles generated (<0.063 mm), they are rarely used in the manufacture of concretes and mortars. In this regard Ledesma [6] has analyzed the effect of ceramic recycled aggregates on some properties of mortars. Although, in general, a reduction in its mechanical characteristics is observed it presents acceptable values in its compressive and flexural strength with substitutions of up to 50%.

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In this study the reutilization of ceramic waste, proceeding from defective pieces used in building, in the manufacture masonry mortars has been analyzed. 35% and 70% have been added to the habitual percentages of substitution, 20%, 50% and 100%, since these percentages are not frequently studied. A wide experimental program has been developed to analyze the physical and mechanical properties of the manufactured mortars. The study has been completed by determining the deformations due to shrinkage.

## 2. Experimental study

### 2.1. Materials

The cement used was CEM III-A 42.5 N/SR. Table 1 summarizes the main features.

In this study siliceous natural aggregates and ceramic recycled aggregates (CRA) proceeding from waste of pieces of defective ceramics employed in ventilation ducts were used. The principal physical and mechanical properties have been analyzed. Fig. 1 and Table 2 summarize the properties of both types of aggregates. The granulometric fraction used was 0/2 mm both for natural aggregate and the CRA.

### 2.2. Dosage of the masonry mortar

A masonry mortar of plastic consistency and with a relation cement-sand 1: 6 was manufactured. The amount of water used was 15% with regard to the rest of components. Additives were not used in its dosage. To analyze the influence of the ceramic recycled aggregates on the properties of the mortar, the natural sand has been replaced by CRA (20%, 35%, 50% 70% and 100%).The percentages of CRA replace, in volume, the same quantity of sand that forms part of the mixture.

In order to obtain the same workability in all mixes it was necessary to increase the quantity of water as the proportion of CRA was increased. Table 3 shows the mixes the used.

### 2.3. Experimental program

The experimental program carried out includes six different mixes. The first mix corresponds to the control mortar. The rest of the mixes correspond to mortars with different percentages of ceramic recycled aggregates.

The manufacturing procedure followed has been the following: first of all, the sand was introduced into the mortar mixer, later the CRA, then the cement and finally the water. The materials were mixed manually with a metallic rod for 10 s. Finally, this mass was mixed at a slow speed for 75 s.

Twelve prismatic specimens of $40 \times 40 \times 160$ mm [14] and three specimens of $25 \times 25 \times 285$ mm [15] were manufactured. Then the specimens were cured according to the specifications of Table 4 [16].

The bulk density of the fresh mortar [17], density of hardened mortar [18], the flexural and compressive strength [16], the coefficient of water absorption by capillarity [19] and shrinkage [20] has been determined. Flexural strength, compressive strength and water absorption by capillarity tests were carried out after 28 days. The measurements of the shrinkage tests were carried out from the second until the twenty-eighth day, as is stated in the standard UNE-EN 1015-11 [16].

**Table 1**
Cement properties.

| | | |
|---|---|---|
| Loss due to calcination (%) | | 1,5 |
| Insoluble residue (%) | | 0,3 |
| Expansión le chatelier (mm) | | 42,4 |
| Setting (min) | Begin | 4 |
| | Final | 0,1 |
| Compressive strength (MPa) | 2 days | 20,1 |
| | 28 days | 56,6 |

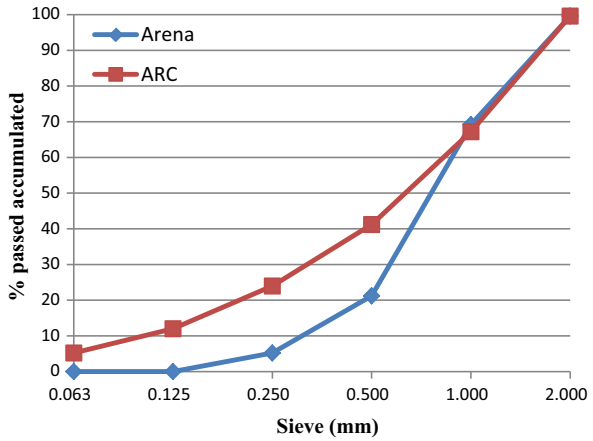


**Fig. 1.** Granulometric curves.

**Table 2**
Properties of aggregates.

| Property | Sand | Arc |
|---|---|---|
| Humidity | 0,20% | 2,50% |
| Density (kg/l) | 2,83 | 2,02 |
| Absorption at 24 h (%) | 0,40% | 11,90% |
| Sand equivalent, SE (10) | 95 | 73 |

## 3. Analysis of results

### 3.1. Mortar density

The density of the fresh mortar was immediately obtained after the mixing process. The density of the hardened mortar was calculated after 28 days. Figs. 2 and 3 show the density of the fresh and hard mortar respectively, depending on the percentage of RCA. It can be seen that, when the percentage of CRA increases, the density of the mortar decreases. This fall of density follows an almost linear progression for mortars in fresh and hard condition.

However, in the mortar with 50% of CRA it was observed that the density in fresh condition does not present the same reduction as the rest of the specimens. This was caused by a little surplus in the amount of initial water in this sample of mortar, since once the time of curing had passed by and the free water evaporated, the density of the mortar with 50% of CRA showed the same reduction as the others, as can be seen in Fig. 3.

### 3.2. Flexural strength

The flexural strength of the mortars was determined after 28 days. The results observed in Fig. 4 correspond to the average strength obtained for the series of 9 specimens corresponding to each of the different percentages of CRA. It can be observed that the flexural strength increases with the percentage of CRA. This is undoubtedly caused by the reduction that the amount of effective water was experiencing when the percentage of substitution was increased.