



# Incorporation of fine plastic aggregates in rendering mortars



Alexandra M. da Silva<sup>a</sup>, Jorge de Brito<sup>b,\*</sup>, Rosário Veiga<sup>c</sup>

<sup>a</sup> Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisbon, Portugal

<sup>b</sup> ICIST, Department of Civil Engineering, Architecture and Georresources, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisbon, Portugal

<sup>c</sup> Department of Buildings, LNEC – National Laboratory of Civil Engineering, Av. do Brasil 101, 1700-066 Lisbon, Portugal

## HIGHLIGHTS

- Two types of plastic recycled aggregates up to 15% of sand volume in rendering mortars.
- Some properties declined: mechanical and adhesive strength, water absorption.
- Improvement in water vapour permeability, impact resistance and dimensional stability.
- The shape and number of recycled particles are relevant and need to be considered.

## ARTICLE INFO

### Article history:

Received 28 April 2014

Received in revised form 29 July 2014

Accepted 23 August 2014

Available online 16 September 2014

### Keywords:

Mortar

Renderings

Modified coating mortars

Recycling

Plastic waste

Plastic aggregates

PET

Performance

## ABSTRACT

The increasing growth of plastic in our Society has triggered the search for methods to solve the industry's waste disposal. The interest of recycling this material, both in ecologic and economical terms, is not only due to its aggressiveness towards the environment but also to its high volume of landfilled material along with the fact that it is non-biodegradable.

This paper approaches these issues within the context of sustainable development, considering a new application for plastic waste and studying the effects of its incorporation in mortars. Three substitution ratios of recycled plastic for natural aggregate have been considered, 5%, 10% and 15%. This substitution was made in volume and only in the 1–2 mm fraction. This research also studied two types of PET aggregates, PP and PF aggregates that stand for plastic pellets and plastic flakes.

The results show that, although the incorporation of plastic aggregates led to a worse performance in some properties, in others the modified mortars revealed a significantly improved performance in comparison with the control mortar (without plastic).

© 2014 Elsevier Ltd. All rights reserved.

## 1. Introduction

Plastic is a relatively inexpensive, durable and versatile material. These characteristics lead to the creation of thousands of products, which have benefits in terms of quality of life, employment and economic activity [1]. As a result, our Society is extremely reliant on plastic, and its production rate has grown on average 9% per year [2].

According to the PlasticsEurope report, the global production of plastic in 2013 was around 241 Mton, with Europe and China as the major consumers with 20.4% and 23.9% [3].

However, plastic also has negative consequences, such as emissions of greenhouse gases or ecological damage. Usually, plastic is non-biodegradable material, and therefore the waste remains for

long periods of time in the environment, representing a risk to human health and the ecosystem [4].

Currently Europe is leading the market in terms of sustainable development through European legislation, with the aim of protecting the environment. For the past decade, there has been a constant growth, both in mechanical recycling and energy recovery, which suggests that the recycling of plastics will continue to increase in the future [2,3].

The construction industry, acknowledging the importance of environmental issues, has sought to find solutions that are able to combine economic growth and environmental preservation. To this end, several studies have been conducted in order to incorporate plastic in construction processes. One of the methods is the substitution of natural aggregates by recycled plastic aggregates in cementitious materials (mortars or concrete), but its application has direct implications on the concrete or mortars' performance depending on the type of plastic used and the characteristic being evaluated. Previous studies on the use of recycled plastic aggre-

\* Corresponding author. Tel.: +351 218419709; fax: +351 21 8497650.

E-mail addresses: [alexandra.cvmilva@gmail.com](mailto:alexandra.cvmilva@gmail.com) (A.M. da Silva), [jb@civil.ist.utl.pt](mailto:jb@civil.ist.utl.pt) (J. de Brito), [rveiga@lnec.pt](mailto:rveiga@lnec.pt) (R. Veiga).

gates have been mostly focused on concrete [5–8] and the literature is scarce on mortars' applications.

The incorporation of other materials, in particular industrial waste, is not only better for the environment but may also lead to improvements in certain properties. Some studies have been published and show the potential of various types of waste aggregates: brick [9], concrete [10], rubber [11], glass [12] and plastic [13–24], more specifically PET, [13–20].

## 2. Literature review

Recycling waste as mortar or concrete aggregates has several sustainability-related benefits, but their properties are usually less beneficial than those of natural aggregates. This raises the issue of finding the optimal replacement ratio in order to decrease the less desirable effects of the substitution or to improve the characteristics of mortars [5].

Considering the results from previous studies of mortars with incorporation of various waste materials as partial replacement of natural aggregate, it is evident that the present knowledge concerning the variations introduced in the mortars is insufficient to predict the performance and durability of these materials as wall renders and plasters and also to determine the best replacement ratio for the referred uses.

Most of the studies of mortars containing PET aggregates only analysed a single property or a limited set of properties, such as fresh and dry bulk density, mechanical strength, water absorption, modulus of elasticity, gas permeability and Interfacial Transition Zone (ITZ) characteristics. This work will try to fulfill some gaps in this area of knowledge.

According to the literature, both fresh and dry bulk density decrease with the incorporation of waste aggregates. This occurrence can be explained by the lower bulk density of plastic, rubber and glass waste compared to that of sand.

From the literature it appears that the main concern in incorporating plastic or other plastic aggregates in mortars is the significant loss of mechanical strength. This substantial decline of the mechanical properties seems to be mostly caused by the heterogeneities created by the plastic aggregates within the cement paste, particularly in the Interfacial Transition Zone (ITZ). Through a microstructural analysis, using scanning electron microscopy (SEM), some authors [16–18] were able to analyse the Interfacial Transition Zone (ITZ). This analysis revealed a complete adherence between the cement matrix and the siliceous aggregates in the control mortar, whereas in the mortar with plastic aggregates there were voids between these aggregates and the matrix.

In terms of water absorption, the results of the previous studies are not very consistent and can even be contradictory. In some studies the sorptivity coefficient of the mortars containing PET aggregates was lower in comparison with the control mortar and hydrous transfers were either slower or faster as the ratio of substitution increases. This occurrence was justified by the shape of the aggregate that was used and also by the non-sorptive character of PET that contributed to slow down the propagation of the imbibition front by forcing the hydrous flow to bypass them, i.e. by increasing tortuosity [14,16]. On the other hand, in other studies [17–20] the apparent porosity and water absorption seem to increase with the plastic content. The authors link these results to the poor adhesion between the matrix and plastic aggregates, which increase the mortars' porosity and led to an increase in capillary absorption.

Concerning the modulus of elasticity, studies show that the modulus' values decrease as PET quantity increases. The reduction of the modulus of elasticity is due both to the reduction of composite bulk densities and to the plastic aggregates, which decrease the

velocity of the wave by disturbing the ultrasonic wave propagation [16].

As for gas permeability, there was an increase of permeability coefficient in mortars with plastic aggregates. Once again the weak bond between the matrix and the plastic aggregate certainly increases the porosity of the mortar, which may explain the measured increase in permeability of plastic mixes. The more the plastic aggregates are used the more the porosity of the mix will increase [17].

From this literature review, it can be concluded that the present study (i) corroborates the few results on some of the properties of mortars incorporating PET aggregates (ii) provides so far unique data on the durability of this type of mortars (based on tests such as adhesive strength, water vapour permeability, impact resistance and accelerated ageing never before published on mortars with PET; and (iii) presents an unprecedented analysis of the influence of the shape of the PET aggregate, by comparing the results obtained from the same tests in identical laboratorial conditions, using two differently shaped aggregates.

## 3. Experimental programme

The campaign was planned in two phases. The purpose of the first one was to perform a series of tests in order to evaluate the essential characteristics of the mortars and to identify the substitution ratio with the most satisfactory results. In the second stage, another set of tests was carried out on the previously selected mortar, in order to obtain a more detailed characterization of its behaviour.

Table 1 lists the tests performed within the experimental campaign as well as the specifications used.

The 5%, 10% and 15% aggregate substitutions were carried out in the 1–2 mm fraction only and keeping the same grading curve of the sand. The viability level was set in comparison with the performance of a control mortar, consisting of 100% sand aggregates, water and cement, at a volumetric ratio of 1:4 (cement/aggregate).

### 3.1. Materials

The mortars were made with: Portland cement (CEM II/B-L 32.5N); siliceous sand from the Tagus River; and two types of granulated plastic waste, PP and PF aggregates, presented in Fig. 1. Table 2 shows the values of the components' densities [6] and bulk densities and Fig. 2 illustrates the grading curves of the natural and both plastic aggregates.

Information about the two types of PET recycled aggregates was collected from Selenis, a plastic recycling plant located in Portalegre, Portugal. PF aggregates were manufactured by shredding waste PET bottles to sizes 1–4 mm and PP aggregates were produced in sizes 1–4 mm, by applying a thermal process to shredded PET bottle particles. Fig. 3 represents the manufacturing process of both aggregates.

### 3.2. Mix proportions

All the mortars were produced at the volumetric ratio of 1:4, cement to aggregate, and according to the mixing procedure defined in the European standard EN 1015-2. The amount of water was decided based on European Norm EN 1015-3 (1999) [34]. A stricter slump flow range was adopted, instead of the range proposed by the norm ( $170 \pm 3$  mm versus  $175 \pm 10$  mm proposed by the norm), in order to more accurately control the effect of water.

Table 3 presents the composition of all the mixes produced.

## 4. Results and discussion

This work is part of a research that has been developed at Instituto Superior Técnico (IST,) University of Lisbon, and at the National Laboratory of Civil Engineering (LNEC), in Portugal, aiming at studying the implications of incorporating waste as aggregate in concrete and mortars. Besides comparing the results obtained with studies in which plastic aggregates have also been incorporated in mortars, it was found suitable to compare some of them with those of previous studies using other types of waste, since the same test methods were carried out under identical laboratory conditions. As the watertightness of plastic aggregates is a factor with significant influence on the mortar's performance, it

Download English Version:

<https://daneshyari.com/en/article/257285>

Download Persian Version:

<https://daneshyari.com/article/257285>

[Daneshyari.com](https://daneshyari.com)