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The incorporation of construction and demolition wastes as recycled mixed aggregates in non-structural concrete precast pieces

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ABSTRACT

Concern for the environment has lately heightened awareness about the need for recycling in the construction industry. However, some standards, such as the Spanish standard, only accept the recycling of aggregates derived from concrete, which limits the extensive use of construction and demolition waste, which are produced in much bigger volumes. The aim of this work was to explore the possibility of using recycled mixed aggregates (RMA) in the preparation of precast non-structural concretes. To that end different percentages of natural aggregate were replaced by RMA in non-structural elements (25, 50, 75 and 100%). Contents of cement, water, and the dosages commonly used by companies were unchanged by the introduction of RMA. The characterization of the prepared elements has been done using the specific tests for each type of non-structural element (terrazzo for indoor use, hollow tiles, kerbstones and paving blocks): compression and flexural strength, water absorption, dimensional tolerances, abrasion and slipping resistance. The paving blocks, kerbstones, and hollow tiles prepared were tested for 360 days. The stability of the tested properties confirmed the possibility of using these wastes on an industrial scale satisfying the standard requirements.

However, the surface of terrazzo with RMA is not as good as that prepared with natural aggregate.

1. Introduction

Recycling and reuse are becoming increasingly necessary in today's world. The construction industry, one of the greatest offenders in terms of pollution, is starting to be concerned about the issue. One of the main environmental problems caused by civil work and building construction is the amount of construction and demolition waste material (C&DW) created every year, which is deposited mainly in dumps. In addition to that, for every new work huge amounts of aggregate are required. A current trend to avoid the accumulation and treatment of waste and to reduce the consumption of natural resources needed to produce the aggregate is the use of recycled aggregates which retain the required properties of concrete. C&DW were used to produce concrete and the mechanical properties, as well as the water absorption were measured at 28 days (Medina et al., 2014), reaching the conclusion that regarding those properties the produced concrete would be apt for housing construction, but no measurement in the long term was taken, and properties may change with time. Mefteh et al. (2013) studied the influence of the moisture in the recycled aggregates determining that using pre-wet or saturated surface-dried aggregates improves the mechanical properties measured at 28 days, but again no measurement is made in the long term. This works deal with laboratory prepared samples also, and no specific use is thought for the prepared concrete samples. Other works determine the mechanical properties after one year (Thomas et al., 2014) but samples are prepared in the laboratory and some factors, such as w:c ratio are changed, fact that could be a problem when trying to manufacture concrete at an industrial scale. The measurement of the evolution of the properties required for the constructive use of the prepared elements is very important, because it shows the tendency, tha in case of being a decreasing tendency will not guarantee the properties in the long term.

Directive 2008/98/CE about wastes (European Parliament, 2008) states the necessity of reducing the use of natural resources and the

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need for recycling. It predicts that by 2020 70% of the C&DW generated should be reused, recycled and assessed.

By means of processing C&DW, recycled aggregates are obtained. Depending on their original waste material, recycled aggregates could be concrete, ceramic or a mixture (recycled mixed aggregate, RMA). RMA constitutes around 80% of C&DW(Regional government of Madrid, 2012). It comes from building demolitions and contains a wide range of materials, such as concrete waste, pavement material, ceramic products, and, in lower quantity, other materials such as gypsum, glass, wood, etc. A paper recently published (Rodríguez et al., 2015) studies the real situation of the reusing of C&DW in Spain, focused on the work of the recycling plants, and on the role of the Spanish Government. One of the conclusions of the work is that the government's role should be more active promoting the reusing of C&DW. Present work is focused to explore the possibility of using these wastes at industrial scale for some constructive elements, and could help to enhance the clean industries.

Efforts have been made on the study of reusing C&DW to obtain different constructive elements. Some studies (Sousa et al., 2003; Yang et al., 2011) have shown that, in elements made of vibro-pressed precast concrete, such as blocks or pavement blocks, the use of concrete recycled aggregates, in fine fraction as well as coarse fraction, the substitution of natural aggregate by RMA up to 50% or 60%, had no strong effect. Other studies have analysed the behaviour of concrete pavements made with ceramic recycled aggregates. It was observed that increasing the percentage of substitution decreases strength, density and abrasion resistance. However, these works show that, up to a substitution percentage of 32.5%, the criteria established by Regulation EN 1338 on pavement blocks are fulfilled (Jankovic et al., 2012).

A comparison has been made between the performance of specimens of non-structural precast concrete for pavements (blocks), some of them with concrete recycled aggregates and others with ceramic recycled aggregates. The results show that with ceramic recycled aggregates density and compressive and tensile strength decrease, and the level of water absorption increases because of the higher absorption of water by ceramic materials used. The substitution of 25% of concrete aggregates with ceramic recycled aggregates produces pavement which fulfils the Hong Kong regulation on traffic areas (Poon and Chan, 2006).

Soutsos et al. (Soutsos et al., 2011). showed that it is possible to produce concrete for pavement blocks using concrete and ceramic recycled aggregates with similar mechanical properties to those of natural aggregate, without any need to increase the amount of cement. Even tough some works replicated the industrial procedure in a laboratory (Soutsos et al., 2011), no one of these elements were produced at industrial scale, and the properties were measured at a given age (in general 28 days), leaving the uncertainty of the evolution of the behaviour of the properties due to the presence of recycled aggregates.

There are not many studies on the use of RMA in non-structural vibro-pressed precast concrete (López Gayarre et al., 2013; Poon et al., 2009). According to the results obtained in these studies, compressive strength, or resistance, in the case of vibro-pressed elements, decreases whenever the proportion of RMA increases, both for coarse fraction and for fine fraction. The loss of resistance is higher when the water/cement ratio is lower (Chen et al., 2003; Mas et al., 2012b), or if concretes with higher strength are used (Mas et al., 2012a). Regarding the influence of recycled coarse and fine fraction, the addition of fine aggregates causes less loss of strength with low substitution percentages. Nevertheless, for higher substitution percentages, the loss of strength is equal. Other authors (Lovato et al., 2012) have found that a 100% recycled fine fraction substitution causes an 18% decrease in resistance. This decrease is lower with a 100% coarse fraction substitution (24% decrease), because of the difficulties of compacting when ceramic coarse aggregates are used. The use of fine fraction is also discussed by other authors (Evangelista and de Brito, 2007). However, other studies on recycled concrete with substitutions of concrete fine recycled aggregate did not obtain satisfactory results (Etxeberria et al., 2007; González-Fonteboa and Martínez-Abella, 2008). Because of these differences, the use of fine fraction in the future should not be dismissed, but more research on it is needed.

The results of flexural strength and tensile strength are contradictory. Some studies state that the addition of RMA causes a reduction of strength (Lovato et al., 2012; Mas et al., 2012a, 2012b), caused by a higher porosity of recycled aggregates and the presence of ceramic materials. Nevertheless, other researchers find that recycled aggregates does not have an important influence on tensile strength (de Brito et al., 2005). They state that their addition improves the tensile strength in relation to the use of conventional concretes, except in the case of 100% substitution (Etxeberria et al., 2007), despite the fact that recycled aggregate is usually more fragile than natural aggregate.

Because of the lower density of recycled aggregates, concretes made with RMA show lower densities than reference concretes. Recycled concrete absorbs more water, as can be expected from the density data. This property increases more if fine recycled aggregates are added than if the replacement is made by coarse recycled aggregates (Lovato et al., 2012; Sousa et al., 2003).

Slipping resistance of recycled concretes presents contradictory results. Yang et al. found that, using recycled aggregates, mainly concrete waste, the slipping resistance improved with increasing substitution percentage (Yang et al., 2011). Conversely, Poon and Lam stated that using recycled aggregates from concrete and glass waste did not change the slipping resistance (Poon and Lam, 2008).

The resistance to abrasion decreases with the percentage of substitution by ceramic recycled aggregate (Jankovic et al., 2012). The use of RMA presents the same tendency: it keeps its values with 20% substitution, and the resistance to abrasion decreases with 40% substitution (Mas et al., 2012b). Some researchers have observed that ceramic aggregate is harder than the rest (Mas et al., 2012b; Poon and Lam, 2008).

This work is focused on the possibility of using a coarse fraction of RMA in the production of elements made of vibro-pressed precast concrete: kerbstones, pavement blocks, terrazzo and hollow tiles. In order to study how RMA affects the properties of these items, different substitution percentages have been used, testing its influence in terms of resistance, bending strength, water absorption, density, abrasion, and slipping resistance. The results seem to be promising as regards the use of mixed recycled aggregates at industrial scale, since all elements were produced in real industries, with their technology and using the dosages provided and employed by the companies; few works cover this essential way to reuse big amounts of C&D wastes. Also, in this work several properties have been measured up to one year after their preparation. The measurements have been made to check the guaranty that these products have for using according to the Spanish and European mandatory Standards. These results guarantee that changes in properties are not important and they still fulfil the required standards, independent of the age of the prepared element.

2. Materials

Two different types of concrete were used, but with similar characteristics. For terrazzo and hollow tiles, CEM II A-LL 42,5 R concrete was used according to the Spanish Standard (AENOR,