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Improvement of recycled concrete aggregate properties by polymer treatments

Valerie Spaeth *, Assia Djerbi Tegguer

Building Materials Department, IFSTTAR, Institute of Science and Technology, 14-20, Boulevard Newton, F-77447 Champs sur Marne, France

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Abstract

The recycling of concrete, bricks and masonry rubble as concrete aggregates is an important way to contribute to a sustainable material flow. The limited reuse of recycled concrete aggregates (RCA), even partially, instead of natural aggregates, can be explained by the influence on the properties of fresh and hardened new RCA-based concretes. Experimental studies were carried out on the improvement of RCA performance, especially water absorption and fragmentation resistance. The use of polymer based treatments was applied and then the performance achieved was characterized in order to show the relevance of such polymer treatment. Beneficial effects of appropriated polymer based treatments applied on RCA were obtained especially lower water absorption and better fragmentation resistance.

Keywords: Recycled concrete aggregates; Water absorption; Water repellent polymers; Fragmentation resistance; Cement materials

1. Introduction

Decreasing natural resources of sand and gravel and increasing problems with waste management support the recycling of the accumulating waste materials. If the vision of a sustainable material flow is to be realized, the amount of recycled waste has to be increased. The building industry in particular is a major consumer of materials and at the same time a major producer of waste. One possibility is to recycle and reuse inorganic building waste as concrete aggregates. However, the composition of these aggregates can vary substantially and their properties have a significant influence on the properties of the concrete (Chen et al., 2003; Khalaf and DeVenny, 2005, 2004; Ryu, 2002; Hoffmann et al., 2012).

The reuse of RCA in concrete will contribute to valorize the construction wastes within the framework of the sustainable development. However, its application in construction field is still limited. Generally, the physical and mechanical properties of concrete made of recycled aggregates, were found to suffer compared to natural aggregate concrete (Chakradhara et al., 2011; Kou and Poon, 2011, 2009; Casuccio et al., 2008; Achtemichuk et al., 2009; Topçu and Sengel, 2004).

The physical properties of recycled aggregates depend on both adhered mortar quality and the amount of adhered mortar. The adhered mortar is a porous material; its porosity depends upon the w/c ratio of the recycled concrete employed (Etxeberria et al., 2007). The crushing procedure

* Corresponding author.
E-mail addresses: valerie.spaeth@ifsttar.fr (V. Spaeth), assia.tegguer@ifsttar.fr (A. Djerbi Tegguer).

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and the dimension of the recycled aggregate have an influence on the amount of adhered mortar (Nagataki, 2000; Hansen and Narud, 1983; Hansen, 1945; Sánchez de Juan and Alaejos Gutiérrez, 2009; Tam et al., 2007). The density and absorption capacity of recycled aggregates are affected by adhered mortar. The absorption capacity is one of the most significant properties which distinguishes recycled aggregate from raw/natural aggregates, and it can have an influence both on fresh and hardened concrete properties due to the presence of the porous cement mortar.

RCA properties were investigated by Sánchez de Juan and Alaejos Gutiérrez (2009) which showed the relationships between mortar content and absorption as well as mortar content and Los Angeles abrasion (LA). When attached mortar content is high, absorption increases too. The same trend is observed with regard to LA abrasion. The amount of mortar attached to fine fraction is higher to coarse fraction which showed the great heterogeneity of RCA. The main properties unfavorably affected by mortar content are absorption, density, LA and sulfate content.

The presence of RCA and the porous nature of the old cement mortar affect the bond between the RCA and cement paste when used in new concrete.

With regard to the mix design, one of the methods considered and available at present is to restrict substitution of recycled aggregates, to maintain employment of fine natural mineral additives used as partial replacement of cement and/or adding reducing agents to water (Kou and Poon, 2011; Tam et al., 2007). The poorer quality of RCA often limits its utilization.

In the literature, a number of RCA beneficiation treatments, available today, have been recently proposed to enhance the quality of RCA through reduction of the mortar present (25−70% decrease of mortar). In these treatments, one or a combination of mechanical (mechanical grinding process), thermal (microwave or conventional heating) and chemical treatments (pre-soaking or cycle soaking) are usually used to remove the attached mortar of RCA and reduce the loss of recycled aggregate properties at the present time (Sánchez de Juan and Alaejos Gutiérrez, 2009; Akbarnezhad et al., 2011; Tam Vivian et al., 2007).

In this same context, the investigation lead to the chemical treatment development which can improve the properties of RCA without removing the mortar based matrix.

The study, presented here, deals with the influence of different polymer based treatments on RCA (12–20 mm) already used in the protection of structures (grout, render...).

Polydiorganosiloxanes (also called PDMS) and alkylalkoxysilanes (also called silane) have become a very important class of materials used for water-repellent post-treatment of masonry or concrete (for example: Impregnation or sealer additive to protect structural concrete from deicing salt ingress and freeze–thaw damages) (Büttner and Raupach, 2008; Schueremans et al., 2008), additives in non load bearing concrete to control efflorescence or chloride penetration (Zhao et al., 2011), post-treatment or additives in Fiber reinforced cement boards (Lecomte et al., 2010), where durability and minimal impact on substrate appearance are important. This kind of treatment enables to decrease water absorption of porous construction materials (such as the post- treatment at the surface of the existing materials).

Since this kind of treatment is already applied on cementitious materials (both mortar and concrete), the application on crushed concrete as aggregate will be feasible in order to improve the mechanical and physical properties of aggregates.

This paper reports an experimental study to improve the properties of recycled concrete aggregates (RCA) by their impregnation with polymers. The effects of polymers applied on the water absorption, the microstructure and fragmentation resistance of the recycled aggregate concrete were evaluated.

The aim is to determine the best conditions for an efficient and sustainable polymer impregnation (PI) improving physical and mechanical RCA properties which should become closer to natural aggregates. In addition, the mode of treatment should be compatible with building yard practice.

2. Sample preparation

Natural and recycled aggregates were used as the coarse aggregate. Natural crushed aggregates are limestone type with density 2.7 g/cm^3. Recycled aggregates were crushed from ordinary concrete (OC) which was made to overcome the problem of heterogeneity due to the complexity of the mixtures of recycled aggregates. The water/cement ratio of ordinary concrete (OC) is 0.49 with cement type CPA-CEM I 52.5, the mixture proportions are reported in Table 1. Concrete specimens were prepared from a single batch. The concrete mixtures were cast in specific molds and compacted using a mechanical vibrator. After casting the specimens were stored in a room maintained at 20 °C and about 95% relative humidity (RH) for 24 h, and were cured in water at 20 °C for 90 days. The characteristics of conventional concrete are shown in Table 2. The open porosity was measured by water saturation. After 90 days of cure, the concrete was crushed in distinct granular fractions via French center. This choice allows easing the reproducibility of the tests and having “conventional

Table 1
The mix design composition of used conventional concrete.

Mix ingredients (kg/m^3)	OC
Coarse aggregate, 12–20 mm	777
Medium aggregate, 4–12 mm	415
Sand (Boulonnais), 0–5 mm	372
Sand (Seine), 0–4 mm	372
Cement CPA-CEM I 52.5	353
Total water	172
w/c	0.49