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Mechanical properties of concretes with recycled aggregates and waste brick powder as cement replacement

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Abstract

The cement industry is responsible for around a 5 % of the CO_2 emissions worldwide and considering that concrete is one of the most used materials in construction its total effect is significant. An alternative to reduce the environmental impact of concrete production is to incorporate certain amount of residuals in the dosing, limiting the replacement percentages to avoid significant losses in the mechanical properties of the final material. This study analyses the variation in the mechanical properties of structural concretes with recycled aggregates and waste brick powder as cement replacement to test the effect of the simultaneous use of different residuals in the same material. All concretes are dosed for a compressive strength of 30 MPa. The recycled aggregates are obtained from prefabricated pipe debris with a compressive strength of 20 MPa. The waste bricks are obtained from construction demolitions. Four levels of replaced cement by waste brick powder are considered: 0 %, 5 %, 10 % and 15 %. Also, two kinds of samples are studied regarding the amount of recycled aggregates: 0 % and 30 %. All these levels are combined to analyze the effect of both residuals in the mechanical properties of the concrete through compressive strength tests, flexural strength tests and elasticity modulus tests, all of them after 28 curing days. Results show that when no recycled aggregates are used, the cement can be replaced up to a 15 % by waste brick powder. But when both residuals are combined the amount of waste brick powder recommended without significant losses in the final material properties is limited to a 5 %. Replacing a 30 % of the aggregates together with a 5 % of the cement can considerably reduce the environmental impact of the final material.

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Keywords: Recycled aggregates; waste brick powder; replacement of cement; mechanical behaviour of recycled concrete.

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1. Introduction

Concrete is one of the most used materials in construction and, at the same time, one of the materials with higher contribution to the amount of construction and demolition waste (CDW) generation. In concrete production the main responsible for CO_2 production is the use of ordinary Portland cement with a contribution rate roughly equivalent to 80–90 % [1]. Hence, an effective way to reduce the environmental impact of concrete production is to minimize the CO_2 emission related to cement.

Viera et al. [2] studied the effect of adding fine aggregates from waste bricks and ceramic sanitary ware in concretes, concluding that these fine aggregates contribute to the pozzolanic activity. They found that the use of these residuals increased the strength of the concretes compared to a traditional control one. Puertas et al [3] found that ceramic materials, used as cement replacement, have pozzolanic activity after at least 8 curing days. Kulovaná et al [4] study the replacement of up to a 60 % of brick residuals as cement, with a 0.4 water/cement ratio, concluding that the use of up to a 20 % does not compromise the mechanical properties of the concrete and it enhances up to a 50 % its heat conductivity. On the other hand, Katzer [5] analyzes mortars with 10 % and 50 % brick waste replacements, finding that these residuals can be used in materials with low mechanical requirements (over 0.6 water/cement ratios). This disparity in the results can be attributed to the particle size distribution of the residual, while Katzer [5] uses material with particles under 8 mm, Kulovaná et al [4] mainly replace material under 100 microns.

Moreover, the use of ceramic brick residuals enhances the durability due to a refinement in the pore structure. Bignozzi and Bonduà [6] found that the use of a 25 % of ceramic residuals as cement supplement increases the cement durability compared to ordinary Portland cements. Similar results are obtained by Pacheco and Jalali [7,8] using 20 % of brick and sanitary ware ceramic waste. On their behalf, Toledo et al [9] and Vejmelková et al. [10] conclude that the use of up to a 20 % of ceramic brick has no influence in the compressive strength and elasticity modulus of the mortar, and Lavat et al. [11] establish that 20 % to 30 % of the cement can be replaced by adequately grinded ceramic roof tile.

Besides, the replacement of up to a 25 % of cement by brick waste has been tested along with the use of waste glass as sand replacement. Results have proven that the brick powder is able to counteract the negative effects of the use of glass in the alkali-silica expansive reaction responsible of the production of fissures in the concrete [12].

An alternative to reduce even more the CO_2 emissions and the amount of CDW from concrete production is to replace, not only some amount of cement but also other of the raw materials, such as coarse aggregates. Several studies [13-23] have proven the feasibility of the use of recycled aggregates (RA) if the percentage of replacement is limited [16-23]. Differences between the mechanical properties of traditional concrete and concretes with RA have been mainly attributed to the old mortar adhered to the surfaces of the RA. Two interfaces have to be considered when using RA rather than one, the old interface, between the old mortar and the RA, and the new one, between the RA and the new cement mixture [14]. The quality of these interfaces, given by the quantity and quality of the old adhered mortar, is a key factor influencing the mechanical behavior of recycled concrete [15,24].

Despite the use of RA and waste brick powder (WBP) has been studied in construction materials, there is still a lack of information about the mechanical behavior of concretes produced with both residuals simultaneously. Therefore, the goal of this research is to analyze the effects of the simultaneous replacement of WBP as cement and RA as natural coarse aggregates, in particular, in the mechanical properties (compressive strength and flexural strength) of concrete mixtures, to efficiently maximize the reuse of concrete waste. The aim of this study is to optimize the mixture combining the considered parameters, maximizing the amount of WBP and RA reused.

2. Methods and materials

2.1. Cement and bricks

Pozzolanic cement, equivalent to ASTM type P cement, was used. The targeted 28-days-compressive concrete strength was set at 30 MPa.

WBP, used as cement replacement, was obtained from industrial brick residuals from demolition debris.