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Eco-toxicity assessment of concrete prepared with industrial wastes

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Abstract

The technical performance and the environmental behavior of new materials are key factors in their acceptance. In this work, wastes from local industries (lime sludge and biomass fly ashes) replaced natural fine aggregates in the concrete production. The concrete mechanical strength was evaluated and eco-toxicity was assessed using duckweed as biomarkers. The results showed that wastes addition to the concrete mix led to a decrease of 3% and 35% in the compressive strength when fly ashes and lime were used, respectively. The bioassays performed did not show different behaviors between conventional concrete and concrete produced with the wastes.

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Keywords: Concrete; duckweed; eco-toxicity; fly ashes; lime sludges

1. Introduction

The building construction as it is done nowadays is based in the concrete utilization. Concrete is prepared by mixing Portland cement with fine aggregates (sands), coarse aggregates (gravel), kneading water and adjuvants (to improve its performance).The concrete is used not only in the structural part of buildings (such as reinforced concrete or pre-stressed concrete) but also in art pieces, coatings, sidewalk guards and bridges. Is a quite moldable

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material, allowing the buildings construction with the most diverse formats, given stability and resistance to the structure.

The concrete production contributes for natural resources depletion and wastes generation. The natural resources extraction contributes also for visual negative impacts, considering the landscape deforestation due to limestone or clay extraction for cement production. Moreover, wastes have a negative impact in the environment, contributing to the life quality degradation of all living beings. Thus, the waste reuse should be taken into account by this industry sector. There are already several success cases related with wastes incorporation in building materials, in particular in concrete and paving materials. For example, the sugarcane bagasse ash in concrete manufacturing improved the products performance while reducing the material cost (James and Pandian, 2017). Similar conclusions were achieved with municipal solid waste incineration fly ashes, plastics, including plastic bags, glass, construction and demolition wastes, gypsum, rice husk ash, blast furnace slag, silica fume and several others (Batayneh et al., 2007; Wagih et al., 20013; Ghernouti et al., 2014; De Boom and Degrez, 2015; Su et al., 2015; James and Pandian, 2017). One of the major advantages of these practices is the utilization of local wastes producing concrete with lower carbon foot-print.

The concrete utilization is associated with some toxicity related to the high pH or heavy metals in leaching waters, instigating to corrosion and dermatitis, respectively (Winder and Carmody, 2002). The mix of wastes in the concrete manufacturing may have a role in decreasing these toxic effects. Toxicological analysis elucidates on the adverse effects in biomakers caused by the interaction between chemicals, living organisms and/or biological systems. Aquatic and terrestrial plants are essential components of a healthy ecosystem. Several organisms are used for this purpose, like luminescent bacteria, *Lemna gibba L.*, seeds for germination or growing assays, among others. Choi et al. (2013) used *Daphnia magna* as an aquatic test species to evaluate the aquatic acute toxicity of leachate from concrete prepared with different wastes mixes, ordinary Portland cement with pozzolanic admixtures, pulverised fuel ash, ground granulated blast furnace slag (GGBS) and GGBS containing loess. Even traditional concrete, made with Portland cement, showed 100% *D. magna* immobilization, while GGBS and GGBS containing loess showed less toxicity. No effect was observed with low contents of GGBS containing loess. The authors suggested that the use of these materials in concrete may be useful to reduce eco-toxicity of concrete leachates.

In order to assess the environmental behavior of concrete prepared with ashes or lime as partial/total fine sand replacement, several mixes with different proportions of wastes were prepared to evaluate the compressive strength at 28 days and the eco-toxicological effects in *Lemna gibba L.*, also known as common duckweed.

2. Material and methods

In this study, four types of concrete samples were prepared: Concrete, Ash 50, Ash 100 and Lime 100. The base concrete mix included cement, fine sand (sand 1), coarse sand (sand 2), as well as fine gravel (gravel 1) and coarse gravel (gravel 2) and water. The other samples were produced with wastes incorporation. The sand 1 was replaced by 50 and 100% of fly ashes, for the Ash 50 and Ash 100, respectively, and by 100% of lime sludge for Lime 100, as mentioned in Table 1. The wastes were obtained in local industries, the former in a biomass thermoelectric power plant and the latter in a paper mill production. The preparation of 150x150x150 mm^3 cubic samples was carried out according to NP EN 12390-1:2012 and molding and curing followed NP EN 12390-2:2009. The compressive strength at 28 days was determined according to NP EN 12390-3:2009 using a Multitester equipment (Controls C5600/FR). Leaching tests were carried out following the EN 12457-4:2002, for crushed samples after 28 days, in order to perform a chemical characterization of cured concretes. The raw materials were also analyzed using the same procedures. The parameters assessed were pH, electric conductivity, redox potential (ORP) and dissolved oxygen with specific electrodes in a multiparameter meter (Hach, model HQ30d flexi). The toxicology effect in *Lemna gibba L.* (Duckweed) growth was determined according to standard methods for water and wastewater examination (APHA, 1998). Ten Lemna fronds were gently placed in 100 mL Erlenmeyer containing 25 mL of nutrient medium made with previous leachate solutions as solvent. The flasks were placed at 25°C in the presence of light (continuous cool white fluorescent lighting with a 100 W lamp) during four days. Control assay using only nutrient medium solution was made. All tests were performed in triplicate. Chlorophyll *a, b* and *c* was also quantified in the solutions according to standard methods (APHA, 1998).