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Developing a Commercial Self-Compacting Concrete Without Limestone Filler and With Volcanic Aggregate Materials

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Abstract

Self-compacting concrete (SCC) is a concrete with enhanced fresh properties that allows pouring without external compaction. Its advantages also are extended to good segregation resistance, higher homogeneity, lower permeability, which among others, lead to a product with higher durability. Although the SCC advantageous, up to the begin of this research program, never a SCC composition was been produced and commercialized in the Madeira Island. This paper describes the experimental program carried out on the development of a commercial SCC composition, using the materials currently available in the local market of Madeira Island. Moreover, it aims to contribute to the establishment of a methodology that leads to optimized compositions to satisfy the performance requirements of the commercial SCC compositions. Several SCC mix compositions were tested, studies being initially carried out on pastes and mortars. As limestone filler is not currently available in the local market, the powder content was increased by incorporating fly ash, being the water-to-cement ratio kept low by using a superplascyzer and a plasticyzer. All the aggregates were from volcanic origin; the fine sand was from the ocean and the coarse sand, fine gravel and coarse gravel were crushed. At the end, an optimized SCC composition was validated in real/commercial conditions: it was produced in a ready-mix concrete plant, transported and applied in a real structure wherein self-compacting properties were required due to high reinforcement content. Since no markedly changes were introduced from production up to casting, results were considered satisfactory. Consequently, the concrete plant decided to commercialize the SCC composition in the Madeira Island market.

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Keywords: Commercial Concrete; Crushed Aggregates; Madeira Island; Self-Compacting Concrete; Volcanic Aggregates.

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1. Introduction

Self-Compacting Concrete (SCC) has been worldwide developed based on the Okamura et al. (2000) methodology since 1988. Typically, limestone filler is incorporated to increase powder content and high quality granitic or limestone aggregates are used, with the content and maximum size being limited (RILEM TC 174-SCC, The European guidelines, Wallevik et al. (2003), Silva et al. (2009)). Due to its geological origin and its geographical location, there are no granitic or limestone stones in the Madeira Island. Therefore, there is no limestone filler and concrete aggregates (fine and coarse) currently available are crushed and from volcanic origin. The scarcity of the suggested raw-materials to produce SCC conditioned its development in Madeira Island. However, demand for concretes with high durability, as well as, with high surface finish quality has motivated the development of SCC in Madeira Island.

Thus, an extended research project was developed between the University of Madeira and the company Cimentos Madeira to develop SCC compositions using the raw-materials currently available locally, the end goal being its commercialization. From the research work developed there were published three master's dissertations – the scientific contributions of master's theses of Gomes (2012) and Silva (2012) were essentially on the design of SCC compositions in the laboratory. This paper regards to the scientific contributions present in the third dissertation – Neves (2013), i.e. it documents the procedure followed from the SCC composition developed in the laboratory to the composition produced in the concrete plant for its first commercialization using the materials currently available in Madeira Island. Laboratory evaluation and production of various SCC compositions were, firstly, carried out to achieve economical and robust compositions. Then, a SCC composition was validated for commercialization, being the production process, transport and placement occurred under real conditions to check the "new" product.

2. Experimental Program

2.1. Materials and lab equipment

Two cements currently available in the Madeira Island were used: CEM II / AL 42,5R and CEM II / BL 32,5N (specific gravity of 3100 and 3000 kg/m^3, respectively), both produced the Secil-Outão plant. Due to the (expected) need of fine materials (RILEM TC 174-SCC, Wallevik et al. (2003)) to reach self-compactability fly ash (specific gravity of 2360 kg/m^3) was also used as powder material. Note: although limestone filler is widely used in the production of SCC, it is not currently available in the Madeira Island. Water was supplied from the public network. The superplasticizer Glenium Sky 548 and the plasticiser Pozzolith 390N were used.

Two types of aggregates were used in mortar and concrete compositions, all aggregates being from volcanic origin. Two sands: the finer sand (Sand 0/2) was from the ocean and the coarser sand (Sand 0/4) was crushed. Three crushed gravels: Gravel 4/10, Gravel 8/16 and Gravel 11/22. Table 1 summarize the standardized test results for the characterization of all aggregates and its granulometry.

Paste flowability and viscosity was evaluated with the mini cone (19 mm in the upper diameter, 38 mm in lower diameter, 57 mm in height) and the Marsh cone, respectively. Rheology of mortars was studied by measuring its flowability ($G_p=(d_{flow}/d_0)^2-1$) and viscosity capacity. These tests were carried out using the cone and V-funnel for mortars described in The European guidelines for SCC. Self-compacting properties of the concretes were assessed by the D_{flow}, V-funnel, L-box and segregation tests carried out according to the European Standards for SCC: EN 12350 - {8, 9, 10 and 11} of 2010. Equipment used and mixing procedures for pastes and mortars, although slightly adapted for the materials used, were similar to the procedures described in Standard EN 196-2. For the concretes, mixtures in the laboratory were made in current concrete mixer with 150 liters capacity. The concrete for commercialization was produced in the ready-mix concrete plant.

2.2. Composition formulation and tests

SCC compositions were designed based on the trial-error procedure, with results being analysed for each trial, allowing quickly to reach SCC compositions with the fresh and hardened requirements. It is known that conventional concrete design methods are not applicable for SCC, so it was necessary to adapt another methodology.