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Durability of recycled aggregates concrete: a safe way to sustainable development

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Abstract

Fine and coarse recycled aggregates recovered from demolished masonry and concrete structures were utilized in the manufacture of new concrete mixtures. Three properties of these new concretes were analyzed: water absorption, total pores volume, and carbonation. The recycled concrete families were created by replacing parts of the natural aggregates forming families of concrete with 0%, 20%, 50%, and 100% of aggregates from recycled sources. The usual comparison between mixtures by comparison between behaviors of concrete families. This research shows that the mix design nomogram (MDN) is a new and useful tool that allows the researchers to compare properties and behaviors of different concretes. The results show that the family concrete with the highest pore volume and with the same compressive strength of 20, 30, and 40 MPa (2900, 4350, and 5800 psi) did not always correspond to the concrete family with the highest degree of carbonation. This experiment also showed that some compositional characteristics of concrete could have more influence on the durability that the traditional physical aspects.

Keywords: Absorption; Carbonation; Corrosion; Durability; Waste management

1. Introduction

Every aggressive agent present in the environment surrounding a concrete structure can percolate, diffuse, and penetrate across the pores of the concrete according to transport mechanism laws. Water absorption by immersion and total pore volume are considered better indicators in evaluating the potential durability of concrete than capillary absorption, which only occurs under special circumstances in which the concrete is not saturated and is in the presence of water. Furthermore, indirect ways of evaluating concrete durability, such as porosity studies, can be insufficient for measuring the effectiveness of behavior of the concrete in the presence of aggressive external agents. This research could demonstrate that knowing and weighing the influence of the type of concrete, and its composition in recycled aggregate is more important than its physical characteristics in the performance analysis of recycled concretes.

Wirquin et al. [1], in 2000, reported that a study of water absorption in recycled aggregate concretes showed that the processes of water absorption in recycled aggregate and in natural aggregate concretes are similar and obey the same laws. In addition, Mehta and Monteiro [2] reported that the water, as a primary agent, is able to create and degrade natural and artificial materials, as concrete. It is also a central factor behind for most of the problems regarding concrete durability, as water works as a transport vehicle for aggressive ions and as a cause of chemical processes causing physical and mechanical degradation of concrete structures.

Water, ions, and gas penetrating the concrete also can change the concrete degradation kinetics during the structure service life. This investigation shows that it is possible to evaluate the influence of recycled aggregates to the depth of carbonation of concrete and that CO_2 gas penetration depends on the cement's composition, porosity, and aggregate mineral composition (i.e., chemicals aspects).

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The use of mix design nomogram (MDN) introduced by Helene and Monteiro [3] allows the researchers to make a correct and relevant comparison between the different concrete families, adopting the same ascending reference compressive concrete strength like 20, 30, and 40 MPa (2900, 4350, and 5800 psi), instead of the usual poor comparison between individual mixture results.

2. Materials and methods

Blended Portland cement, comprised of 35% blast furnace slag, with a Blaine fineness of 385 m^2/kg, density of 2990 kg/m^3, with an average compressive strength at 28 days of 39 MPa (5655 psi) for W/C = 0,48, was used in all concrete mixtures. It is once the most frequent cement used in ordinary concrete structures in Brazil.

Fine natural aggregates, washed quartz river sand, presenting 2650 kg/m^3 density, with a fineness modulus (FM) of 2.6, and water absorption in saturated dry surface condition (SDS) of 1.8%, and coarse natural aggregates-type granite crushed as rock gravel, presenting 2700 kg/m^3 density, D_{max} = 25 mm, with an FM of 7.0 and water absorption in SDS of 0.8% were used, once both are usual and safety aggregates in the São Paulo city region.

The fine and coarse recycled concrete aggregates (FRCA and CRCA) that were used had been obtained (crushed) from a homogeneous concrete structure 6 months old presenting 25 MPa (3626 psi) average compressive strength for an average W/C = 0.66, 2320 kg/m^3 density, D_{max} = 25 mm, and FM = 6.6 for coarse aggregate, and D_{max} = 2.4 mm and FM = 2.5 for fine aggregates, and its composition is cement paste made with the same blended cement, same granite as coarse aggregate, and same natural quartz river sand as fine aggregate. The FRCA and CRCA present 10.3% and 5.6% water absorption in SDS condition, respectively.

The fine and coarse recycled masonry aggregates (FRMA and CRMA) that were used had been obtained (crushed) from 1-year-old and homogenous clay brick walls covered with mortar made with cement, calcium hydroxide, and natural quartz river sand according to ASTM C 270 Type N [4]. In average, the fine and coarse aggregates present 76% clay and 24% mortar, 1890 kg/m^3 average density, D_{max} = 25 mm, and FM = 6.5 for coarse aggregate and D_{max} = 2.4 mm and FM = 2.5 for fine aggregates. FRMA and CRMA present 13.0% and 7.9% water absorption in SDS condition, respectively.

To obtain the recycled aggregates, the old concrete and masonry were passed through a jaw crusher and the resulting product was later subjected to a sieving operation. The fractions corresponding to fine and coarse aggregates were used to produce 12 concrete families, always in laboratory SDS condition. The results were compared with those given for a 13th concrete family, produced exclusively with natural aggregates and called reference concrete family.

2.1. Concrete mix proportion

Three dry aggregate/cement ratio by mass were used for each concrete family: 3/1, 4.5/1, and 6/1, all of which had the same fresh workability by slump test [70 ± 10 mm (3 in)], replacing natural aggregates by 0, 20, 50, and 100 mass% of recycled concrete or masonry aggregates. There are 13 concrete families, and 39 different concrete mix proportions were made.

The main tests were performed beginning at 28 days. All specimens were stored in a standard humid chamber, during their first 14 days; after which, they were kept exposed in a laboratory ambient (55–65% relative humidity and 20–26 °C).

2.2. Properties measured

The following were measured: compressive strength by ASTM C 39 [5], water absorption and total pores volume by ASTM C 642 [6], and accelerated carbonation test by RILEM CPC 18 method [7]. In addition, cement content, water content, water cement ratio by mass, entrapped air, slump test, and fresh concrete density were measured by conventional lab methods.

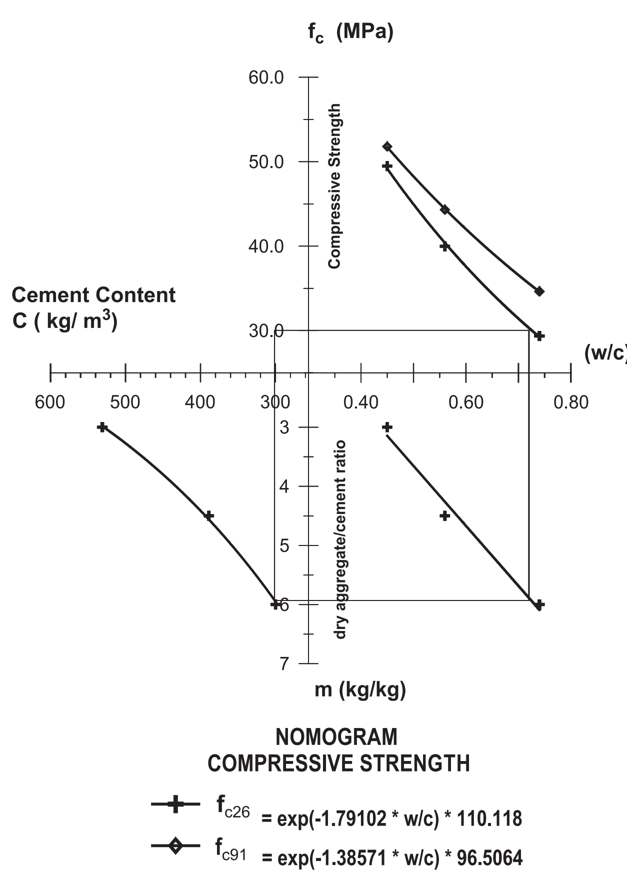

Fig. 1. Strength MDN for concrete family 50–50% FRMA.