XV International Conference on Durability of Building Materials and Components
DBMC 2020, Barcelona
C. Serrat, J.R. Casas and V. Gibert (Eds)

Influence of the Particle Size Distribution of Natural Sands in the Accelerated Alkali-Silica Expansion Test (AMBT)

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Keywords: *Alkali-Silica Reaction, Accelerated Mortar Bars Test, Natural Sand, Grading Composition.*

1 Introduction

The alkali-silica reaction (ASR) is an internal reaction in concrete that occurs between certain components of aggregates considered "reactive" (opal, chalcedony, quartz, tridymite, cristobalite, chert and volcanic glass) and ions form the pore solution of concrete (hydroxyls, alkalis and calcium ions). The reaction products expand in presence of moisture, causing cracking, displacements, structural deformations, pop-outs and reduction in mechanical performances. Service life of structures may be severely affected (Nixon and Sims, 2016).

In Uruguay, given the availability of natural sands, the fine fraction of the aggregate in the concrete – portion of an aggregate passing 4.75 mm sieve and predominantly retained on the 0.15 mm sieve - usually is obtained by two sands, one identified as "fine sand" and the other as "coarse sand". Coarse sands present large particle size generally the highest proportion in these is retained in the sieves of greater aperture (between 2.36 mm and 0.30 mm). The fine sands usually present particle size between 0.30 mm and 0.15 mm. Both types of fine aggregates must be mixed to form a suitable particle size distribution to be used in concrete.

The accelerated mortar bar test AMBT consists in evaluating the variation in length of mortar bars immersed in an aggressive solution of sodium hydroxide at (80±5) °C for a period of 14 to 28 days. This standard procedure indicates that the aggregate under evaluation shall have a specific size distribution. The material must be used in a dry condition, previously washed, with all particle passing through sieve 4.75 mm and retained at sieve 0.15 mm (10% retained at 2.36 mm, 25% retained at 1.18 mm, 0.60 mm and 0.30 mm and then 15% retained at 0.15 mm).

The aim of the work was to analyses the influence of the particle size distribution in aggregate in the expansive behavior of the mortar in the AMBT test and to evaluate the amount of material leached to the NaOH (sodium hydroxide) solution in which the bars are immersed. The relevance of the work was to improve the reliability of the result to evaluate the reactivity of the natural coarse sand, without the need to grind the material.

Two natural sands (identified AGA and AGB) of siliceous quartz-feldespathic origin were taken from the Santa Lucía river. Both sands present potentially reactive component to ASR and after being evaluated in the AMBT test have a higher expansion than the limit of 0.10 % at 14 days of immersion and 0.19 % at 28 days.

The AMBT was performed according to IRAM 1674 (IRAM, 1997) except for the particle size distribution of the aggregate which was conformed as indicated in Table 1.

Table 1. Particle size distribution for mixture in AMBT test.

Sieve size		AGA sample					AGB sample				
passing (mm)	retained (mm)	AGA (reference)	236 AGA	118 AGA	600 AGA	300 AGA	AGB (reference)	236 AGB	118A GB	600A GB	300 AGB
4.75	2.36	10	100	-	-	-	10	100	-	-	-
2.36	1.18	25	-	100	-	-	25	-	100	-	-
1.18	0.60	65	-	-	100	-	25	-	-	100	-
0.60	0.30	-	-	-	-	100	40	-	-	-	100
0.15	pan	-	-	-	-	-	-	-	-	-	-

The initial length, at intermediate test times and at the end of the immersion period (28 days) in the aggressive solution of 1N NaOH at (80±5) °C were recorded. The mortar expansion was calculated as the average expansion of the three bars tested for mixture.

The suspended solid content in the NaOH solution was determined. This was made by filtering a fraction of the solution on Filter Paper Grade 43 and quantifying the mass of solids retained in dry condition. The elemental chemical composition (percentage referred to the mass of the suspended solid in dry condition) was then determined using a portal X-ray fluorescence spectrometer. The main interest of this analysis was to detect the presence of silica (Si) in the NaOH solution. This would be indicating that alkali silica reaction took place, but the gel leached into the solution, eventually without causing expansion. The equipment used was considered adequate for this determination. However, it only quantifies elements with an atomic number greater than or equal to 12 (among the elements that cannot be detected are sodium, oxygen and calcium).

The influence of the particle size distribution on the expansion of the mortar in AMBT test was observed. For both sand samples, the greatest expansion was presented in mortars fabricated with different grading size composition (reference) and the lowest expansion was presented in mortars with a single size of 2.36mm. At the same sand sample, different behaviors - discoloration, efflorescence, leached material- were observed to the naked eye according to the particle size composition in both sands included in the analysis. This difference was caused by a change in the mortar microstructure. The greatest surface efflorescence was presented in mortars fabricated with a single particle size of 1.18 mm and 0.60 mm.

The evaluation of the leachate concentration and its chemical composition allowed detecting the presence of the silica in the NaOH solution. Bars fabricated with the smallest size particle of 0.30mm exhibited negligible leachate. However, the bars fabricated with the largest particle size of 2.36mm presented the largest amount of leached material. In this cases silica was detected in the NaOH solution so the alkali silica reaction took place, but the gel leached into the solution. The evaluation was performed only on a sand sample (id AGA).

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