

The Chemical Durability of Cement Pastes and Geopolymers Substituted With Dolomite-Based Quarry-Dust

E. Cohen¹, A. Peled², G. Bar-Nes³

¹Energy Engineering Unit, Ben-Gurion University of the Negev, Be'er-Sheva, Israel

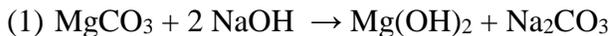
²Structural Engineering Department, Ben-Gurion University of the Negev, Be'er-Sheva, Israel

³Chemistry Department, Nuclear Research Centre Negev (NRCN), Israel

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INTRODUCTION

In recent years, growing environmental concerns have led the cement industry to make modifications in cement production, manifested by the use of supplementary cementitious materials (SCMs) as raw materials within the cement mixture. In the present study the use of dolomite-based quarry-dust (QD) to generate a low-energy, environmentally-friendly structural material was explored. QD was added either as an additive to conventional Portland Cement (PC) or to geopolymeric binders, formed by the alkali activation of local class F fly ash (FA). A significant increase in compressive strength, due to QD addition, was found for both CEM- and FA- based mixtures [1]. The chemical durability of the cementitious systems and FA-based geopolymeric mixtures for which the binder (cement/FA) was replaced with 40 % wt. QD was evaluated using two different tests: (a) Expansion tests to assess the durability of these dolomite-based, Mg-rich mixtures - as brucite ($\text{Mg}(\text{OH})_2$) may be formed according to Equation (1) (known as the 'alkali-carbonate reaction') and hence induce volume increase and expansion.



Expansion tests were performed according to ASTM C490 test method. Bar samples were cast in 25x25x285 mm stainless steel molds. Cement bar samples were kept in a moist cabin for 24 hours from casting. Later, submerged in 80 °C tap water container for an additional 24 hours and finally tap water was replaced by 1 molar NaOH solution pre-heated to 80 °C. Geopolymeric test samples were kept in an oven at 40°C for 48 hours from casting. Later, bars were submerged in 1 molar NaOH solution pre-heated to 80 °C. Both samples remained in the heated alkali solution for more than 14 days. Length measurement was carried out with a dedicated length comparator apparatus, every 2-4 days.

This testing procedure is an adaptation of the ASTM C1260 method which permits detection, within 16 days, of the potential for deleterious alkali-silica reaction of aggregate in mortar bars. In our study this test is used to assess the alkali-carbonate reaction; (b) susceptibility of the QD containing products to acidic conditions was measured as the weight loss of the samples immersed in 5 % wt. sulfuric acid solution during a period of 100 days.

RESULTS

Expansion-test results for both the cementitious systems and FA-based geopolymeric mixtures replaced with 40% wt QD, denoted respectively CEM40 and FA40, are presented in Figure 1. Table

1 presents the mix compositions of all samples. The test results revealed that all the mixtures expanded below the standard limit value of 0.1% [2], classifying the dolomite-based QD used here as a non-alkali-reactive aggregate.

Table 1. Mix composition of samples

Samples	cement [%wt]	quarry dust[%wt]	water [%wt]	samples	Fly ash [%wt]	quarry dust[%wt]	activator [%wt]
<i>CEM</i>	100	0	50	<i>FA</i>	100	0	50
<i>CEM40</i>	60	40	30	<i>FA40</i>	60	40	30

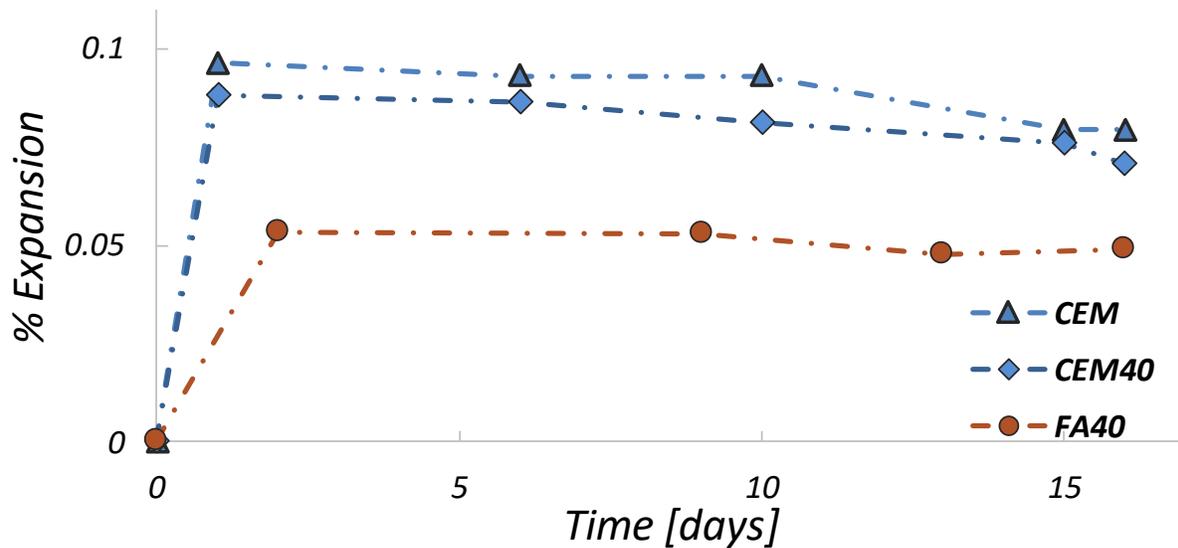


Figure 1. Expansion results of CEM mixtures, with and without QD, and FA mixtures with QD (the dashed lines are only visual aids).

The weight loss in the CEM, CEM40 and FA mixtures during the acidic immersion process is described in Figure 2. The highest weight loss was measured for the CEM40 sample (36%). A slightly lower weight loss of 30% was obtained for the CEM0 sample, which shows a change in the trend after approximately 40 days of immersion, i.e., a step-like function. This change probably occurred when the delamination of the gypsum layer developed on the sample surface area (Fig.3). The weight loss in QD-free FA (FA0) was significantly more moderate, leading to a total weight loss of only 13%. However, in the FA40 mixture, the sample disintegrated so rapidly that it could not be accurately measured (not presented).

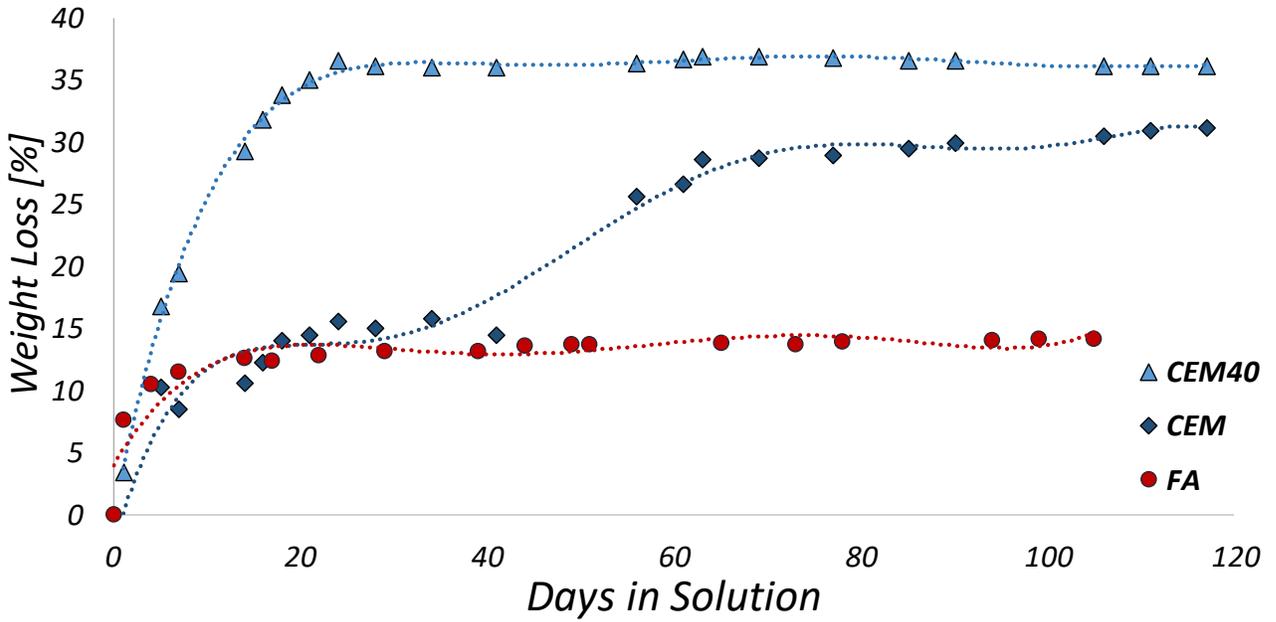


Figure 2. Weight loss in 5% sulfuric-acid solution of FA and CEM mixtures, as well as the weight loss of a CEM-based mixture with QD additive (CEM40). (The dotted lines are visual aids).

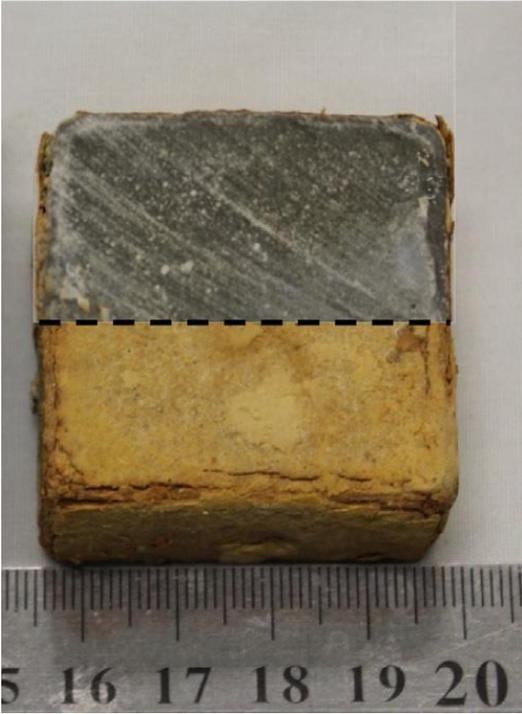


Figure 3. Image of the CEM0 sample after immersion in a 5% sulfuric acid solution. Bottom image presents the outer sample surface (in direct contact with the acid solution) and top image taken from the middle of the cube (no direct contact with the acid solution)

CONCLUSIONS

The chemical durability of QD bearing matrices was explored in the present study. One of the main concerns of using Mg-rich additives such as QD is the formation of magnesium hydroxide phase, brucite, which relates to volume increase and cracks in the hardened mix. Expansion measurements proved that QD has no effect on thermal expansion and all samples measured complied with the standard limit average expansion percent of 0.1%.

Static immersion tests in sulfuric acid solution emphasized the differences between FA based geopolymers and hydraulic calcium silicate-based cements such as PC. The FA based materials were found to be more durable to the acidic solution, with an overall weight loss of 14% compared to more than 30% weight loss in CEM sample. However, for the QD bearing samples this trend has reversed, as the formation of calcium sulfate (gypsum) on CEM sample surface produced a sealing effect which delayed the dissolution of QD, which is highly susceptible to acid [3]. The high permeability of the FA matrix facilitated the dissolution of QD in the acidic media and it dissolved rapidly. Therefore the vulnerability of these QD containing products to acidic conditions must be further studied and carefully considered.

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