

Polymer action on the alkali-silica reaction

Introduction

The alkali-silica reaction (ASR) in concrete progressively transforms silica minerals into an alkali-silica gel with hygroscopic properties (Figure 1), which can expand significantly due to hydration and crack both aggregate and surrounding cement paste. Due to the extent and severity of ASR-related durability problems in concrete structures, continuous improvement of existing preventive solutions and development of novel approaches are required.

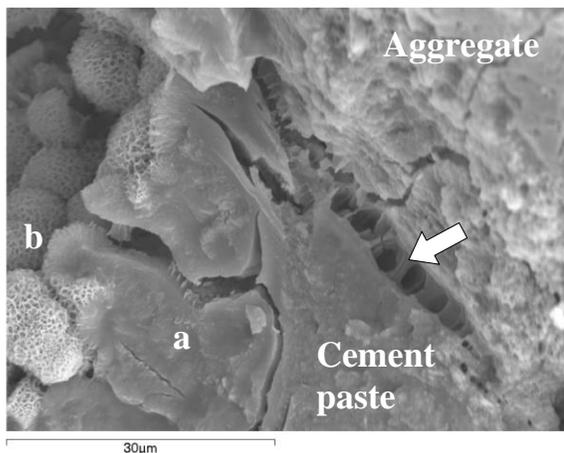


Figure 1: SEM image showing polymer film at the interface between aggregate and cement paste (arrow) and both amorphous (a) and crystalline (b) ASR products contained in an adjoining pore.

At the National Laboratory of Civil Engineering (LNEC), Portugal, and with financial support from Fundação para a Ciência e a Tecnologia (FCT) given to the research project PTDC/ECM/101810/2008 – Polymer-modified Cement Mortars for the Repair of Concrete Structures, an ongoing study aims to assess the influence of polymers on the degradation mechanism of cement-based materials due to ASR. For polymer dosages in excess of 10% of the mass of cement a continuous network of polymer film starts to form amongst cement hydrates, effectively transforming the cement matrix into a polymer-cement co-matrix (Figure 1). The effect of this polymer network on the expansion and microcracking resulting from ASR was assessed for a variety of polymer-modified cement-based mortars (PCMs) using acrylic-styrene, styrene-butadiene and epoxy polymers and performance was compared to that of an unmodified cement mortar (CM).

Tests and main results

ASR has been accelerated in mortar bars through two different test environments, both based on increased temperature and exposure to sodium alkalis and water sources:

- rapid 28-day test consisting of a 80 °C 1N NaOH solution immersive bath;
- slow test up to 11 months consisting of a 38 °C high RH (>90%) environment with the $\text{Na}_2\text{O}_{\text{eq}}$ content of mortar bars raised to 1.25% through the addition of NaOH to the mixing water.

The rapid test was early deemed unfit for the purpose of assessing the performance of polymer-modified cement-based materials, as the usually observed sorptivity reduction effect of polymers in cement-based materials was impaired in the aggressive 80 °C alkaline environment. This resulted in both higher exposure of the aggregate particles in PCMs to the ASR-inducing sodium alkalis present in the NaOH solution and higher water absorption compared to an unmodified CM.

In the slow test environment, the relative water absorption of PCM bars agreed with their respective water transport properties determined at a standard laboratory temperature of 20 °C, thus better depicting their expected performance in field conditions. Given the importance of water absorption in the ASR expansion mechanism, further testing proceeded with expansion monitoring of mortar bars in the more accurate accelerating conditions of the slow test environment.

It was determined that the expected response of PCMs to ASR is characterized by higher expansion than unmodified CM. While the lower modulus of elasticity of PCMs implies that, for the same expansive pressure generated by expanding ASR products, specimens of PCMs develop higher strain, lower pore interconnectivity may restrain the migration of expanding ASR products, thus resulting in the build up of expansive pressure and also explaining the higher expansion rates.

Even though PCMs expanded more than the unmodified CM, damage resulting from ASR expansion, and not expansion itself, should be the main concern related to ASR. An assessment of microcracking intensity due to ASR was thus required.

Scanning electron microscope (SEM) observations revealed significantly reduced microcracking in the cement paste of PCMs compared to that of the unmodified CM (Figure 2), even for the acrylic-styrene PCM specimens which expanded more than twice as much. This behaviour was in agreement with the higher tensile strength, ductility and resistance to microcracking of PCMs and showed the potential for polymers to reduce ASR-related damage in mortar and concrete. Subsequent stiffness damage tests (SDTs) on mortar bars subjected to an 11 month period of the slow test environment will allow quantitative assessment and validation of these results.

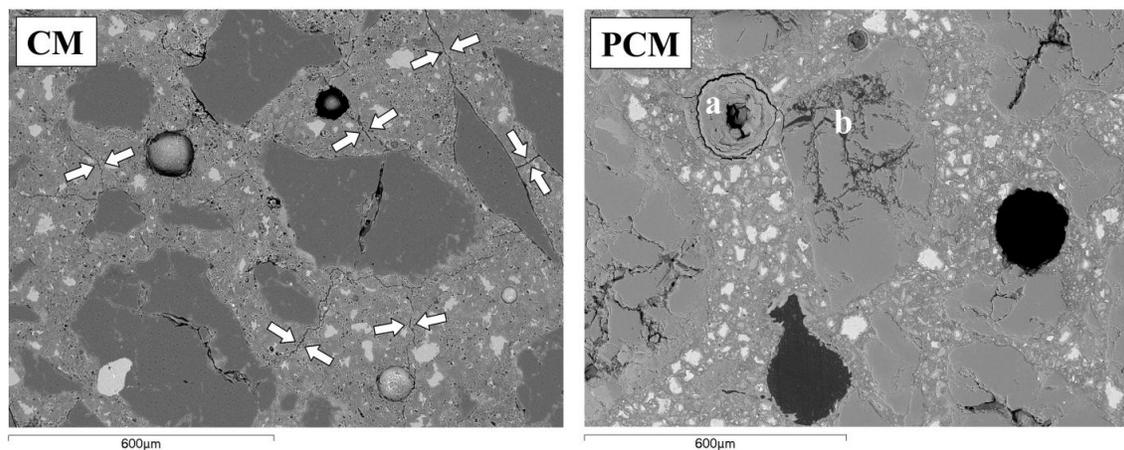


Figure 2: SEM images showing widespread microcracking (between arrows) in the cement paste of the unmodified CM and the absence of microcracking in the cement paste of a styrene-butadiene PCM despite more extensive evidence of ASR gel (a) and aggregate particle degradation (b) of the latter

