Applied alkali-silica reaction diagnostics

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Introduction

The deterioration of concrete structures due to alkali-silica reactions (ASR) poses significant challenges in civil engineering. Concrete is made of cement and aggregates (from sand to small pebbles). In the ASR alkalis from the porewater in the cement matrix react with silica from the aggregates. This reaction is expansive and can lead to severe damages of concrete structures [1]. Here we connect surface crack mapping of a concrete building on a meter scale with light microscopic analyses and SEM investigations on a micrometre scale. The aim of the study is to improve the understanding of the ASR processes and their application to damage assessment.

Methods and Results

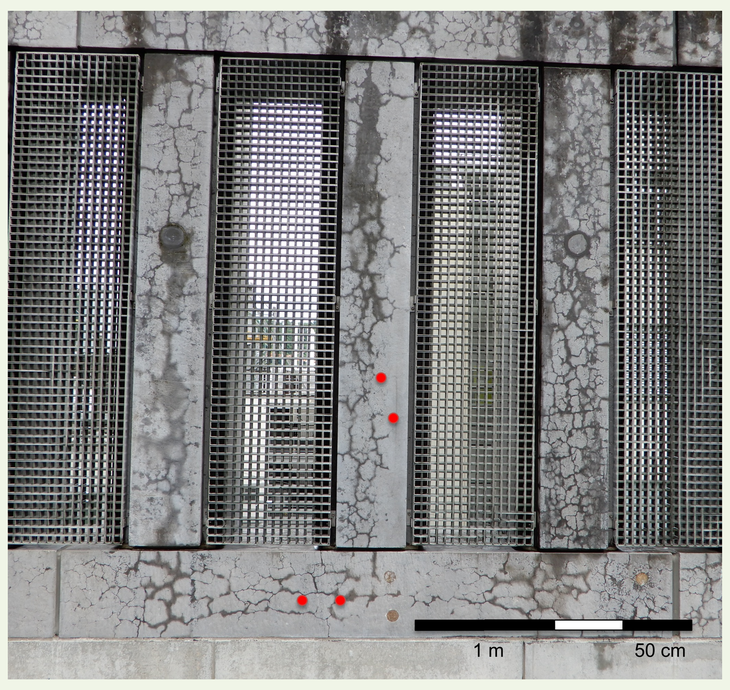


Figure 1: Concrete precast elements of a damaged building wall with the collected drill core samples in red.

The surface crack mapping and the measurements of the crack width index (RI) allowed an initial assessment of the damage caused by ASR (see Figures 1 and 2). The RI is a widely used method for estimating ASR-induced damage [2].

Figure 3: Drill core with a diameter of 3 cm and a length of 21 cm.

With the microscopic analysis of the thin sections ASR product was identified, localised and categorised. In Figure 4 the ASR products are visualised together with cracked aggregates. The ASR products are distributed along cracks connecting cracked aggregates.

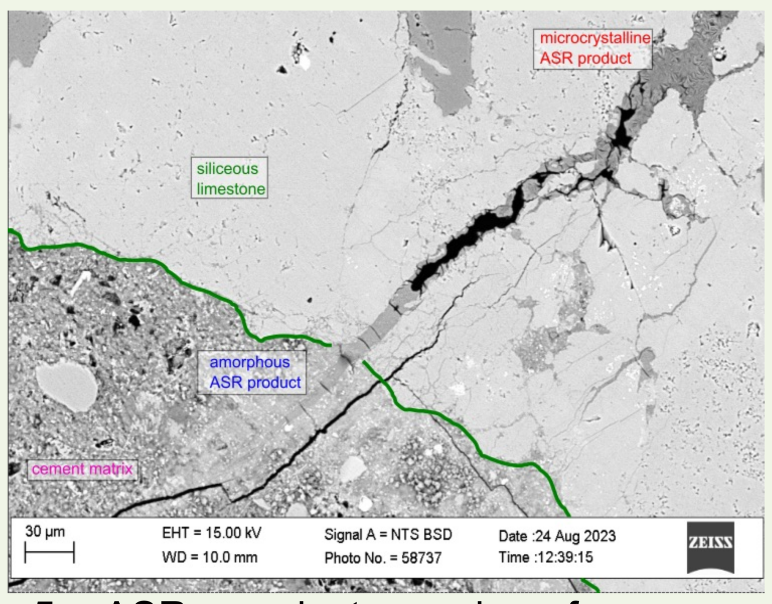
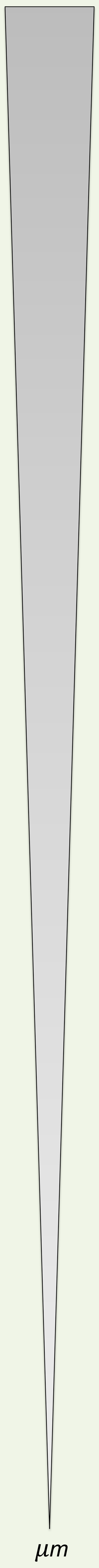


Figure 5: ASR product coming from a cracked aggregate into the cement matrix at a depth of 7.7 cm.

Figure 5 shows a backscatter image of microcrystalline ASR product with its typical structure within a siliceous limestone aggregate from an area of intermediate RI.



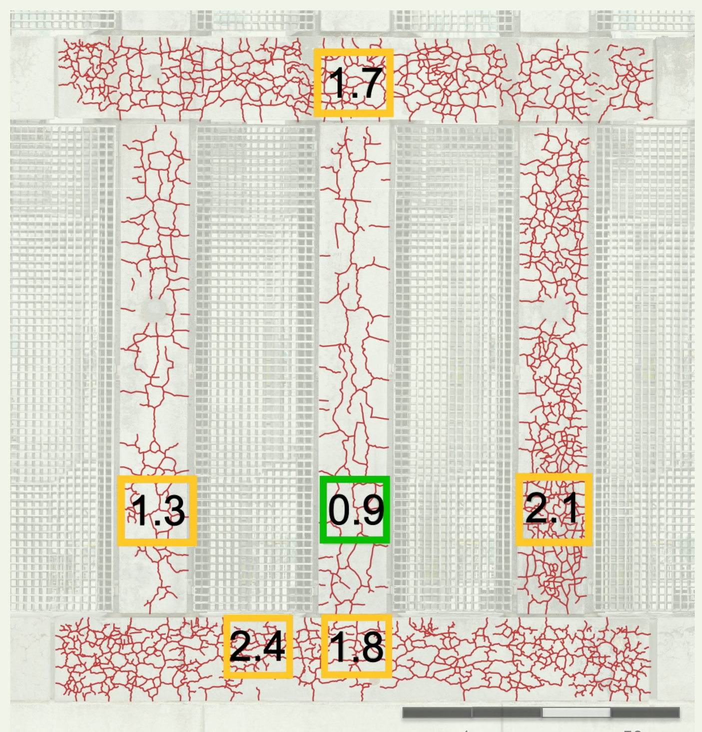


Figure 2: Damaged concrete beams of a building wall with mapped surface cracks in red and the crack width indexes (RI in [mm/m]) in green for a low ASR damage (<1 mm/m) and in yellow for an intermediate ASR damage (1-3 mm/m).

The drill cores (see Figure 3) were processed to thin sections using UV resin, to better visualise the cracks, pores and ASR products within.

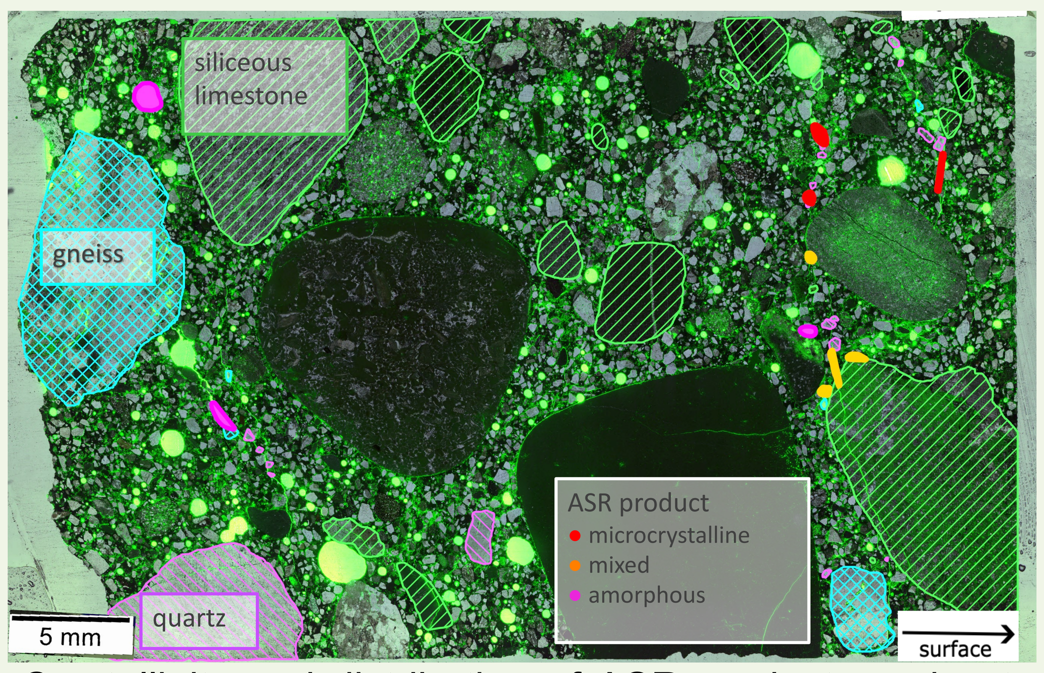


Figure 4: Crystallinity and distribution of ASR products and petrography of the cracked aggregates of a thin section from sample 1 at a depth of 17-21 cm using combined polarised light and UV fluorescent light microscopy.

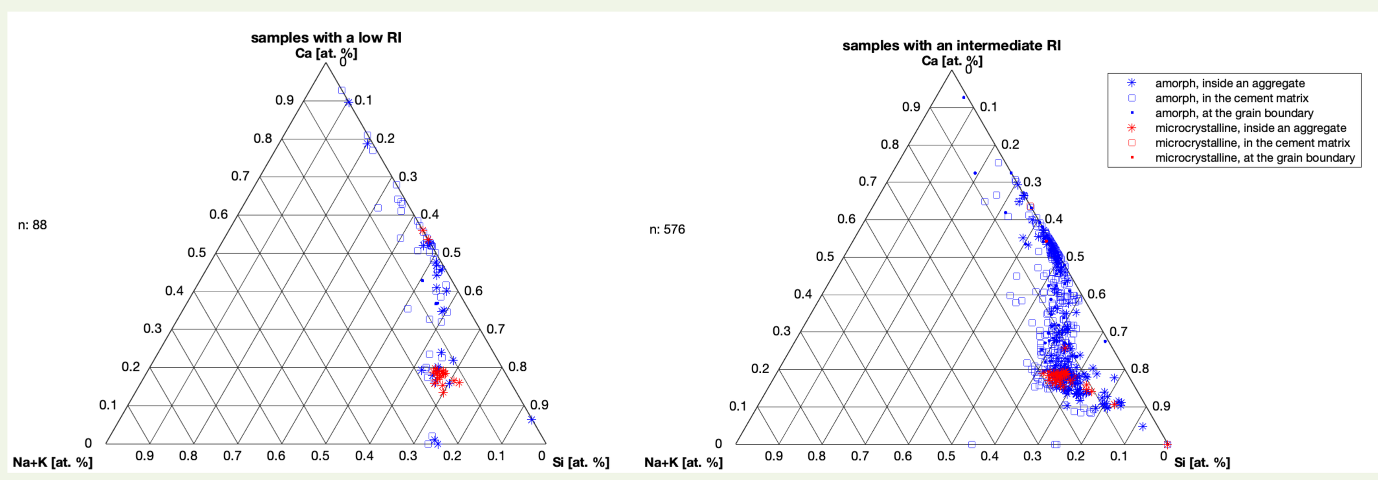


Figure 6: EDAX measurements in ternary diagrams (Ca, Si and Na+K in atomic fractions), from samples representing intermediate RI values (1-3 mm/m; samples 1 and 2) and low RI values (<1 mm/m; samples 3 and 4).

- The chemistry of microcrystalline ASR products show little variation, while the amorphous products have a wide range of chemical compositions. As the concentration of Ca increases, the levels of Na and K decrease.
- There is no chemical difference between ASR products from more damaged (high RI) and less damaged (low RI) areas.
- The majority of microcrystalline ASR products are located within aggregates (see Figure 6).

Conclusion

- ASR products could be identified in the investigated damaged concrete, their properties agree with literature [3].
- The degree of damage does not influence the chemistry of the ASR products.

Outlook

- Does the aggregate petrography influence the chemistry of the ASR products?
- How can the findings be used for the assessment of damaged concrete infrastructure?

References:
[1] Taylor, H. (1997). Cement Chemistry. London: Thomas Telford Publishing, p. 1-4, 136-138.
[2] sia Schweizerischer Ingenieur- und Architektenverein. (2011). Erhaltung von Tragwerken - Betonbau. SN 505 269/2, S. 24, 25, 41.
[3] Rajabipour, Farshad; Giannini, Eric; Dunant, Cyrille; Ideker, Jason H.; Thomas, Michael D.A. (2015). Alkali–silica reaction: Current understanding of the reaction mechanisms and the knowledge gaps. Cement and Concrete Research, 76, 130-146. doi:10.1016/j.cemconres.2015.05.024