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Concrete damaging processes from sulphate attack

F. Mittermayr (1), D. Klammer (1), S. Köhler (1), A. Leis (2), M. Böttcher (3), and M. Dietzel (1)

(1) Institute of Applied Geosciences, Graz University of Technology, Rechbauerstraße 12, Graz, Austria (f.mittermayr@tugraz.at), (2) Institute of Water Resources Management, Joanneum Research, Elisabethstrasse 16/11, 8010 Graz, Austria, (3) Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Seestrasse 15, 18119 Rostock, Germany

For the past decades concrete degradation by various processes as the thaumasite form of sulphate attack (TSA) and alkali-aggregate reactions (AAR) have repeatedly been discussed in the literature (LÓPEZ-BUENDÍA et al., 2006; PIPILIKAKI et al., 2008). Especially tunnel sites provide a great potential for concrete damaging processes as different ground water and temperature may occur. To gain new insights in the complex reactions and to decipher the origin of compounds of newly formed damaging minerals as thaumasite, investigations were carried out at Austrian railroad and highway tunnels. The investigations include a chemical characterisation of groundwater, concrete and natural in situ rock samples. Additionally stable isotope distribution of $^{34}S/^{32}S$, $^{13}C/^{12}C$ and $^{18}O/^{16}O$ were analysed.

The case study “Bosruck railroad tunnel” revealed a serious damage of the shotcrete lining producing safety issues for the highly frequented tunnel. The interlayer between the sooty brick wall lining and the shotcrete lining shows intense sulphate attack causing pieces to fall down. XRD analyses indicate that the damaged horizon is composed mainly of thaumasite with small amounts of calcite, gypsum. However, ettringite was not characterised. The local ground water is enriched in sulphate and saturated with respect to gypsum ($>$ 15 mM SO_4^{2-}) due to the dissolution of local marine evaporites. The sulphate minerals of the damaged horizons, local ground waters and local evaporites comprise $\delta^{34}S_{CD}$ values from 15 to 27 ‰Thus, the sulphate minerals from the damaged horizons indicate sulphate from local ground water. Soot relicts as a potential source of sulphur can be ruled out as the respective analysed $\delta^{34}S_{CD}$ values are in the range of 4 ‰The dissolution of dolomite aggregates is believed to be associated with the interaction of highly enriched sulphate solutions. However, it seems unlikely that thaumasite formation is an actual consequence of dolomite dissolution. As stated by ZHOU et al. (2006), the formation of thaumasite is favored at pH $>$ 10.5 in contrary to dolomite dissolution. It is suggested that the pH is decreasing during the sulphate attack.

A further a case study was carried out at the second tube of the currently under construction “Tauern highway tunnel”. In the tunnel driving the former rescue tunnels are included into the new construction. Smaller cross section dimension of the rescue tunnels require the removal of the existing concrete. Due to the fact that highly enriched sulphate containing ground water was found at the construction of the first tube 30 years ago, sulphate-resisting Portland cements (SRPC) were used. The low C_3A content significantly reduces the formation of ettringite and gypsum. However, thaumasite even appears in these concretes with negligible availability of Al by consuming C-S-H phases. This results in a significant decrease of the concrete stability. An extensive alteration of the shotcrete was found in the rescue tubes. The cohesion-less white mush was analysed by XRD. Apparently the cement matrix has completely been replaced by thaumasite and to a lower extend by calcite. Dolomite aggregates ($\delta^{13}C_{VPDB}$-1%¸) have disappeared completely in altered areas in contrary to non damaged areas. $\delta^{13}C_{VPDB}$ values of the DIC in the local highly SO_4^{2-} (15 - 120mM) enriched ground water and thaumasite at the shotcrete behind the inner concrete lining yield $\delta^{13}C_{VPDB}$ values close -9 ‰Accordingly, the DIC of the ground water can be directly related to the formation of thaumasite. The $\delta^{13}C_{VPDB}$ values of the DIC of high alkaline solutions (pH $>$ 11) and the associated calcite sinter in the tunnel building comprise a $\delta^{13}C_{VPDB}$ range from -19 to -36 ‰ indicating a strong impact of CO_2 from the tunnel atmosphere.

References

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