Thaumasite Formation from Sulphate Attack (TSA) Case Study at Austrian Tunnel Sites

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Concrete deterioration by sulphate attack at tunnel sites has been repeatedly reported over the past years (e.g. Romer et al. 2003). The formation of thaumasite seems to be a guiding process at many tunnels in contrary to the formation of ettringite and gypsum. Ettringite can be significantly reduced using sulphate-resisting Portland cements (SRPC) with low C_3A content. Thaumasite however appears in concretes with negligible availability of Al but higher levels of limestone filler (Lee et.a. 2008,) by consuming C-S-H phases and therefore resulting in a significant decrease of the concrete stability (Bellmann and Stark 2007). In recent years thaumasite formation has been studied and some risk factors have been identified (Köhler et.al. 2006, Schmidt et.al. 2008). Nevertheless, processes that lead to the formation of thaumasite have not yet been entirely understood. To gain new insights in the TSA case studies including the application of stable isotopes ($^{34}S/^{32}S$, $^{13}C/^{12}C$ and $^{18}O/^{16}O$) are carried out at Austrian railroad and highway tunnels.

In the Bosruck railroad tunnel shotcrete pieces were falling down causing safety issues for the highly frequented tunnel. The interlayer between the sooty brick wall lining and the shotcrete shows intense sulphate attack. Investigations by XRD revealed that the damaged horizon is composed mainly of thaumasite with small amounts of calcite, gypsum, and ettringite. The analysed local ground water is enriched in sulphate ($>$ 6 mM SO_4^{2-}) due to the dissolution of local marine evaporites. The sulphate minerals of the damaged horizon and local evaporites comprise $\delta^{34}S_{CD}$ values from 14.8 to 22.2 and from 15 to 27‰ (Spötl and Pak 1996), respectively. 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 between 3.4 and 4.1‰.

At the Tauern highway tunnel a second tube is currently under construction. In the tunnel driving the former rescue tunnels are included into the new construction. Due to a smaller cross section dimension of the rescue tunnels, the existing concrete had to be removed. An extensive alteration of the shotcrete was found in cohesion-less mush, which was analysed by XRD. The cement matrix of the shotcrete is completely replaced by thaumasite and to a lower extends by calcite. $\delta^{13}C_{VPDB}$ values of the DIC in the local highly SO_4^{2-} (15 - 120mM) enriched ground water, thaumasite at the shotcrete lining found behind the inner concrete lining, and thaumasite at the exterior shotcrete layer yield values close to -8, -11, and -9 ‰, respectively. Accordingly, the DIC of the ground water can be related to the formation of thaumasite. In contrast, the $\delta^{13}C_{VPDB}$ values of the DIC of high alkaline solutions (pH $>$ 12) and the associated calcite sinter in the tunnel building comprise a range from -19 to -36 ‰ indicating a strong impact of CO_2 from the tunnel atmosphere.

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