Sulfate attack and the role of internal carbonate on the conditions of thaumasite formation

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Introduction

Concrete deterioration due to the formation of thaumasite caused by sulfate attack has been reported worldwide. In Switzerland the concrete lining of several tunnel structures are affected.

The project aimed to clarify the conditions of thaumasite formation in cementitious systems exposed to various sulfate environments in the laboratory and to determine the role of internal carbonate as part of the chemical reactions.

→ Influence of carbonate ($CaCO_3$) in the cement

→ Influence of leaching and temperature

→ Influence of tricalcium aluminate (C3A) from clinker

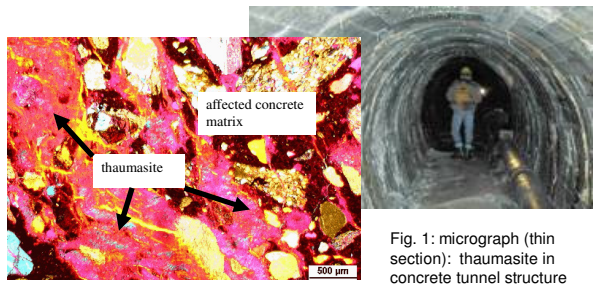
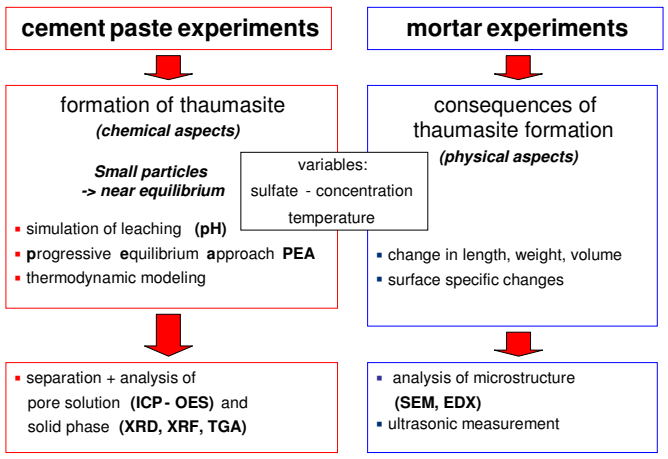
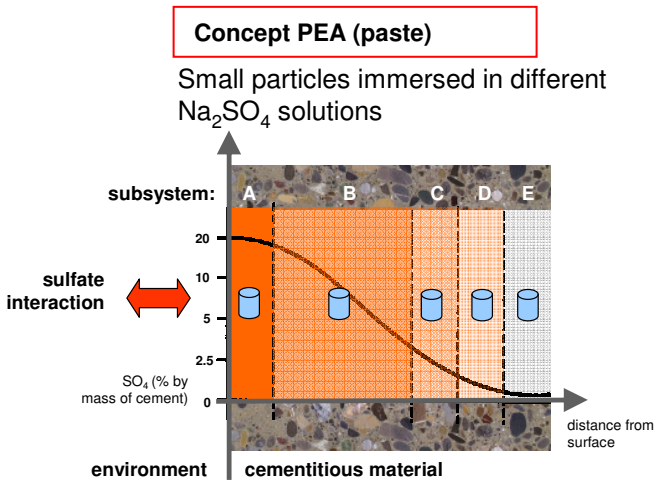


Fig. 1: micrograph (thin section): thaumasite in concrete tunnel structure

Experimental approach

- Variations in C_3A, $CaCO_3$ content, temperature (8, 20 °C) and comparison leached versus unleached conditions
- Laboratory cements produced with two industrial clinkers
- Comparison of experimental results with thermodynamic modeling
- Cement paste (near equilibrium) and mortar experiments (physical aspects)





Results

Cement paste

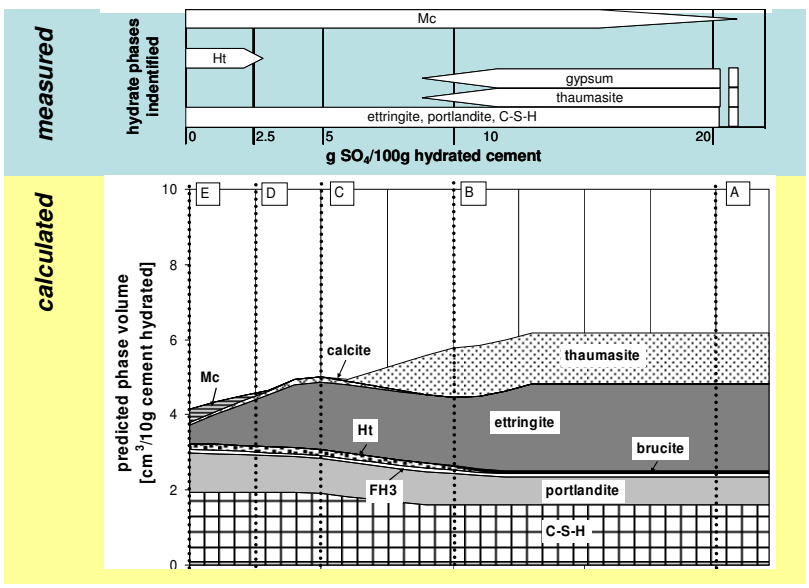


Fig. 2: Measured and calculated hydrate assemblage of an OPC sample with 5% limestone immersed in Na_2SO_4 solutions [1].

- Thaumasite forms only in the presence of high sulfate contents (molar SO_3/Al_2O_3 >3)
- Thaumasite stable at 8 and 20 °C
- Thaumasite formation faster at lower temperatures
- Leaching reduced thaumasite formation slightly [1]

Mortar

- Difference in chemistry near surface <-> core [2]
- Thaumasite formation restricted to surface
- Initially ettringite and gypsum precipitation; thaumasite is last sulfate phase that forms
- Thaumasite not (main) cause for sulfate damage
- Test depends on time, Na_2SO_4 concentration, exchange cycles, porosity, temperature, …

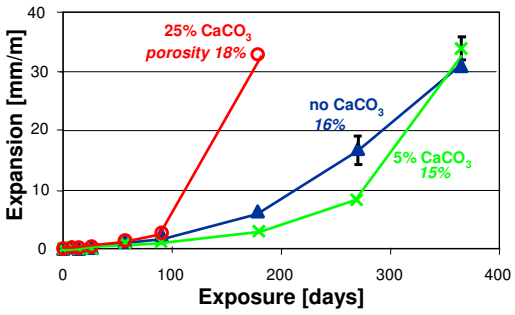


Fig. 3: Expansion and porosity of mortar samples immersed in 44 g/l Na_2SO_4 solution.

- Limestone influences the hydrate assemblage of hydrated cement before sulfate interaction:
  - 5% -> porosity ↓, expansion ↓
  - 25% -> porosity ↑, expansion ↑

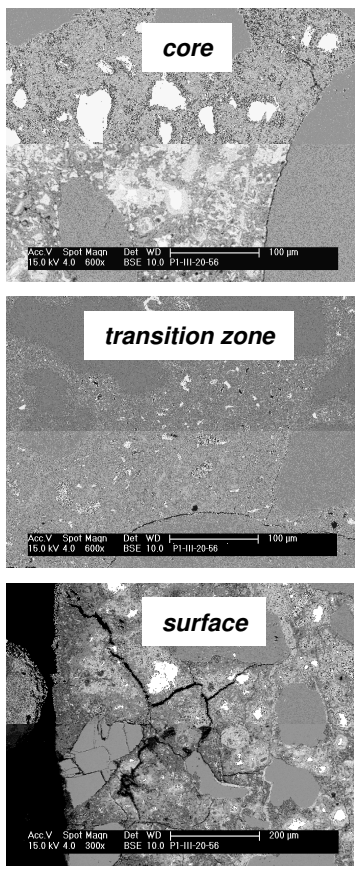


Fig. 4: BSE images of different zones in mortar samples immersed in 44g/l Na_2SO_4 solution after 56 days [2].

Literature

[1] T. Schmidt, B. Lothenbach, M. Romer, K. Scrivener, D. Rentsch, R. Figi, A thermodynamic and experimental study of the conditions of thaumasite formation, Cem. Concr. Res. 38 (2008) 337-349.

[2] T. Schmidt, B. Lothenbach, M. Romer, J. Neuenschwander, K. Scrivener, Physical and microstructural aspects of sulfate attack on ordinary and limestone blended Portland cements, Cem. Concr. Res. in press (2009).

Acknowledgements

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