Application of calorimetry for hydration study of belite-ferrite-ye'elimite cements

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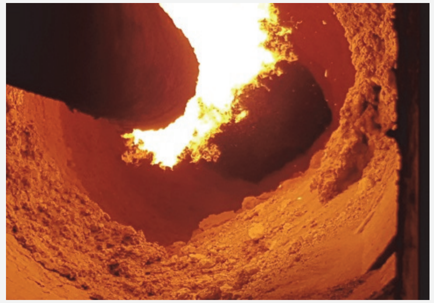
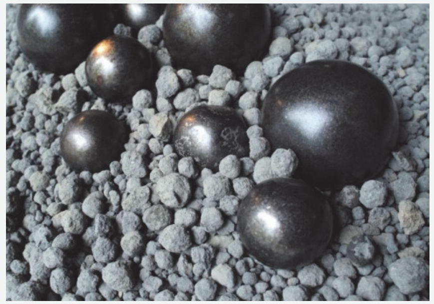
Outline

- Background
- Hydration of BYF
- Hydration of Ye'elimite
- Parameters influencing

  hydration of Ye‘elimite
- Retarders
- Conclusions





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Background

- **HeidelbergCement considers introduction of the alternative hydraulic binders like belite – ye'elimite – ferrite binder (BYF) to the market**
- **The advantages of such systems include**
  - BYF provides a low-CO_2 alternative to Portland cement
  - Production is matured
  - Raw materials are available
  - Similar characteristics and performance evolution to PC based binders

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Background

Application examples

RMX monolithic road construction (5*60 m) with and without reinforcement

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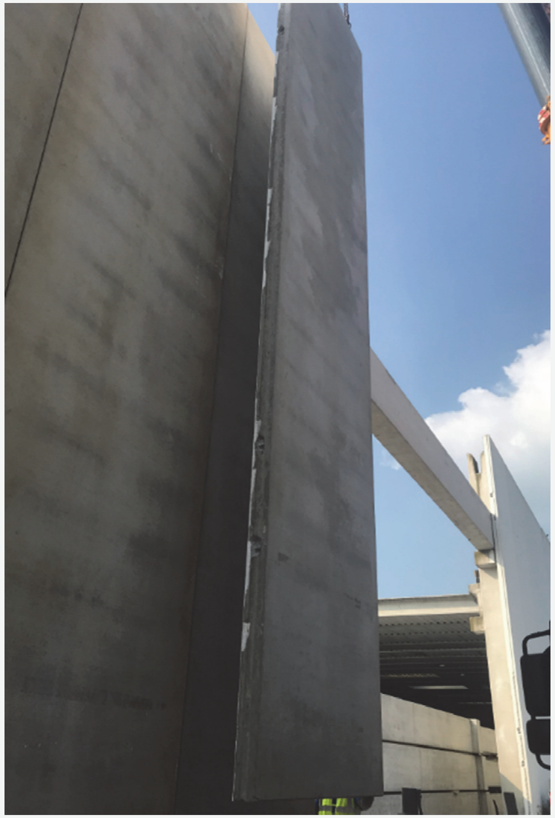
Background

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 637138."

Application examples
Production of reinforced panels



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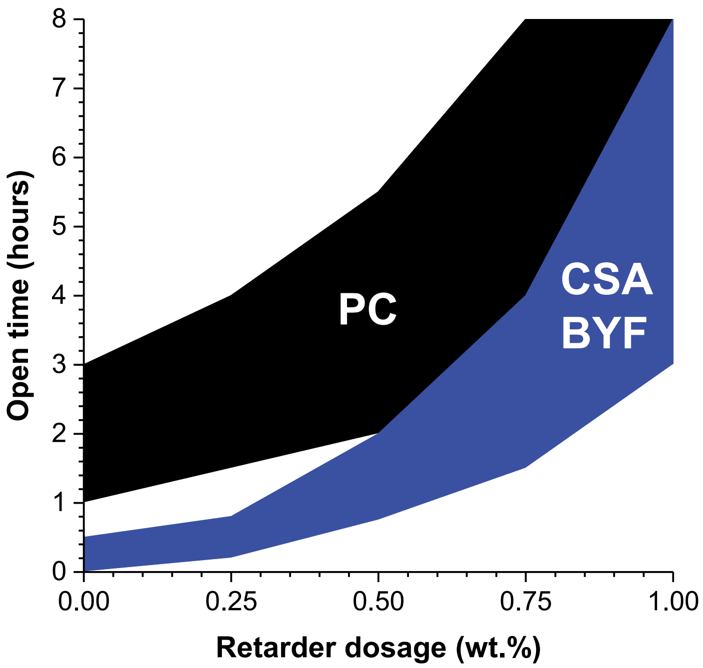
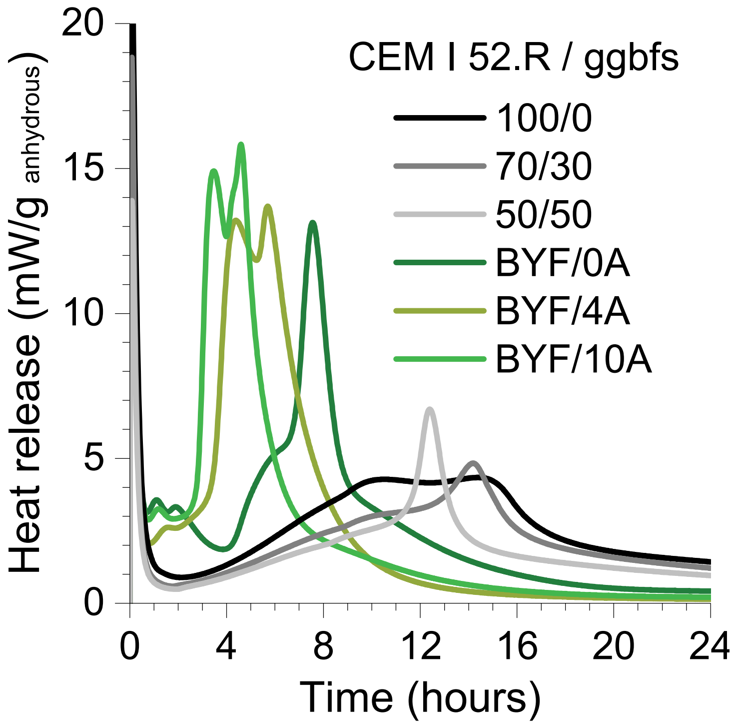
Background

- **Hydration mechanisms are well investigated**
- **There are still several phenomena lacking a sound understanding**





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Hydration of BYF system

- **Ye'elimite is rapidly hydrating phase**

$$C_4A_3\overline{S} \rightarrow C_3AC\overline{S}H_{12} + AH_3$$

$$C_4A_3\overline{S} + C\overline{S}H_2 \rightarrow C_3A3C\overline{S}H_{32} + AH_3$$

- **Belite and ferrite phase react slower**

$$C_2S + AH_3 + C_3A3C\overline{S}H_{32} \rightarrow C_3AC\overline{S}H_{12} + C_2ASH_8$$

$$C_2S \rightarrow C - S - H + CH$$

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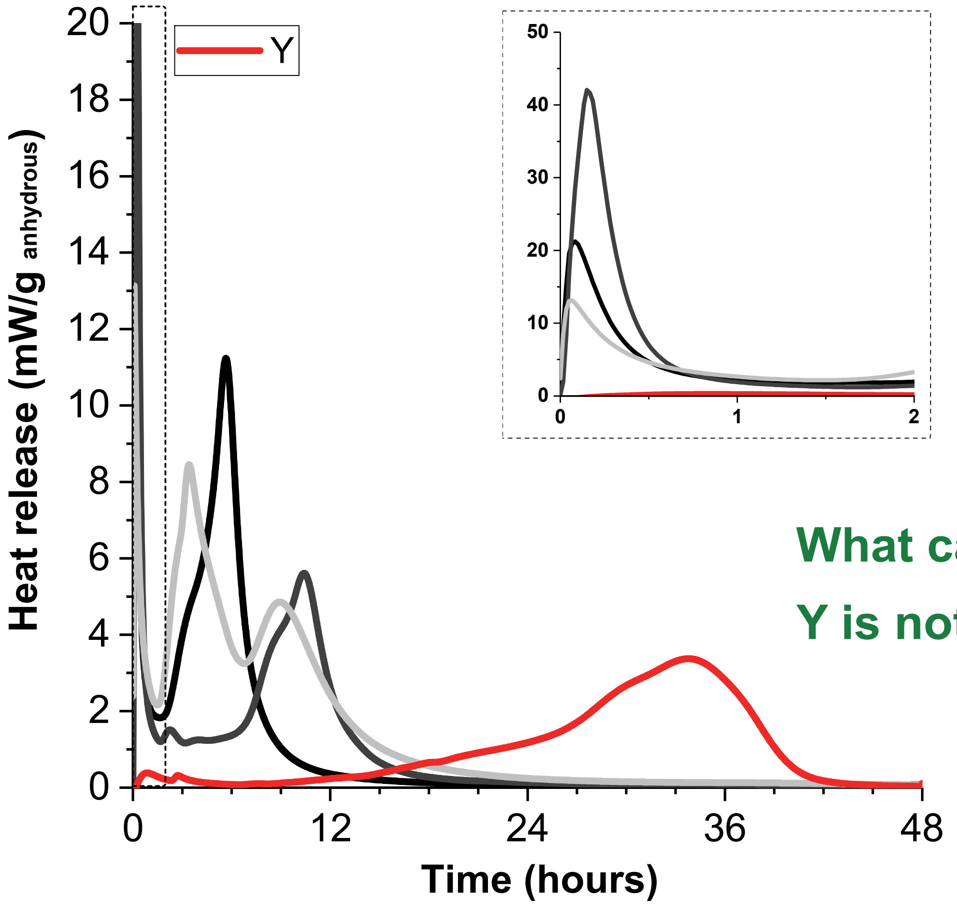
Hydration of BYF system

- **BYF clinker from one industrial trial (45-48% B; 28-30% Y; 3-5% F)**
- **Isothermal conduction calorimetry**



What causes the differences in BYF?

Y is not representative for BYF?

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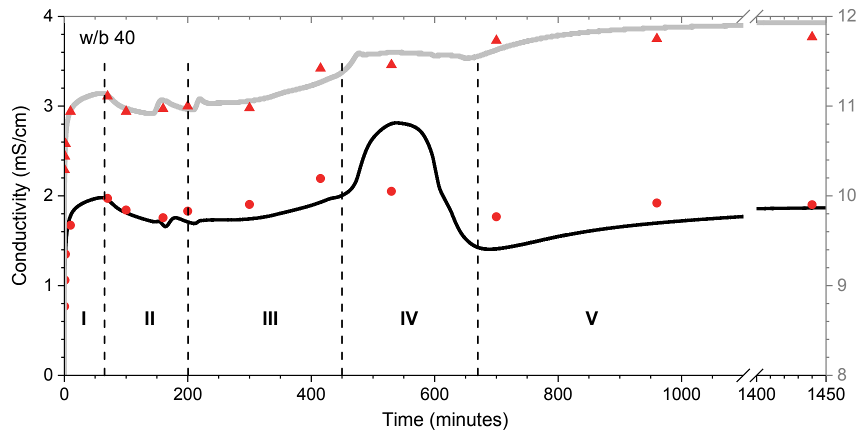
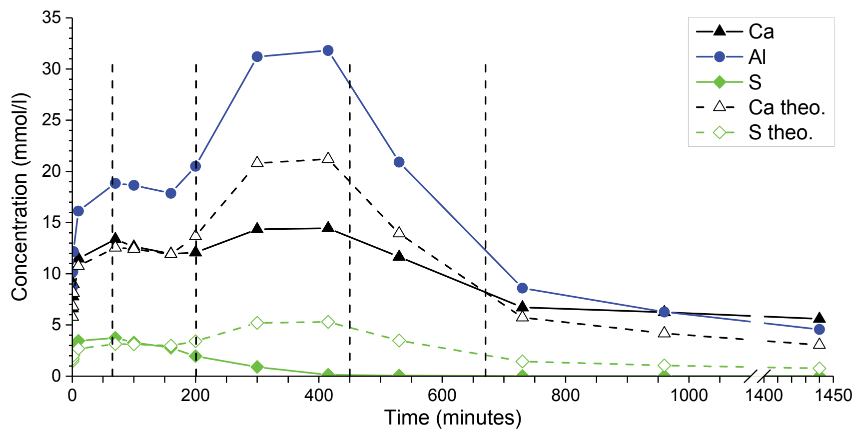
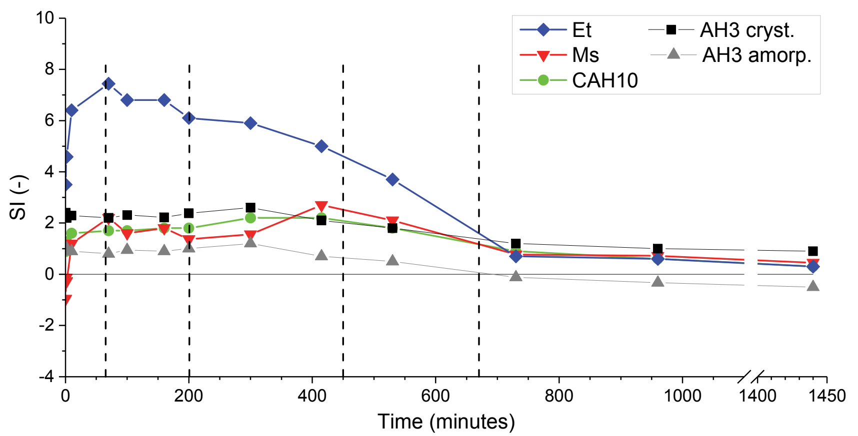
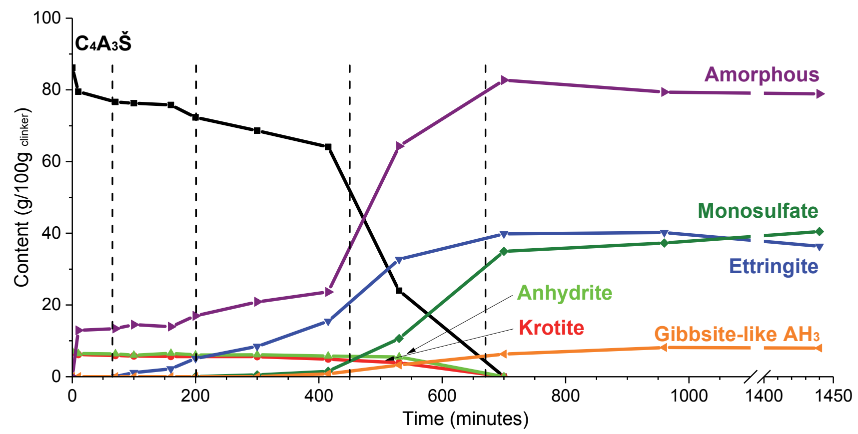
Hydration of ye‘elimite: PhD of Frank Bullerjahn









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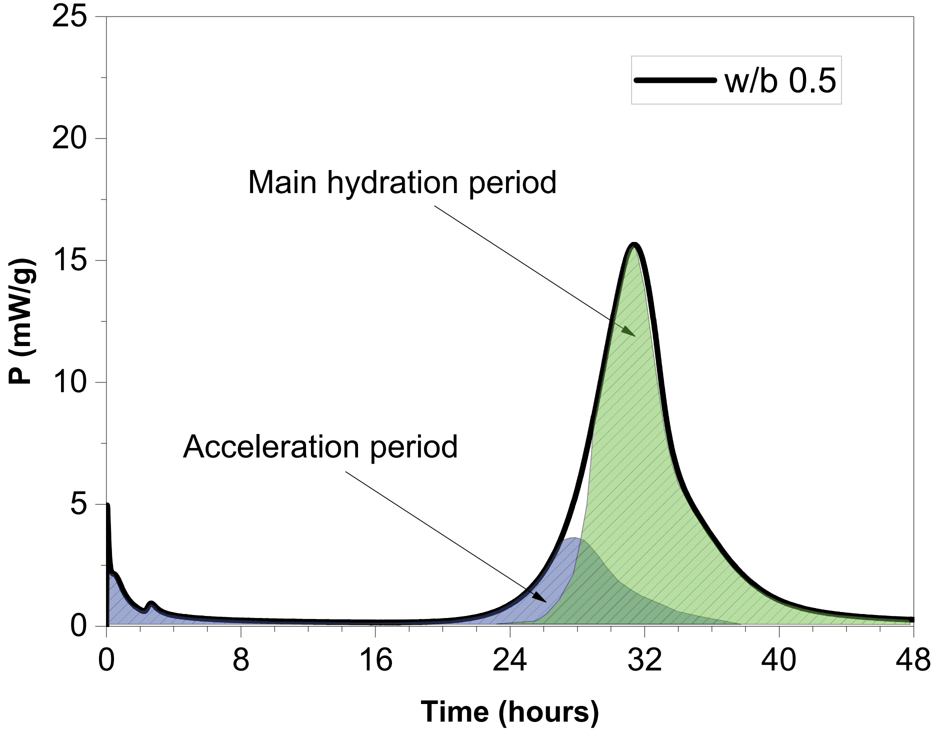
Hydration of ye‘elimite: PhD of Frank Bullerjahn

- **The main hydration peak is associated with the reaction of ye’elimite**
  - Acceleration period: formation of ettringite
  - Main hydration peak; formation of monosulphate



Two main reactions

$$3\ C_4A_3\overline{S} + 98\ H \rightarrow 1\ C_6A\overline{S}_3H_{32} + 2\ CAH_{10} + 2\ AH_3$$

$$1\ C_4A_3\overline{S} + 18\ H \rightarrow 1\ C_4A\overline{S}H_{12} + 2\ AH_3$$

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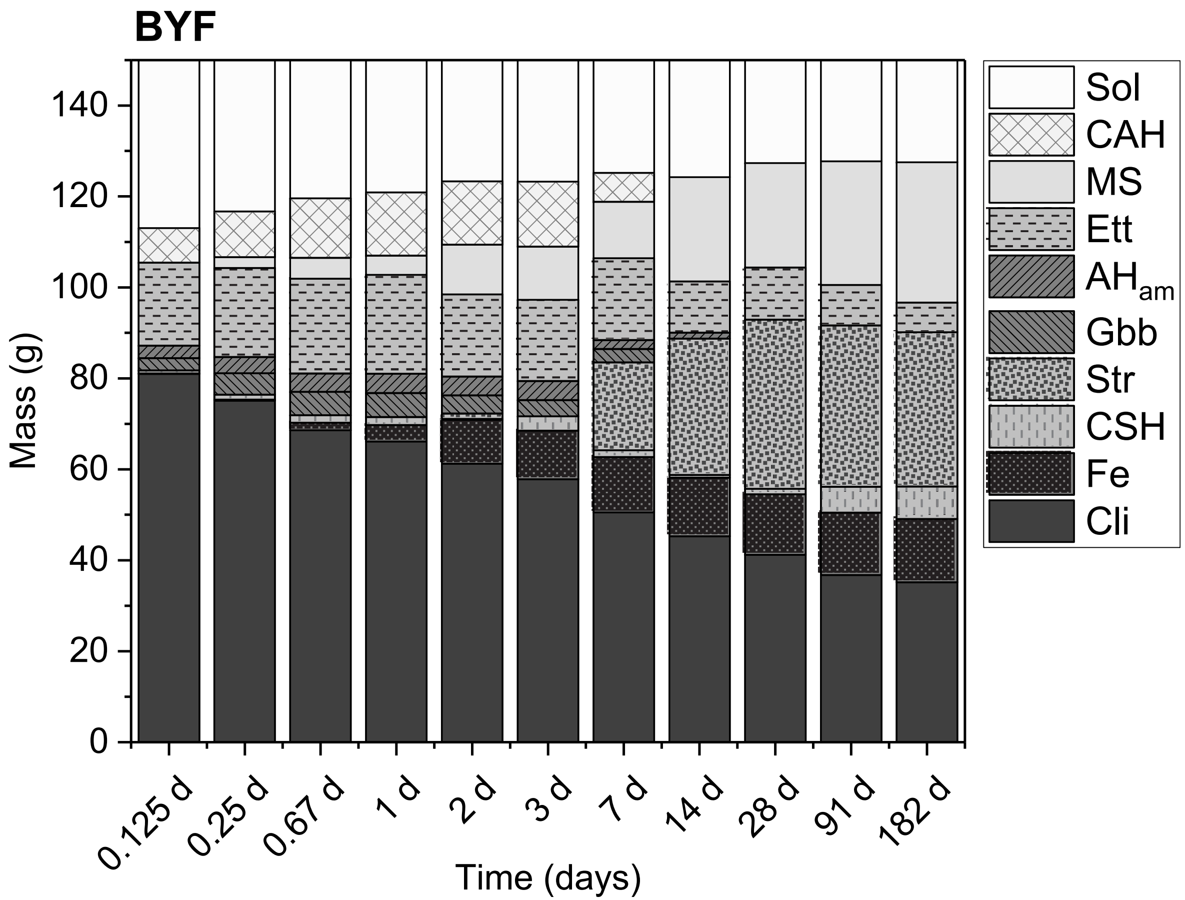
Hydration of BYF clinker (no sulfate addition)

- CAH_{10} is the main component of amorphous at early times
- At later times the strätlingite and monosulfate dominate



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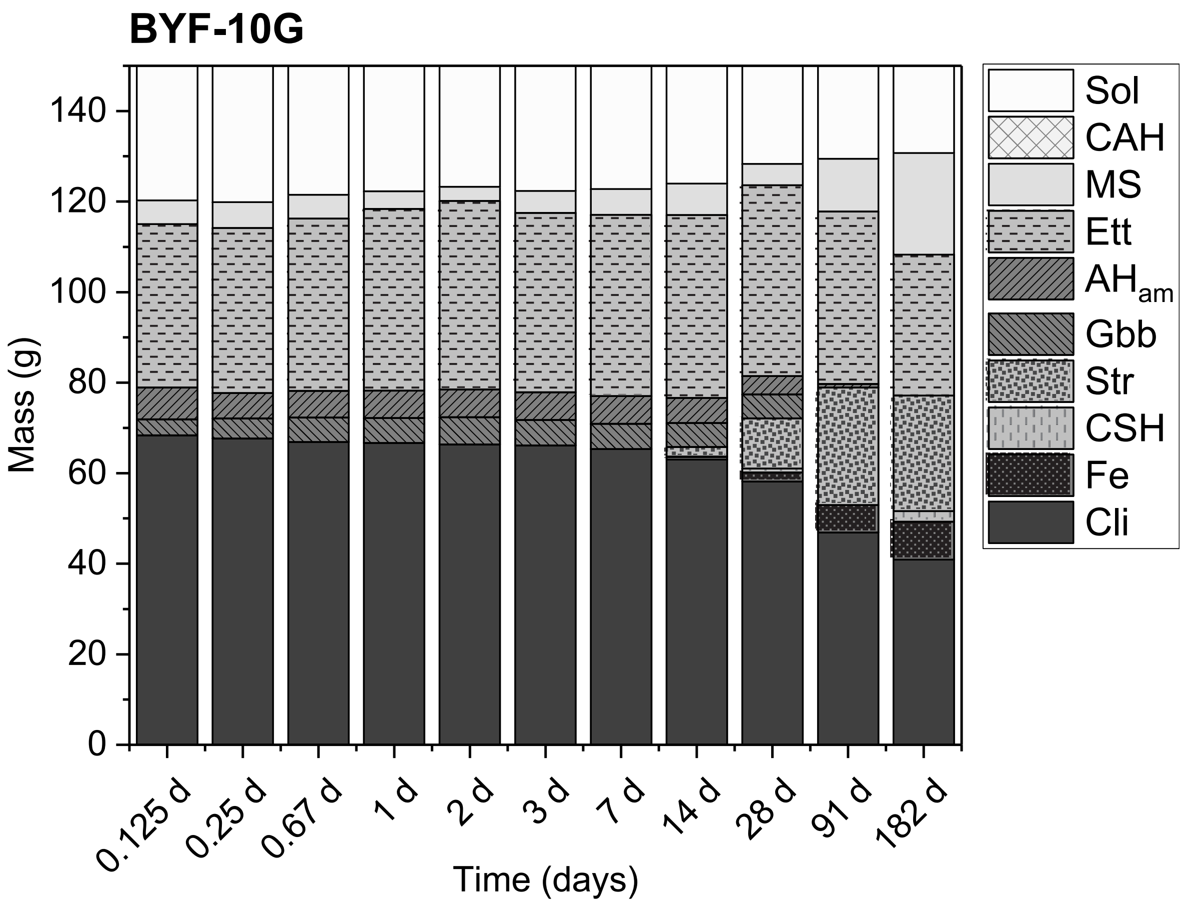
Hydration of BYF clinker with sulfate addition

- **Ettringite is the dominating phase, no CAH_{10} present**
- **Formation of strätlingite and monosulfate delayed**



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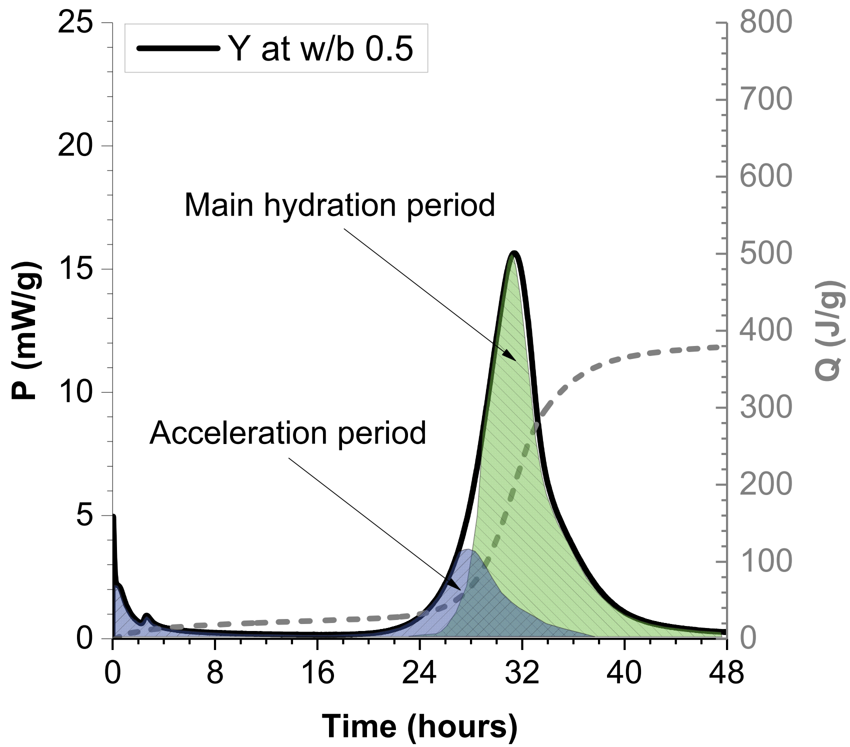
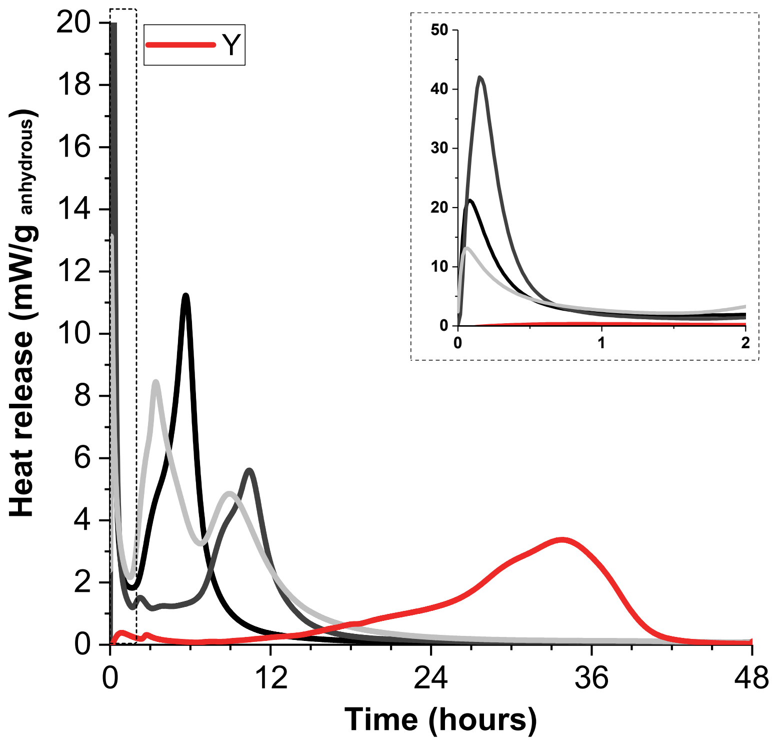
Hydration of ye‘elimite: PhD of Frank Bullerjahn

- **Why in cement, the ye’elimite hydration is so rapid?**





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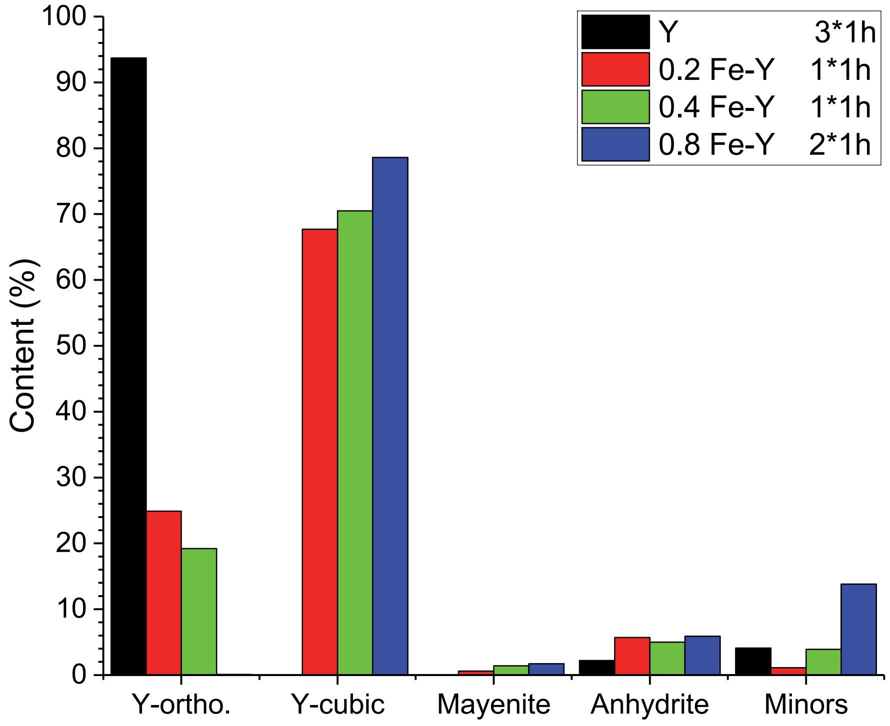
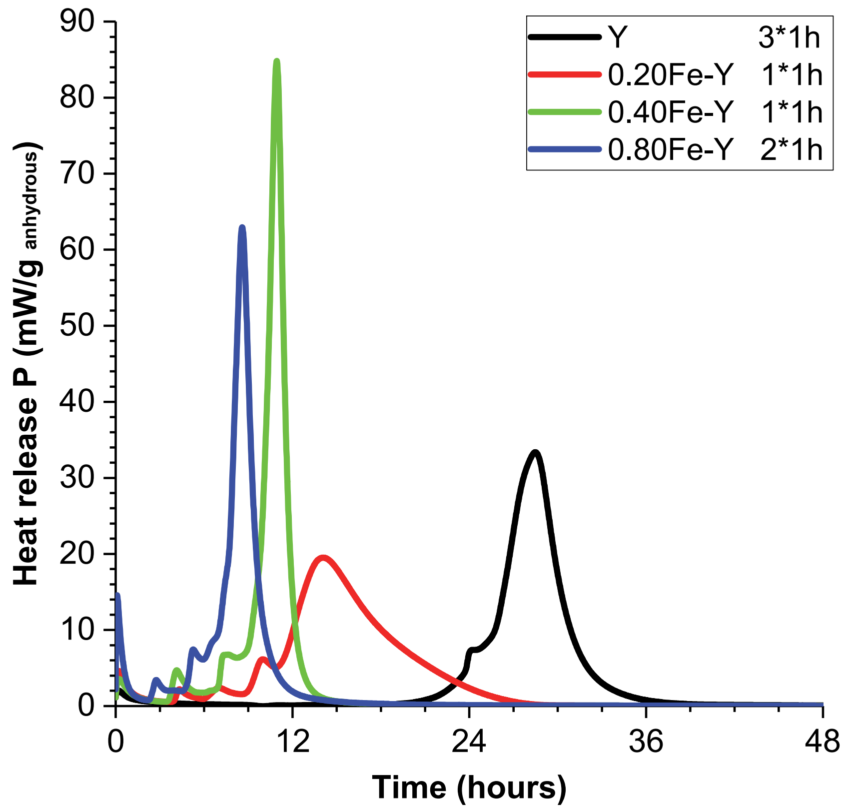
Parameters influencing hydration of Ye‘elimite

- **Synthesis of iron solid solution of ye’elimite at 1300 °C**
  - With x from 0.00 to 0.80 in $C_4A_{3-x}F_x\overline{S}$





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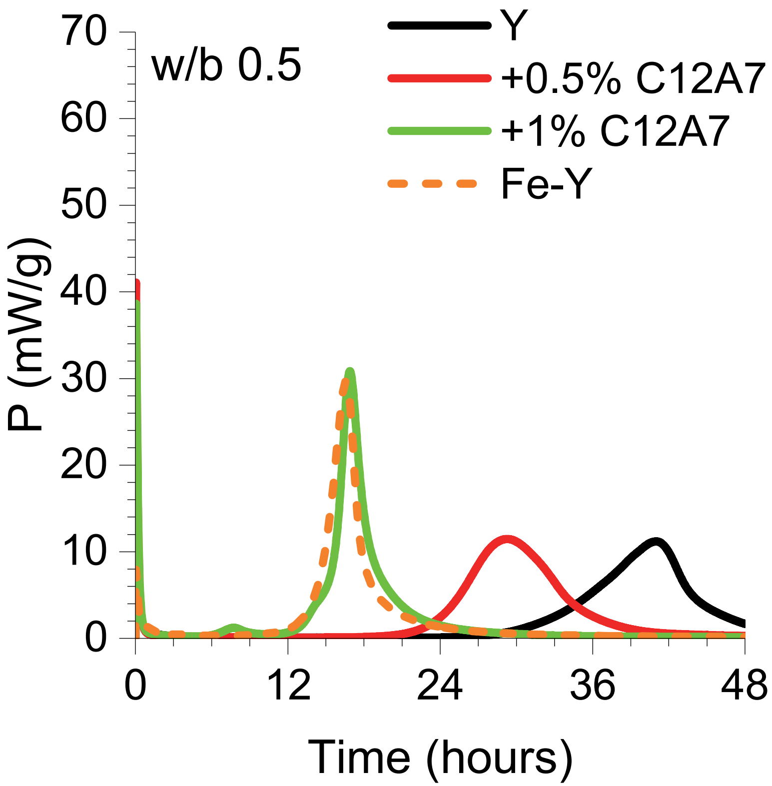
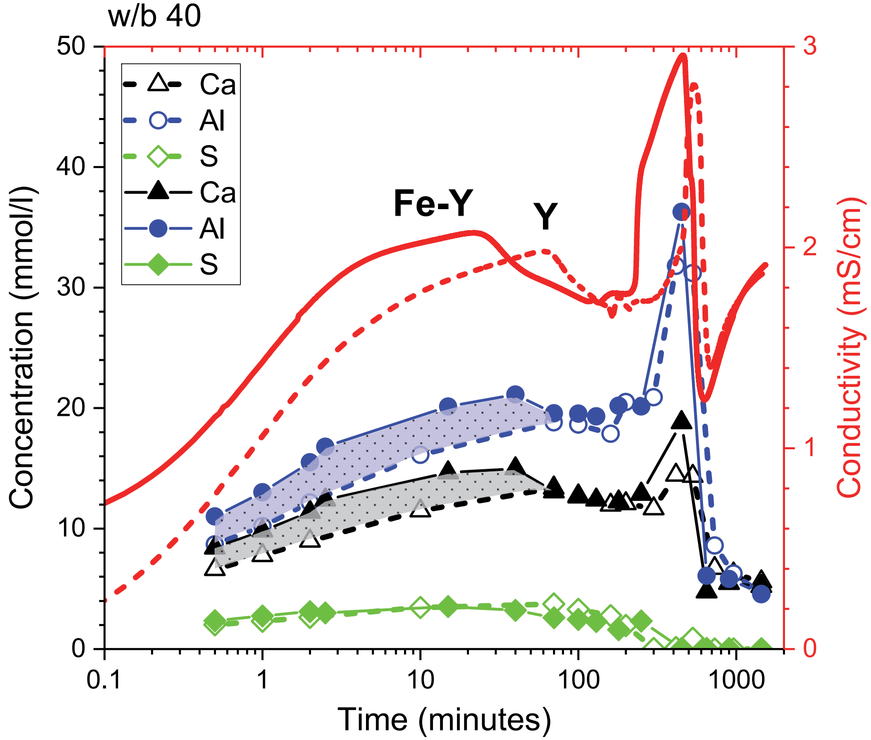
Parameters influencing hydration of Ye‘elimite

- **Effect of mayenite**



Explains higher Ca and Al concentration



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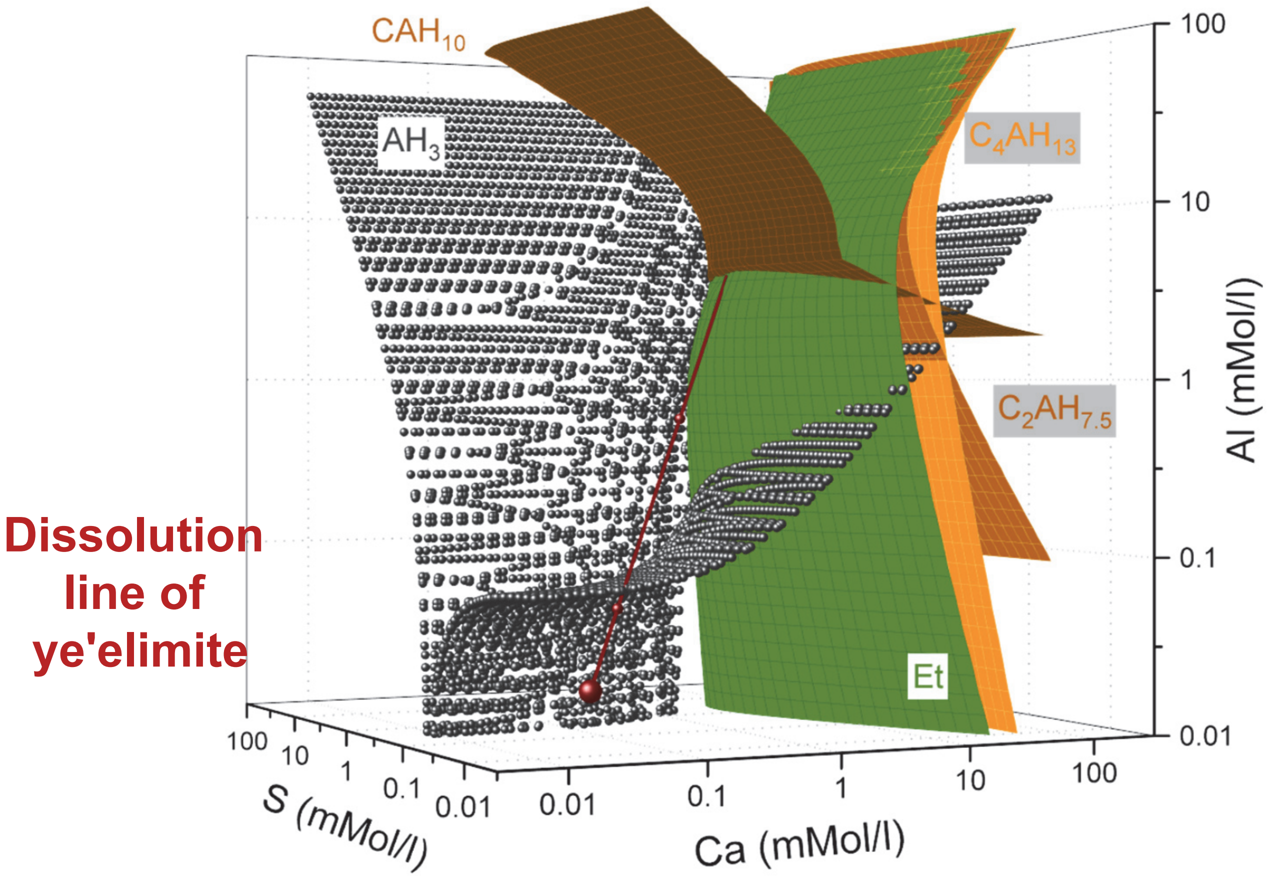
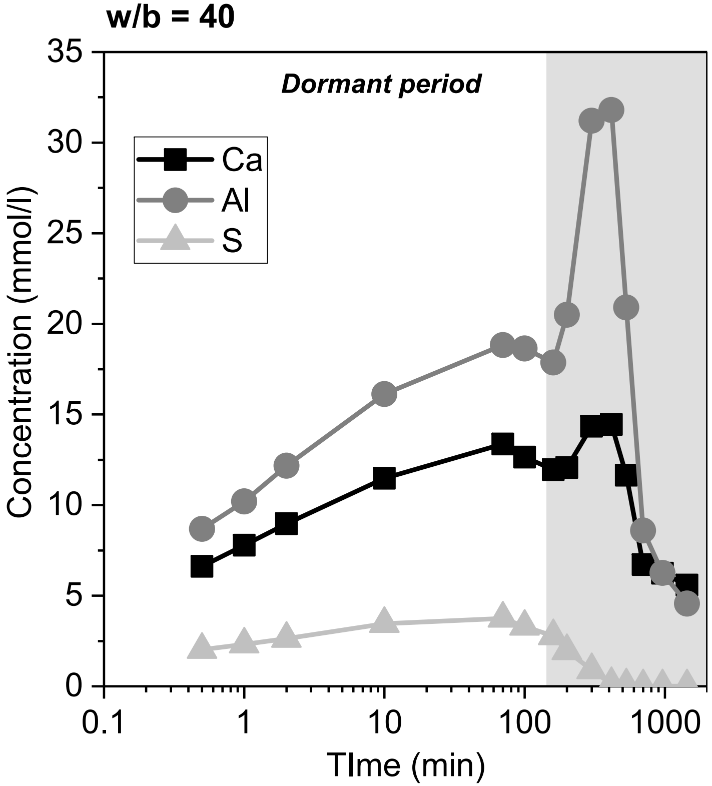
Parameters influencing hydration of Ye‘elimite

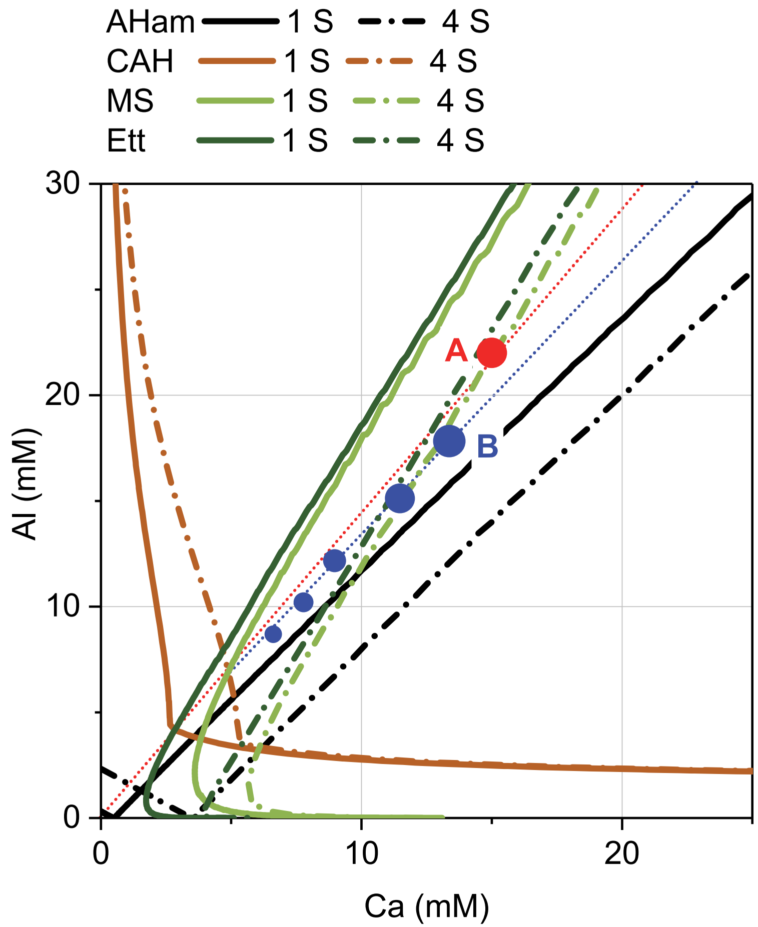
- **Analysis of the pore solution allows to understand the effect of mayenite**



Parameters influencing hydration of Ye‘elimite

- **Analysis of the pore solution allows to understand the effect of mayenite**





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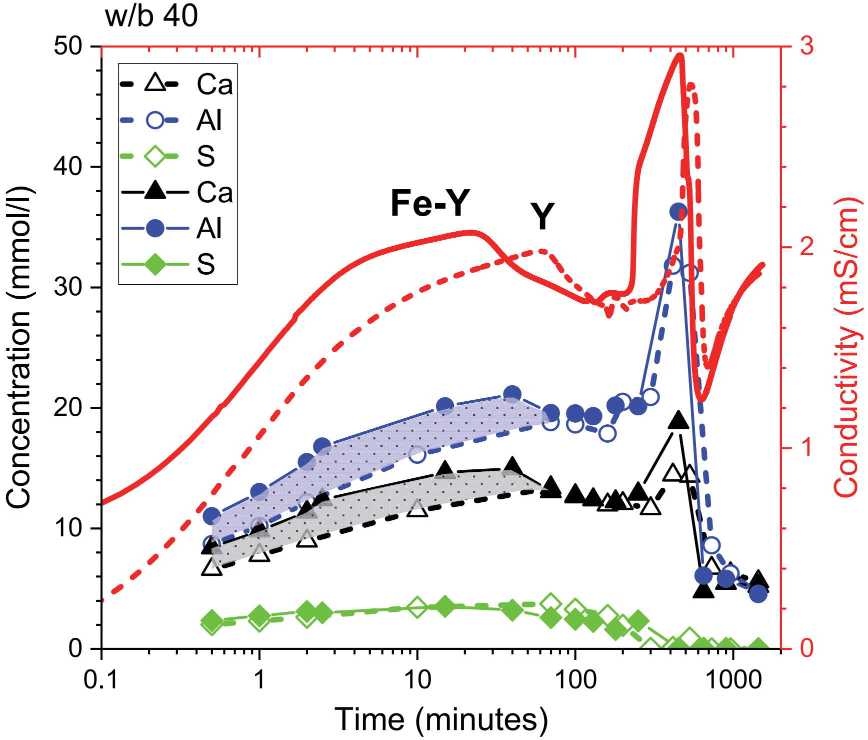
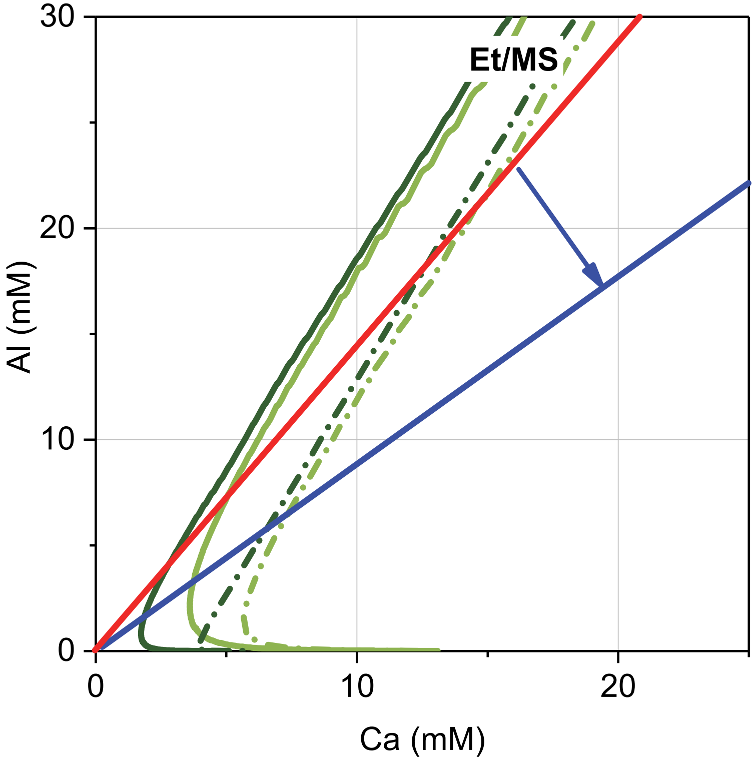
Parameters influencing hydration of Ye‘elimite

- **Mayenite dissolution results in the increase of Ca/Al ratio in the pore solution**

Explains higher Ca and Al concentration





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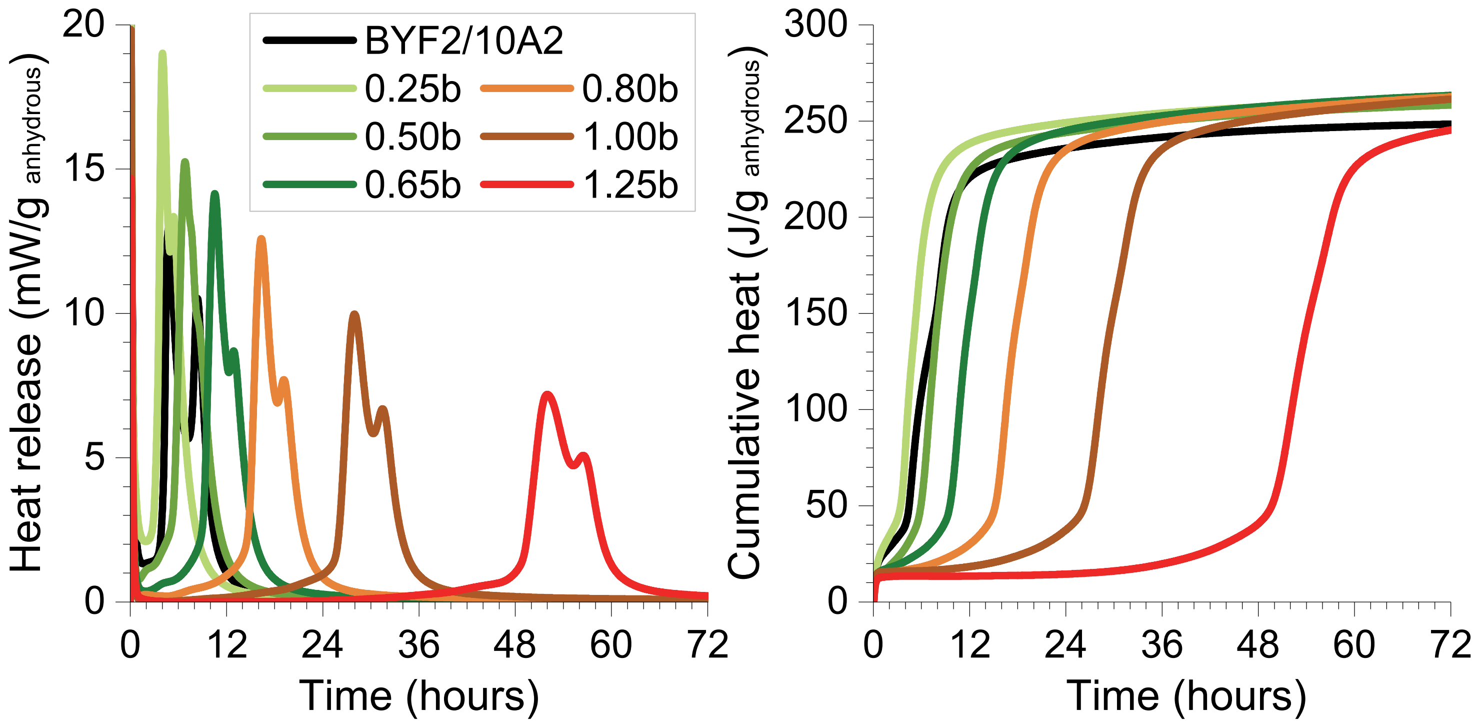
Effect of retarder

- **Borax delays the onset of reaction, but not delays strongly the ye'elimite hydration**



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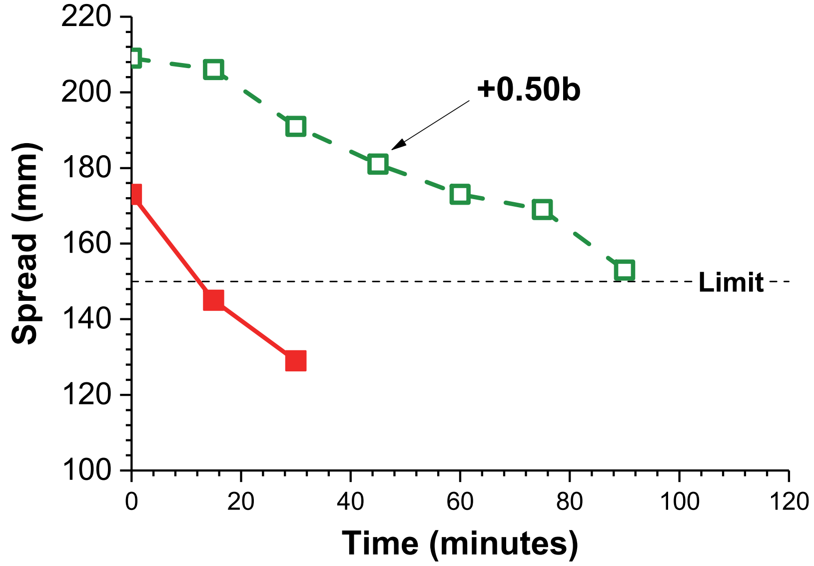
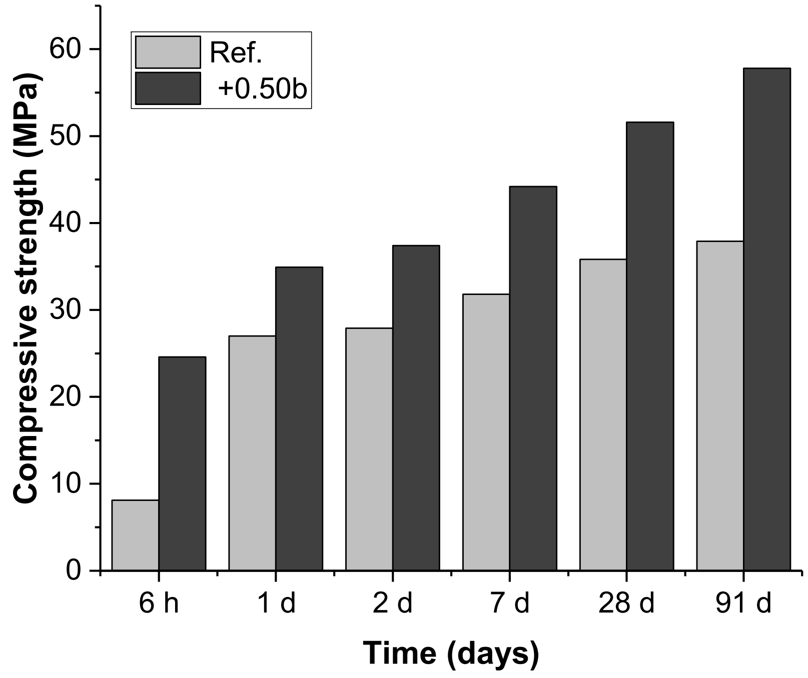
Effect of retarder

- **Proper retardation has effect on overall cement performance**





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Conclusions

Hydration of ye'elimite

- **Hydration of ye'elimite dominates the early hydration of cement**
- **Two main hydration reactions instead of a single reaction of ye'elimite**

Parameters influencing the hydration of ye'elimite

- **The presence of mayenite causes the faster hydration**
  - Iron improves the raw mix burnabillity causing the faster formation of ye'elimite, followed by its decomposition -> Formation of secondary mayenite

Retarder - borax

- **Borax delays the onset of reaction, but not delays strongly the ye'elimite hydration**

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