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

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Outline

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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-CO₂ alternative to Portland cement
- Production is matured
- Raw materials are available
- Similar characteristics and performance evolution to PC based binders
Background

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

Application examples
Production of reinforced panels

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- Hydration mechanisms are well investigated
- There are still several phenomena lacking a sound understanding
Hydration of BYF system

- Ye’elimite is rapidly hydrating phase

\[ C_4A_3\bar{S} \rightarrow C_3A\bar{C}\bar{S}H_{12} + AH_3 \]

\[ C_4A_3\bar{S} + C\bar{S}H_2 \rightarrow C_3A3C\bar{S}H_{32} + AH_3 \]

- Belite and ferrite phase react slower

\[ C_2S + AH_3 + C_3A3C\bar{S}H_{32} \rightarrow C_3A\bar{C}\bar{S}H_{12} + C_2ASH_8 \]

\[ C_2S \rightarrow C – S – H + CH \]
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?
Hydration of yeʻelimite: PhD of Frank Bullerjahn

Slide 9 12.12.2018
Application of calorimetry – Maciej Zajac
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

\[
3 \, C_4A_3\overline{S} + 98 \, H \rightarrow \quad 1 \, C_6A\overline{S}_3H_{32} + 2 \, CAH_{10} + 2 \, AH_3
\]

\[
1 \, C_4A_3\overline{S} + 18 \, H \rightarrow 1 \, C_4A\overline{S}H_{12} + 2 \, AH_3
\]
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
Hydration of BYF clinker with sulfate addition

- Ettringite is the dominating phase, no CAH$_{10}$ present
- Formation of strätlingite and monosulfate delayed

![Graph showing hydration of BYF-10G](Image)
Hydration of ye‘elimite: PhD of Frank Bullerjahn

Why in cement, the ye‘elimite hydration is so rapid?
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 \( C_4A_{3-x}F_xS \)

![Graphs showing content and heat release over time for various iron solid solutions of ye‘elimite.](image-url)
Parameters influencing hydration of Ye‘elimite

Effect of mayenite

- Explains higher Ca and Al concentration

![Graph showing the effect of mayenite on hydration](image)
Parameters influencing hydration of Ye‘elimite

- Analysis of the pore solution allows to understand the effect of mayenite
Parameters influencing hydration of Ye‘elimite

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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

![Graph showing the increase of Ca and Al concentration over time](image)
Effect of retarder

- Borax delays the onset of reaction, but not delays strongly the ye’elimite hydration
Effect of retarder

Proper retardation has effect on overall cement performance
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 burnability 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