INSIGHTS ON THE FRESH PROPERTIES OF CONCRETE MADE OF LIMESTONE CALCINED CLAY CEMENT

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SIKA TECHNOLOGY AG
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RESEARCH & DEVELOPMENT @ SIKA

KEY FIGURES

- 896 EMPLOYEES IN R&D WORLDWIDE
- INVESTMENT of CHF 161.4 Million (2.8% of net sales) in R&D activities 2016
- 72 PATENT APPLICATIONS in 2016
- 20 GLOBAL TECHNOLOGY CENTERS in 9 countries:
  - 5 in Asia (CN, JP)
  - 3 in Americas (US, BR)
  - 12 in Europe (CH, DE, UK, ES, FR)
- 18 REGIONAL TECHNOLOGY CENTERS
  - 3 in Asia
  - 6 in Americas
  - 9 in EMEA (4 in Africa, ME, CE)
- 60 LOCAL TECHNOLOGY CENTERS
SIKA AT A GLANCE

Sika is a specialty chemicals company with a leading position in the development and production of systems and products for bonding, sealing, damping, reinforcing, and protecting in the building sector and the motor vehicle industry.

17,500+ employees  
100+ countries  
170+ factories worldwide  
6.25 bn $ net sales 2017

PCE POLYMERS

SIKA WORLD MAP OF PCE POLYMER PRODUCTION SITES

Yearly production ~300'000t PCE
SIKA’S CURRENT EXPERIENCE & KNOW-HOW ON THE FRESH PROPERTIES OF LC3 CONCRETE

WORK STATUS 2015

CURRENT ALTERNATIVE CEMENT SITUATION

- SLAG
  - world production 2014: 550 MT -> 13% cement (4000 MT)
  - Nearly half of it used as SCM -> 6% cement
  - 10 countries control 96%
  - 50-80 $/T
  - demand outstrips offer -> insufficient to meet global demand

- FLY ASH
  - world production: ~1000 MT
  - 60% landfill
  - only ¼ reused in cement -> 6% cement
  - + 10 BT legacy in landfill!
### RAW MATERIALS

#### PHYSICAL PROPERTIES

<table>
<thead>
<tr>
<th></th>
<th>BET / m²·g⁻¹</th>
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</thead>
<tbody>
<tr>
<td>Suriname</td>
<td>8.1</td>
</tr>
<tr>
<td>Suriname dried @ 60°C</td>
<td>7.7</td>
</tr>
<tr>
<td>Suriname dried @ 200°C</td>
<td>11.1</td>
</tr>
<tr>
<td>Pontezuela</td>
<td>6.6</td>
</tr>
<tr>
<td>Pontezuela dried @ 60°C</td>
<td>7.3</td>
</tr>
<tr>
<td>Pontezuela dried @ 200°C</td>
<td>9.9</td>
</tr>
</tbody>
</table>

### RAW MATERIALS

#### X-RAY DIFFRACTION PATTERNS

- **Suriname**: BET 8.1 m²·g⁻¹
- **Pontezuela**: BET 6.6 m²·g⁻¹
SURINAME - BEHAVIOR IN SOLUTION

- Particle / platelet stacking
- Cement water slurry + PCE
- Cement water slurry
- Water slurry
- Raw powder

$\theta$°

BET 6.9 m$^2$.g$^{-1}$

- Dispersion by plasticizer $\rightarrow$ Ca$^{2+}$ mediated adsorption
- Re-stacking upon drying
- BET 8.1 m$^2$.g$^{-1}$
SURINAME - DISPERSION BY PLASTICIZERS

- Dispersion by plasticizer -> Ca$^{2+}$ mediated adsorption
- How do calcined clays interact with plasticizers?

Experimental strategy
- Slurry of calcined clays (W/C = 10) + increasing amount of polymers
- Pure synthesized polymers (non filtrated)
- Stirring 1 hrs
- Centrifugation (8000rpm) 10mn
- Neutralisation & dilution
- TOC
PLASTICIZER ADSORPTION ONTO BURNT CLAYS (SURINAME)

Plates reached at around 1 mg PCE / m² limestone

Infinite adsorption limestone filler 1.26 m²·g⁻¹

PLASTICIZER ADSORPTION ONTO BURNT CLAYS (SURINAME)

Infinite adsorption limestone filler 1.26 m²·g⁻¹

PCE1 CE=2 SC=1000

PCE2 CE=2 SC=3000

PCE3 CE=2 SC=500

1 mg PCE / m² → ≈ 7.5 m²
PLASTICIZER ADSORPTION ONTO BURNT CLAYS (SURINAME)

**Infinite adsorption**

- PCE1 CE=2 SC=1000
- PCE2 CE=2 SC=3000
- PCE3 CE=2 SC=500
- b-PCE1 CE=2 SC=1000
- b-PCE2 CE=2 SC=1000

**FL2250 (cat.pol.)**
SURFACE SATURATION OF BURNT CLAY vs POLYMER DOSAGE

Infinite adsorption

- PCE1 CE=2 SC=1000
- PCE2 CE=2 SC=3000
- PCE3 CE=2 SC=500
- b-PCE1 CE=2 SC=1000
- b-PCE2 CE=2 SC=1000
- FL2250 (cat.pol.)

SURINAME VS PONTEZUELA

PCE1 CE=2 SC=1000

Infinite adsorption

- Suriname
- Pontezuela
**ADSORPTION - SUMMARY**

- Calcined clay chemistry has no impact
- Surface saturation of calcined clays varies with plasticizer chemistry and structure
- Within a same family of plasticizer, structural variations seem to have no effect
- Consumption of plasticizers by calcined clays is mainly a high specific surface issue

E.g. LC3: 55% CEM I + 30% Clay + 15% limestone

<table>
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<tr>
<th>s.s. (m².g⁻¹)</th>
<th>0.8</th>
<th>8.1</th>
<th>1.25</th>
<th>→</th>
<th>3.0</th>
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<tr>
<td>CEM I</td>
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**OPEN TIME / SLUMP LIFE & HYDRATION KINETICS**

- Target RMC concrete (2hrs)
  - 400 kg cement. m⁻³
  - W/C 0.5

- Micro-concrete testing (max agg size 8mm)
- Initial mixing 3mn
- Shocking table (15) every 30mn (remix 30s)
OPEN TIME / SLUMP LIFE & HYDRATION KINETICS

PCE
- ref W/C 0.6
- PCE1 0.28% (= saturation of clay)
- PCE1 0.32% (=saturation of clay + limestone)
- PCE1 0.44% (=saturation of clay + limestone + cement dosage)

PCE2
- b-PCE2 0.54%
- b-PCE2 0.60%
- PCE1 0.44%

21  Nov.27th, 2018  LC3 Workshop LaHavana - Insight on fresh properties

22  Nov.27th, 2018  LC3 Workshop LaHavana - Insight on fresh properties
LC3 @ Sika - SUMMARY

- Main influence of burnt clays: increase of specific surface
- Surface chemistry of burnt clays: significantly negatively charged
  \[ \rightarrow \text{strong Ca}^{2+} \text{ mediated adsorption of plasticizers} \]
- Retarders may hardly help
- Former generation of plasticizers show insufficient performance even at high dosage
- Current PCE technology can do the job \( \rightarrow \) cost issue

- Field experience \( \rightarrow \) delayed addition of plasticizer seems to perform ok ...