The Benefits of Rheology Enhancing Admixtures on High Performance Concrete

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Global Megatrends
Population Growth and Urbanization

Consequences of Global Megatrends

*Demand for Resources*

The future world population creates a higher demand for:

- for food
- for energy
- for land
- for water
- for construction and buildings
Consequences on Construction
Easy & Fast Construction, Green Buildings, …

- Fast & Easy Construction
- Systems
- Green Building
- Energy Efficiency
- Design & Style
- Comfort & Health
Consequences on Concrete
Achieve adequate Performance with “Poorer” Materials

Drivers
- CO₂ reduction
- Utilize available materials
- Total cost reduction

Action
- Replacement of OPC by
  - Slag/Fly ash
  - Nat. Pozzolans
  - Fillers / Dust
- Use of poorer quality aggregates

Challenges
1. Stickiness
2. Pumpability
3. Long mixing
4. Poor finish

Solution
- Mix design optimization
  - Advanced concrete admixtures

Rheology Enhancing Admixtures
1. **Stickiness Reduction**

*Faster T500 Times*

**C35 design, 700 mm initial slump flow**

<table>
<thead>
<tr>
<th>Kg/m3</th>
<th>1,4% Standard PCE</th>
<th>1,5% REA type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEM I 52,5N</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>Filler (limestone)</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>G/S</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>total water</td>
<td>195</td>
<td>195</td>
</tr>
<tr>
<td>Water/Binder ratio</td>
<td>0,55</td>
<td>0,55</td>
</tr>
</tbody>
</table>
1. Stickiness Reduction

*Shorter V Funnel Times*
1. Stickiness Reduction

*Shorter L Box Times*

Identical initial slump flows

Identical mix designs

Standard PCE Concrete

22 seconds

6 seconds
2. Improved Pumpability
Rheology characterized by Yield Stress and Viscosity

Intrinsic characteristics
- \( \tau_0 \): yield point; minimum shear stress to initiate the flow
- \( \eta \): plastic viscosity; slope of the shear stress curve vs. shear rate
- \( \tau \): shear stress
- \( \dot{\gamma} \): shear rate

Quantified by measurements using a concrete rheometer
2. Improved Pumpability

*Concrete Viscosity reduced vs Conventional Admixtures (1/2)*

<table>
<thead>
<tr>
<th>Plastic viscosity [Pa*s]</th>
<th>Standard plasticizer</th>
<th>Rheology Enhancing</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0</td>
<td>111</td>
<td>77</td>
</tr>
<tr>
<td>T90</td>
<td>129</td>
<td>80</td>
</tr>
</tbody>
</table>

Slump: S4
W/C 0.45

Lower viscosity maintained even after 90 minutes
2. Improved Pumpability

*Concrete Viscosity reduced vs Conventional Admixtures (2/2)*

Viscosity increased only slightly after 120 minutes and without impact on setting and early strength development.
2. Improved Pumpability

Field Example with high Additions

<table>
<thead>
<tr>
<th>Grade</th>
<th>Cement (OPC 53)</th>
<th>Fly Ash</th>
<th>GGBS</th>
<th>M. Silica</th>
<th>w/b</th>
<th>Free water</th>
<th>20 mm</th>
<th>10 mm</th>
<th>Crushed sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>M80</td>
<td>480</td>
<td>130</td>
<td>45</td>
<td>50</td>
<td>0.21</td>
<td>148</td>
<td>550</td>
<td>430</td>
<td>745</td>
</tr>
</tbody>
</table>

Pumping Pressure: 60 Bar
Nos of Strokes: 5 Strokes/Min
Cylinder Filling: 12%
Pump Output: 3.5 m³/hr
Plant Output: 5.0 m³/hr
3. Faster Mixing Times

*Rheology Enhancing Admixture wets out faster*

**Benefits**

- Potential to increase productivity of batching plant
- Less wear & tear on mixers
- Lower energy consumption

**Standard PCE - 145 Sec**

**Rheology Enhancing Admixture – 92 Sec**
4. Better Finishes

*Benefits in both Plastic and Hardened State*

- **Easier smoothening of surface**
  - Better response to vibration
  - Helpful for large elements

- **Easier filling of complex formwork**
  - Less defects in concrete appearance
  - Very good dispersing effects on SCM
4. Better Finishes

*Particularly with high Carbon Content Flyash*

- Example of fluctuations in surface finish with fly ash containing high contamination with free carbon
- Very good dispersing effects
- Uniform finishes

![Standard PCE vs Rheology Enhancing](image)
Project Reference 1
*Signature Tower, Tun Razak Exchange, Kuala Lumpur, MY (opens in 2018)*

Raft & superstructure for 1,438ft skyscraper

**Challenges:**
- Single continuous pour for raft
- Concrete rheology & pumpability at low w/c ratio
- >2hrs workability retention

**Achievements:**
- 19,400m³ of concrete poured in 60hrs
- Largest continuous pour in Malaysia
- Enhanced concrete rheology
- Improved batching plant productivity

*Made possible with MasterEase*
Project Reference 2
Commercial Building, New Delhi, India

Contractor: Shapoorji Pallonji

Challenges:
- C45 concrete
- Target flow of 650 mm
- Pipe diameter: 125 mm
- Pipe length: 60 m (Horizontal) + two 90° bends + 90 m (Vertical)

Achievements:
- Reduced pump pressure by >15%
- Friction factor reduced from 4.7 to 3.9
- Faster discharge and placement
Project Reference 3
Four Seasons Hotel, Bangkok, Thailand (opens in 2018)

Location: Water front

Challenges:
» C60 and C80 concrete
» Pump height: 305 m

Achievements:
» Reduced pump pressure by >25%
  ▶ Conventional PCE mix: 200 bar
  ▶ MasterEase mix: 140 bar
Project Reference 4
Pumping Trial, Vienna, Austria

Typical PCE

<table>
<thead>
<tr>
<th>Plastic Viscosity (Pa-s)</th>
<th>Pump Pressure (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>93</td>
<td>60</td>
</tr>
<tr>
<td>90</td>
<td>75</td>
</tr>
</tbody>
</table>

-35 %  -17 %
Summary

*Rheology Enhancing Admixtures have many benefits*

- Reduces the initial and *later stage* viscosity of concrete mixtures, as compared to conventional admixture solutions

- Resulting pump pressures and mixing times are reduced vs conventional solutions

**Benefits**

- Faster placement
- Higher usage of poorer materials
- Less wear and energy use
- Easier finishing of surfaces
- Good distribution of SCM’s (FA)
- Better surface aesthetics
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