Role of admixtures in concrete durability

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Presentation objective

To demonstrate how admixture technology can improve the quality of concrete to construct more sustainable structures
Durable concrete?

» Low water/cement ratio

» Supplementary cementitious materials

» Dense reinforcement?

» Able to pump?

» Able to place?

» Able to finish?
Durable Concrete?
**Rheology of Concrete**

- Rheology defines the flow and intrinsic behavior of materials (from Greek *rhéō*, "flow" and *-logia*, "study of")

- “Rheology retention” expresses the ability to maintain these properties over an extended time.

- Scientifically the rheology of the concrete is measured using a rheometer

**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

- $\tau$ : Yield stress

- $\gamma$ : shear rate
Evaluation of rheology

- **ICAR rheometer**

- Measuring 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
Next generation polymers

Concrete performance

Hyper-plasticiser

Super-plasticiser

Plasticiser

Lignosulphonates

Naphthalenesulphonates

Melaminesulphonates

Polyacrylates

Polycarboxylates

development of VEA’s

1950

1970

1980

1990

2008

Plastic concrete

High slump concrete

Self-compacting concrete
Poly Aryl Ether (PAE)

- First new superplasticiser technology for 20 years
- Patented technology
- Much less sticky than any PCE (improved rheology)
Performance objectives for new polymer

Maintain all the advantages of PCE technology: water reduction, workability retention, early strength, …
Sharply decreases the yield stress and plastic viscosity of concrete
Water is good for rheology but....

An increase in the dosage of water will have a direct impact on the mechanical performance.

There is a directly affect on the porosity.
Performance optimisation

Objectives:

» Possibility to reduce the w/c ratio without affecting the viscosity of concrete

» Ensure maintenance of handling and maintaining low viscosity over the entire time of delivery and placement (“rheology retention”)

» Mix design optimisations without compromising on rheology: Higher SCM usage and/or reduced cement. Use of challenging aggregates.

» Improved concrete surfaces

Whilst at the same time improving:

» The robustness of concrete

» Durability of concrete (strength, shrinkage, porosity, etc)
Low viscosity concrete utilising PAE

Same mix design; same slump/flow

Only difference is admixture
Low viscosity concrete utilising PAE

Identical mix design

Identical slump flow
Low viscosity concrete utilising PAE

Identical mix design and identical slump flow
<table>
<thead>
<tr>
<th>Session No</th>
<th>Title</th>
<th>Chair(s)</th>
<th>Hall 1 (50 Auditorium Hall)</th>
<th>Hall 2 (Online Hall)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:15 - 11:30</td>
<td>PERMEABLE CONCRETE PAVEMENTS - REQUIREMENTS, THE USE AND METHODS OF APPLICATION</td>
<td>ALDONA WISLOLO</td>
<td>TBA</td>
<td>Advances in Concrete Production and Use</td>
</tr>
<tr>
<td>11:30 - 11:45</td>
<td>DETERMINATION OF TEMPERATURE VARIATION FOR DIFFERENT CONCRETE CLASSES OF AIRPORT RIGID PAVEMENTS USING LABORATORY STUDIES</td>
<td>MEHMET TEvfik Seferdolu, MUHAMMET Vefa AKPINAR,AYSERGUL GUNER SEFEROGLU</td>
<td>TBA</td>
<td>CONCRETE RHEOLOGY CHARACTERIZATION: AN EASY WAY TO DETERMINING IT</td>
</tr>
<tr>
<td>11:45 - 12:00</td>
<td>USE OF ROLLER COMPACTED CONCRETE IN COMPOSITE SOLUTIONS FOR HIGHWAYS</td>
<td>STEVE CROMPTON</td>
<td>TBA</td>
<td>INTRODUCING A NEW CLASS OF SUPERPLASTICIZERS FOR HIGHLY VISCOUS CONCRETE MIXES</td>
</tr>
<tr>
<td>12:00 - 12:15</td>
<td>CONCRETE PAVEMENTS IN TUNNELS: A SUSTAINABLE CHOICE</td>
<td>G. MARCHESI</td>
<td>TBA</td>
<td>THE EFFECTS OF CEMENT PRODUCED WITH NEW GENERATION GRINDING AIDS (PAAF COMPUNDS), TO PHYSICAL AND MECHANICAL PROPERTIES OF CONCRETE</td>
</tr>
</tbody>
</table>
Advantages of PAE

- Reduces pumping pressure
- Reduced pumping time
- Improved truck utilisation
- Reduced wear and tear on pumps
- Increased life of pipelines
- Concrete easier to place and finish enabling the durability designed into the mix to be realised
Admixtures for enhanced durability

- Shrinkage reducing admixtures
- Crack reducing admixtures
- Corrosion-inhibiting admixtures
- Anti-microbial admixtures
- Waterproofing admixtures
Crystalline waterproofing admixtures

Sealing cracks up to 0.4mm
## Hydrophobic pore-blocking admixtures

<table>
<thead>
<tr>
<th>National Dubai, OPC</th>
<th>400</th>
<th>400</th>
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</thead>
<tbody>
<tr>
<td><strong>Total Free Water</strong> (Added + In Admixtures)</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>(157+3)</td>
<td>(150 + 10)</td>
<td></td>
</tr>
<tr>
<td><strong>Free W / Cm Ratio</strong></td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>Superplasticiser dosage l/m³ ( l/100kg Cm )</strong></td>
<td>4.95</td>
<td>5.15</td>
</tr>
<tr>
<td>(1.238)</td>
<td>(1.288)</td>
<td></td>
</tr>
<tr>
<td><strong>Waterproofer dosage l/m³ ( 1/100kg Cm )</strong></td>
<td>-----</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.0)</td>
</tr>
<tr>
<td><strong>Date of Trial</strong></td>
<td>30-6-02</td>
<td>30-6-02</td>
</tr>
<tr>
<td><strong>Concrete Temperature °C</strong></td>
<td>29.0</td>
<td>29.0</td>
</tr>
<tr>
<td><strong>Workability by Slump mm</strong></td>
<td>Initial 170, 30min 135, 60min 100</td>
<td>Initial 180, 30min 150, 60min 115</td>
</tr>
<tr>
<td><strong>Air Content %</strong></td>
<td>1.6</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Fresh Wet Density kg/m³</strong></td>
<td>2515</td>
<td>2490</td>
</tr>
<tr>
<td><strong>BS 5075 Set Time Initial hrs : mins</strong></td>
<td>5:15</td>
<td>6:45</td>
</tr>
<tr>
<td><strong>Final hrs : mins</strong></td>
<td>6:45</td>
<td>8:00</td>
</tr>
<tr>
<td><strong>Compressive Strength N/mm²</strong></td>
<td>27.0</td>
<td>23.0</td>
</tr>
<tr>
<td>24hrs</td>
<td>45.0</td>
<td>41.5</td>
</tr>
<tr>
<td>3day</td>
<td>54.5</td>
<td>49.5</td>
</tr>
<tr>
<td>7day</td>
<td>61.0</td>
<td>60.0</td>
</tr>
<tr>
<td><strong>BS 1881 Pt 122 Water Absorption 7day</strong></td>
<td>2.5 %</td>
<td>0.75 %</td>
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Microbiologically Induced Corrosion (MIC)

1. Non air breathing bacteria in the raw sewerage produce hydrogen sulfide gas ($H_2S$).

2. Air breathing bacteria (Thiobacillus) in the sewerage system convert $H_2S$ into sulfuric acid ($H_2SO_4$).

3. Sulfuric acid ($H_2SO_4$) is a strong acid that corrodes the concrete structure.
Effects of Micro-organisms on Concrete
Microbiologically Induced Corrosion (MIC)
Anti-Microbial Admixture (AMA)

How Does It Work?

1. Anti-Microbial Admixture (AMA) integrates permanently into the concrete structure

2. Micro-organisms come into contact with the concrete surface and are destroyed

3. The AMA prohibits further growth of micro-organisms

4. The result - a clean concrete surface free of the growth of mold, algae, fungus, viral, and bacterial organisms for the life of the concrete
Features & Benefits

» Water-based, non-flammable

» Not harmful to the environment, safe for producers and contractors to handle

» Can be used in all concrete applications to prevent growth of micro-organisms (precast, manufactured concrete products, cast-in-place, shotcrete, underground constructions, etc.)

» No impact to plastic or hardened concrete properties (air, set time, strength, etc.)

» U.S. EPA Registered

» Compatible with other admixtures for concrete
Why do we need corrosion inhibiting admixtures?

Concrete frequently fails to meet its design life; especially in marine environments.
What is a corrosion inhibitor?

An inhibitor is a substance which retards or slows down a chemical reaction. Thus, a *corrosion inhibitor* is a substance which, when added to an environment, decreases the rate of attack by the environment on a metal.

*Corrosion Basics, An Introduction*

pub. National Association of Corrosion Engineers (NACE)
Corrosion inhibiting admixtures

» Give protection against corrosion of steel in reinforced concrete structures

» Good for structures exposed to cycles of wetting and drying (e.g. structures in a marine environment)

» Do not prevent corrosion completely

» Do delay the time when corrosion starts

» Do delay the rate at which corrosion occurs
Service life of a reinforced concrete structural element

INITIATION

LIFETIME OF THE STRUCTURAL ELEMENT

LIMIT OF SERVICE LIFE

Benefit of C.I. Admixture

$\text{CO}_2$ and $\text{Cl}^-$ penetration

$\alpha \sim$ concrete quality & environment

$\alpha$

$\text{t}_i$

$\text{t}_p$

LIFETIME OF THE STRUCTURAL ELEMENT
Dual mechanism organic corrosion inhibitors

1) Reduce permeability of concrete

2) Form a pacifying layer on steel

Single dosage independent of chloride level
Life-cycle modelling

Yes; specify durable concrete. But…

Enhance the rheology to make the mix:
- Easier to pump
- Easier to place and compact (preferably SCC)
- Easier to finish

Then extend the service life of the structure by adding durability-enhancing admixtures.
Thank you for your attention.