Advances in Chemical Admixture Technology and the Impact on Sustainable Concrete

2010 Concrete Sustainability Conference

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Tempe, AZ
April 13 - 15 2010
Presentation Overview

- Workability retaining admixture
- Optimizing concrete mixes
- Practical use case study
- Impact on environmental sustainability
- Construction team advantages
What is a Workability Retaining Admixture?

**Workability Retaining Admixture** – an admixture that allows concrete or mortar to maintain its fresh characteristics throughout the transporting, placing, consolidating and finishing operations without adversely affecting the time of setting and hardened properties of the concrete or mortar.

An *Innovative* technology in which the additive is specifically dosed to control the length of time that concrete workability is to be retained.

It is **NOT** a retarding or hydration control admixture.

It is **NOT** a water reducer or slump retaining HRWR.
Workability Retaining Admixture

Features

Superior workability retention without retardation
Dosage flexibility – Providing flexible levels of workability retention
Consistent early and late-age compressive strengths
Workability Retention and Air Content

Reference mixture re-tempered with water

- Cement: 540
- Fly ash: 60
- w/cm: 0.43

<table>
<thead>
<tr>
<th>Slump (in)</th>
<th>Air (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>1880</td>
</tr>
<tr>
<td>30 min</td>
<td>1840</td>
</tr>
<tr>
<td>60 min</td>
<td>1840</td>
</tr>
<tr>
<td>90 min</td>
<td>1840</td>
</tr>
</tbody>
</table>

Initial 30 min retemper 60 min retemper 90 min retemper

Reference mixture re-tempered with HRWR

- Slump (in): 9
- Air (%): 1970

<table>
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<tr>
<th>Slump (in)</th>
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<tr>
<td>Initial</td>
<td>2680</td>
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<td>90 min</td>
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</table>
Workability Retaining Admixture

Benefits

- Promotes greater consistency of concrete **workability** at the jobsite
- Promotes consistency in compressive **strengths** via minimized jobsite addition of water
- Minimizes re-dosing of high-range water-reducing admixture at the job site
- Consistent air-entrainment
- Fewer rejected loads and better customer satisfaction due to consistent quality of concrete
- Helps in increased use of supplementary cementitious materials, thereby optimizing mixture costs
- Faster truck turn-around time
- Expanded Delivery Area
Inconsistent Concrete –
The Overdesign Band-Aid

- Producers often find themselves overdesigning mixes in an effort to compensate for potential problems
- This has a direct impact on ROI and profitability
- Product consistency can help to minimize overdesign and reduce mix costs

| Overall Variation | Excellent | Very Good | Good | Fair | Poor  
|-------------------|-----------|-----------|------|------|-------
| Gen. Construction Testing | <400 | 400-500 | 500-600 | 600-700 | >700 

| Overall Variation | Excellent | Very Good | Good | Fair | Poor  
|-------------------|-----------|-----------|------|------|-------
| Gen. Construction Testing | 300 | 450 | 550 | 650 | 800 
| Required Target Strength | 5400 | 5600 | 5780 | 6015 | 6370 
| Overdesign | 400 | 600 | 780 | 1015 | 1370 | 
| # of cement | 40 | 60 | 78 | 101.5 | 137 |
Case Study

Project with no mix design history
- 5000 psi design strength
- Slump – 8 in. target
- Air – 6% target
- Utilized WRA

Started producing and measuring results

<table>
<thead>
<tr>
<th></th>
<th>Strength (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>243</td>
</tr>
<tr>
<td>Average</td>
<td>6,540</td>
</tr>
<tr>
<td>Std Dev</td>
<td>570</td>
</tr>
</tbody>
</table>
Case Study

Given:

Design strength: 5,000 psi

ACI Required Strength: 6,200 psi (based on no history)

Avg. production strength: 6,540 psi

Actual overdesign 1,540 psi

Revised overdesign: 830 psi (revised strength of 5,830 psi)

Optimization potential: 710 psi
Case Study

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<th>Slump (in.)</th>
<th>Air (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>362</td>
<td>362</td>
</tr>
<tr>
<td>Average</td>
<td>8.2</td>
<td>6.2</td>
</tr>
<tr>
<td>Std Dev</td>
<td>1.14</td>
<td>0.9</td>
</tr>
</tbody>
</table>
Case Study

What does this mean?

1) Workability-retaining admixture allows producers to further optimize mixes for performance and economics.

2) Through optimization, ecological benefits can also be realized.
How do you measure ecological benefits?

**Eco-Efficiency Analysis**
Strategic life cycle methodology used to compare the relative ecological and economic efficiencies of alternative

- products (like concrete)
- processes
- technologies

**ISO 14040 (ecological part)**

- Cradle-to-gate
- Cradle-to-grave
- Cradle-to-cradle
Understanding Concrete Sustainability

Plant
- Plant and Fleet
  - NRMCA
    - Green Star Sustainable Concrete Plant Guidelines

Concrete
- Concrete
  - BASF
    - Eco-Efficiency Analysis of Optimized Concrete Mixes

Project
- Projects
  - LEED
    - Point System
      - Optimized Concrete Mixes

"What is my Sustainable Concrete Plant Guidelines?"
Environmental Impact Categories

- **Consumption of Energy**
  - Cumulative energy utilized in the cradle-to-gate analysis
  - Fossil and renewable resources are included

- **Emissions**
  - Described by categories
    - Air
    - Water
    - Solids

- **Toxicity Potential**
  - Potential effect on human health toxicity

- **Risk Potential**
  - Potential for physical hazard (accident and occupational disease)
  - Based on published statistical data

- **Consumption of Raw Materials**
  - Materials are weighted according to reserves and global consumption

- **Land Use**
  - Degree of land development needed to fulfill the production of concrete

Global Warming Potential
Ozone Depletion Potential
Photochemical Ozone Creation Potential
Acidification Potential
Eco-Efficiency Analysis for Concrete Cradle-to-Gate

**Cement Production**
- Mine raw materials
- Heat in kiln
- Grind with gypsum
- Store/load/ship

**Aggregate Quarry**
- Blast/mine
- Crush
- Separate sizes
- Store/load/ship

**Chemical Admixtures**
- Receive raw material
- Manufacture molecules
- Blend ingredients
- Store/load/ship

**Concrete Plant**
- Use of potable water

**Water**
- Separate and process
- Store/load/ship

**Recycled Materials**

EEA concrete analyses can be conducted on ready mixed, precast, manufactured concrete products, paving, self-consolidating and pervious concrete.
Case Study Example:
Conducting an Eco-Efficiency Analysis on Optimized Concrete Mixes

Two Different Mixes: Reference Mix and Optimized Mix

Data Input
- Project name
- Location
- Raw materials and costs
- Mix proportions
- Transportation distances
- Volume of concrete

Analysis
- Environmental profiles
- Sums raw material data
- Calculations
- Compares mix designs
The optimized concrete alternative is shown to be progressively more environmentally preferable in relation to the Reference Mix.
Eco-Efficiency Profile
Economical and Ecological Impact

The optimized concrete mix has the lowest overall environmental burden and is the most economical to produce.
### Ecological Analysis

#### Water Savings

**Water Saved - Truck Washout and Bottled Water**

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Water Saved (gal/yd³)</th>
<th>Annualized Water Saved (gal/yr)</th>
<th>Equivalent Annualized Number of Truck Washouts</th>
<th>Equivalent Number of 1/2 liter Bottles of Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimized Mix</td>
<td>3.2</td>
<td>162,065</td>
<td>720</td>
<td>1,226,831</td>
</tr>
</tbody>
</table>

**Water Saved - Laundry and Shower Equivalence**

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Water Saved (lb/yd³)</th>
<th>Annualized Water Saved (lb/yr)</th>
<th>Annualized # Loads of Laundry Saved (loads/yr)</th>
<th>Annualized # Showers Saved (showers/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimized Mix</td>
<td>27</td>
<td>1,350,000</td>
<td>4,044</td>
<td>12,943</td>
</tr>
</tbody>
</table>
EcoEological Analysis by Ingredient

Energy

The impact of each ingredient is determined for each of the six environmental impact categories and more.
## Ecological Analysis

### Energy and Carbon Footprint

#### Energy Saved - US Homes Equivalent

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Energy Saved (kWh/yd³)</th>
<th>Annualized Energy Saved (kWh/yr)</th>
<th>Annualized US Energy Savings Equivalent (homes/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimized Mix</td>
<td>79</td>
<td>3,934,797</td>
<td>340</td>
</tr>
</tbody>
</table>

#### Smaller Carbon Footprint - CO₂ Uptake for 25-Year-Old Forest Equivalent

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Emissions Saved (lb CO₂ equiv./yd³)</th>
<th>Annualized Emissions Saved (lb CO₂ equiv./yr)</th>
<th>Annualized Forest Equivalent (acres/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimized Mix</td>
<td>75</td>
<td>3,730,169</td>
<td>2,119</td>
</tr>
</tbody>
</table>

#### Smaller Carbon Footprint - Volume of Gasoline Equivalent

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Emissions Saved (lb CO₂ equiv./yd³)</th>
<th>Annualized Emissions Saved (lb CO₂ equiv./yr)</th>
<th>Annualized Volume of Gas Saved (gal/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimized Mix</td>
<td>75</td>
<td>3,730,169</td>
<td>196,325</td>
</tr>
</tbody>
</table>

*Based on a project size of 50,000 yd³ of concrete*
### Ecological Analysis

#### Emissions

<table>
<thead>
<tr>
<th>Smog Reduction - Passenger Car Equivalent</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative</td>
<td>Emissions Saved (lb ethene equiv./yd³)</td>
<td>Annualized Emissions Saved (lb ethene equiv./yr)</td>
<td>Annualized Passenger Cars Off Road (#/yr)</td>
</tr>
<tr>
<td>Optimized Mix</td>
<td>0.02</td>
<td>1,028</td>
<td><strong>8</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acidification Potential - AC Units Equivalent</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative</td>
<td>Emissions Saved (lb SO₂ equiv./yd³)</td>
<td>Annualized Emissions Saved (lb SO₂ equiv./yr)</td>
<td>Annualized AC Unit Equivalent (number/yr)</td>
</tr>
<tr>
<td>Optimized Mix</td>
<td>0.6</td>
<td>31,354</td>
<td><strong>2,090</strong></td>
</tr>
</tbody>
</table>

| Fossil Fuel Consumption - Barrels of Oil Equivalent | | | |
| --- | --- | --- | --- | --- |
| Alternative | Fossil Fuel Saved (lb/yd³) | Annualized Fossil Fuel Saved (lb/yr) | Barrels of Oil Saved (number/yd³) | Annualized Barrels of Oil Saved (number/yr) |
| Optimized Mix | 9.2 | 458,697 | 0.1 | **4,954** |

*Based on a project size of 50,000 yd³ of concrete*
## Construction Team Benefits

### Producer
- Increased quality
- Optimized economics
- Reduced claim potential
- Environmental leadership

### Engineer
- Meets performance requirements
- Quantifiable environmental savings
- Value engineering

### Contractor
- No job delays
- Ease of placement
- Concrete consistency
Advanced Admixture Technology and EEA - Deliverable

- Workability Retaining Admixture provides concrete consistency
- Reduced variation reduces overdesign requirement
- Allows for mix optimization

Eco-Efficiency Analysis on Concrete measures environmental impact
Summary

- Workability-retaining admixture
- Optimizing concrete mixes
- Practical use case study
- Impact on environmental sustainability
- Advantages