Overview

- Brief recap of current state-of-the-practice for improving the freeze-thaw durability of concrete
- Microsphere-based admixture for freeze-thaw durability
  - The technology
  - Mechanism of protection
  - BASF Point-of-Use Manufacturing System
  - Performance data
  - Proposed fresh concrete test method
  - Detection in hardened concrete
  - Field trials
- Summary

We've known since the 1930s...

Entraining Air in Concrete Improves its Freeze-Thaw Durability!

Mechanism of Air Entrainment using Air-Entraining Admixtures

- Air Generated into Concrete During the Mixing Process
- Entrapped / Entrained Air

Air-Voids in Hardened Concrete

Mechanism of Protection by Air-Voids in Concrete

Air entrained; Saturation > 91.7%
Air entrained; Saturation > 91.7%

Mechanism of Protection by Air-Voids in Concrete

Slump and Air Content are Intertwined!

Fluctuations in Air Content

 BATCH PLANT
- Aggregate gradation
- Cement changes
- Supplementary materials
- Concrete temperatures
- Slump consistency
- AE dosage/ dispensing
- Mixing dynamics
- Contamination

 JOBSITE
- Addition of water
- Addition of HRWR
- Addition of pigments
- Addition of fibers
- Mixing dynamics
- Calibration of meter
- Improper testing
- Pumping

Air content variability is the number one production problem facing the North American concrete industry today!
A New Way of Making Concrete Freeze-Thaw Durable

Technology Breakthrough

Liquid Microsphere-based Admixture

Microsphere Particle Size vs. Air Voids from Conventional Air Entrainment

Both 5% Air Content

"Sphere of Influence"

Spacing Factor: 0.008-in. regardless of void size

How many Microspheres?
Frost Resistance Using Microspheres

Chemical Admixtures—Recent Developments 155

microsphere addition to the same extent as that provided by 5% air. The 28-day strength was higher with microspheres, being 40 MPa/mm² and 38 MPa/mm² with 1% hollow spheres and 5% air, respectively.

Vanheusden[16] confirmed some of the findings of Somor.[10] Using 0.3, 0.6, 0.9 and 1.2% microspheres by weight of cement, concretes were made. The resulting compressive strength and frost resistance of these mixtures were compared with those of reference concretes (with and without air entrainment). The frost resistance was improved considerably in concrete containing microspheres. A minimum amount of 0.6% microsphere was needed for good frost resistance. It was also concluded that the compressive strength of air-entrained concrete (with respect to the plain non-air entrained concrete) was less than that containing the microspheres.

Frost Resistance Using Microspheres

An innovative approach in the area of air-entraining admixtures is the use of preformed bubble reservoirs in the form of porous particles. In one method, hollow plastic microspheres with diameters between 10 and 60 μm are added to concrete.[11] The voids in the particle are smaller than those in the air-entrained concrete (10–300 μm). Addition of 1% by weight of cement of these microspheres to concrete corresponds to 0.7% by volume of concrete. The spacing factor equivalent using these spheres is 0.07 mm, well below the permissible maximum. Somor[10] compared the losses in weight of concrete (due to freezing and de-icing salt attack) containing 5% entrained air with that containing 0.3, 0.6, 0.9, 1.2 and 1.5% hollow microspheres. Adequate frost resistance was attained using 0.9% of the microspheres. No further advantage was observed using higher proportions. Thus 1% hollow sphere was found to be as effective as 5% entrained air. The workability as a measure of consistency was increased by the microspheres.
Mechanism of Protection by Microspheres in Concrete

Air entrained; Saturation > 91.7%

Use of Microspheres is NOT New!

- Microsphere technology used in Central Europe
- Shipping and transportation costs prohibitive
- Use limited to niche applications

BASF Point-Of-Use Manufacturing System

- Economic Feasibility

Performance Data

<table>
<thead>
<tr>
<th>Mix #</th>
<th>Nominal Proportions, lb/yd3 (kg/m3)</th>
<th>AEA* Dosage</th>
<th>Microsphere-Based Admixture</th>
<th>Air Content</th>
<th>Slump</th>
<th>Durability Factor</th>
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<tbody>
<tr>
<td></td>
<td>Portland Cement</td>
<td>Fly Ash</td>
<td>Fine Aggregate</td>
<td>Coarse Aggregate</td>
<td>fl oz/cwt (mL/100 kg)</td>
<td>% by volume</td>
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<tr>
<td>1</td>
<td>570</td>
<td>0 (0)</td>
<td>180</td>
<td>90</td>
<td>(171)</td>
<td>(140)</td>
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<td>2.3</td>
<td>7.75 (200)</td>
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<td>3</td>
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* Air-entraining admixture

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<td>2.9</td>
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### Performance Data (High LOI Fly Ash)

<table>
<thead>
<tr>
<th>Mix ID</th>
<th>Fly Ash (% of cementitious)</th>
<th>Air-Entraining Admixture mL/100 kg (fl oz/cwt)</th>
<th>Microsphere-Based Admixture (% by volume)</th>
<th>Air Content %</th>
<th>Slump (mm/in)</th>
<th>Durability Factor %</th>
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<tbody>
<tr>
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<td>60 (1.93)</td>
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<td>210 (8.25)</td>
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<tr>
<td>8</td>
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<td>940 (32.2)</td>
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<td>210 (8.25)</td>
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<tr>
<td>9</td>
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<td>0.75</td>
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<td>220 (8.75)</td>
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<tr>
<td>10</td>
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<td>2.1</td>
<td>210 (8.25)</td>
<td>99</td>
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<tr>
<td>11</td>
<td>20</td>
<td>1.25</td>
<td>2.0</td>
<td>210 (8.25)</td>
<td>99</td>
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</table>

### Performance Data (High SRAs & OCIA)

<table>
<thead>
<tr>
<th>Mix ID</th>
<th>OCIA L/m³ (gal/yd³)</th>
<th>SRA L/m³ (gal/yd³)</th>
<th>Microsphere-Based Admixture (% by volume)</th>
<th>Air Content %</th>
<th>Slump (mm/in)</th>
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<tbody>
<tr>
<td>1</td>
<td>5.0 (1.0)</td>
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<td>5.0 (1.0)</td>
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<td>100 (4.0)</td>
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</tbody>
</table>

OCIA = organic corrosion-inhibiting admixture; SRA = shrinkage-reducing admixture

### Proposed ASTM Test Method (Recovery Test)

1. Scope

1.1. This test method serves the recovery and determination of microsphere content in fresh concrete by the volumetric method.

1.2. The values stated in this test method are intended for use in research. The values stated in each system are not exact equivalents, therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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“Counting Air” - ASTM C 457

Air-Entrained Concrete

Microsphere Technology

Fractured Surfaces

Cut and Lapped Surface, microspheres

Field Trial

Field Trial in Minneapolis, MN
Concept Validation / Market Awareness

In Summary,...

Microspheres vs. Air-Entrainment

Air Content Variability

Mixture Proportioning Considerations

Summary

- Use of microsphere for frost resistance is a proven technology
- A patent-pending liquid microsphere-based admixture
- A patent-pending point-of-use manufacturing system
- Market awareness and market acceptance activities underway
- Commercial availability in 2015

New, Innovative System for Freeze-Thaw Durability
Eliminates the Need for Air-Entrained Concrete!
Coming Soon…

MasterSphere FT 300 Admixture

Thank You