Latest Developments
in
Chemical Admixtures for Concrete

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www.basf-cc.com.au
Overview

- Shrinkage Reducing Agent (SRA)
- ASTM C 1581
- Investigation of early age tensile stresses….
- US DOT studies & recommendations
- Thin White Topping (TWT) project (India)
- 4 x 4 for Rapid Pavement Repairs (USA)
- Microspheres
Types of Shrinkage

- PLASTIC SHRINKAGE
  - Thermal Contraction
- DRYING SHRINKAGE
- AUTOGENOUS SHRINKAGE
- Carbonation Shrinkage
Shrinkage in Concrete

A Reduction in Length / Volume
Factors Affecting Drying Shrinkage

- Concrete Mix Ingredients especially, Water & Coarse Aggregate including shrinkage of the paste, the volume fraction of paste, the stiffness of the aggregate and the strength of the bond between the paste and aggregate

- Design & Construction Practices

- Environmental Influences
Effect of Coarse Aggregate Content on Drying Shrinkage

Figure illustrates the Effect of Aggregate-Cement (a/c) ratio and Water-Cement ratio on Drying Shrinkage
### EXPECTED WATER REDUCTION & DRYING SHRINKAGE

<table>
<thead>
<tr>
<th>Admixture (Type Symbol)</th>
<th>Water Reduction as % of Control (minimum)</th>
<th>Water Content (ltr/m³)</th>
<th>Drying Shrinkage at 56 days (microstrain)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Reducer (WR)</td>
<td>5</td>
<td>190</td>
<td>550</td>
</tr>
<tr>
<td>Retarder (Re)</td>
<td>-</td>
<td>195</td>
<td>540</td>
</tr>
<tr>
<td>Accelerator (Ac)</td>
<td>-</td>
<td>196</td>
<td>610</td>
</tr>
<tr>
<td>Water Reducer Retarder (WRRe)</td>
<td>5</td>
<td>190</td>
<td>510</td>
</tr>
<tr>
<td>Water Reducer Accelerator (WRAc)</td>
<td>5</td>
<td>190</td>
<td>570</td>
</tr>
<tr>
<td>High Range Water Reducer (HWR)</td>
<td>12-15</td>
<td>176</td>
<td>470</td>
</tr>
<tr>
<td>High Range Water Reducer Retarder (HWRRe)</td>
<td>12-15</td>
<td>176</td>
<td>470</td>
</tr>
<tr>
<td>Control</td>
<td>Nil</td>
<td>200</td>
<td>720</td>
</tr>
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</table>

Drying Shrinkage Data with Various Types of Admixtures
Effect of Water Content on Drying Shrinkage
SRA – Mechanism of Action

- Loss of moisture
SRA – Mechanism of Action

- Loss of moisture
- A meniscus forms at air-water interface due to surface tension
• Surface tension forces exert *inward pulling force* on the walls of the pores

• *Surface tension* is most significant in pore sizes ranging from 2.5-50 nm
SRA – Mechanism of Action

- Loss of moisture
- A meniscus forms at air-water interface due to surface tension
- SRAs reduce the capillary tension by reducing surface tension of water
## MasterLife® SRA 200

*Fresh and hardened properties of concrete*

<table>
<thead>
<tr>
<th>Mix</th>
<th>Water Reducer</th>
<th>Dosage (ml/100kg)</th>
<th>SRA</th>
<th>Dosage (L/m³)</th>
<th>Slump (mm)</th>
<th>Air (%)</th>
<th>Fresh density (kg/m³)</th>
<th>w/b</th>
<th>Water (l/m³)</th>
<th>GP Cement (kg/m³)</th>
<th>Fly Ash (kg/m³)</th>
<th>Coarse Sand (kg/m³)</th>
<th>Fine Sand (kg/m³)</th>
<th>20/7 Gravel (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>MasterPozzolith 80</td>
<td>300</td>
<td>-</td>
<td>0</td>
<td>115</td>
<td>1.6</td>
<td>2400</td>
<td>0.593</td>
<td>212</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>MasterLife® SRA 200</td>
<td>2</td>
<td></td>
<td>120</td>
<td>2.6</td>
<td>2370</td>
<td>0.588</td>
<td>208</td>
<td>300</td>
<td>60</td>
<td>575</td>
<td>290</td>
<td>980</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>MasterLife® SRA 200</td>
<td>4</td>
<td></td>
<td>130</td>
<td>2.8</td>
<td>2360</td>
<td>0.584</td>
<td>206</td>
<td>300</td>
<td>60</td>
<td>575</td>
<td>290</td>
<td>980</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>MasterLife® SRA 200</td>
<td>6</td>
<td></td>
<td>125</td>
<td>3.0</td>
<td>2360</td>
<td>0.583</td>
<td>205</td>
<td>300</td>
<td>60</td>
<td>575</td>
<td>290</td>
<td>980</td>
<td></td>
</tr>
</tbody>
</table>

**Summary of trials at Seven Hills**

**Ambient temperature: 23°C**

**Hardened property: Drying shrinkage strain up to 90 days**
MasterLife® SRA 200

Drying shrinkage reduction versus dosage

[Graph showing drying shrinkage strain versus age for different dosages of MasterLife® SRA 200, with labels for Control, MasterLife: 2L/m³, MasterLife: 4L/m³, and MasterLife: 6L/m³.]
MasterLife® SRA 200

Drying shrinkage reduction versus dosage

- 4 L/m³ of MasterLife® SRA 200 reduces drying shrinkage by 100 microstrain at 90 days
- 6 L/m³ MasterLife® SRA 200 reduces drying shrinkage by 160 microstrain at 90 days
- MasterLife® SRA 200 can reduce drying shrinkage by 30% to 50% at 6 L/m³
- Shrinkage is lower as we progress to 90 days for all dosage levels
The magnitude of drying shrinkage is time dependent

On average, nearly 50 percent of the drying shrinkage obtained at 20 years occurred within the first 2 months of drying

And nearly 80 percent within the first year

These values are consistent with drying shrinkage values using SRAs in concrete due to its absorption/adsorption within the pore wall structure
Test Method ASTM C 1581

Standard Test Method for Determining Age at Cracking and Induced Tensile Stress Characteristics of Mortar and Concrete Under Restrained Shrinkage (a.k.a. “Ring Test”)

Summary
Test method measures concrete’s resistance to cracking under restrained shrinkage

1. Concrete placed in instrumented mould
2. Concrete shrinks
3. Steel ring restrains shrinkage
4. Concrete cracks
5. Gauges measure time to cracking and crack width
Test Method ASTM C 1581
Test Method ASTM C 1581

- Heat of hydration peak
- Autogenous and thermal deformation
- Removal of wet cure
- Initial reading after casting
- Cracking
Test Method ASTM C 1581

- μStrain
- μStrain

Control
SRA

Sudden decrease in compressive strain

Time after Initiation of Drying
## Cracking potential classification
(Based on stress rate at time-to-cracking)

<table>
<thead>
<tr>
<th>Time-to-Cracking, $tcr$, Days</th>
<th>Stress Rate at Cracking, $S$, MPa/Day</th>
<th>Potential for Cracking</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0 &lt; tcr \leq 7$</td>
<td>$S \geq 0.34$</td>
<td>High</td>
</tr>
<tr>
<td>$7 &lt; tcr \leq 14$</td>
<td>$0.17 &lt; S &lt; 0.34$</td>
<td>Moderate-High</td>
</tr>
<tr>
<td>$14 &lt; tcr \leq 28$</td>
<td>$0.10 &lt; S &lt; 0.17$</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>$tcr &gt; 28$</td>
<td>$S &lt; 0.10$</td>
<td>Low</td>
</tr>
</tbody>
</table>
Reduction in slab curling & plastic cracking potential

- Decrease in capillary stress
- Increase in viscosity of pore solution
- Decrease in rate of evaporation
- Decrease in settlement
- Decrease in plastic cracking potential
Crack prevention is often a critical parameter in the design and construction of ground and suspended concrete slabs. Often when the degree of restraint is high, uncontrolled cracking can influence the serviceability of a structure.

Designers often use the specification of maximum values for standard 56 day drying shrinkage tests as determined by AS1012.13 in an attempt to control cracking of concrete pavements.
**Investigation of Early Age Tensile Stresses, Shrinkage Strains in Pavements and Standard Drying Shrinkage Tests** [Liza O’Moore, Daksh Baweja & Peter Dux]

32 MPa mix with SRA, Aliphatic alcohol (Evaporation retardant) & Curing compound
0 – 60 microstrain

32 MPa mix without SRA, without Aliphatic alcohol (Evaporation retardant) but with Plastic sheeting
0 – 250 microstrain
Early-age crack mitigation strategies

- SRA reduces evaporation, settlement and stresses that develop on the surface. Each of these benefits reduces the potential for the development of plastic shrinkage cracks. Moreover, the crack width of plastic cracks are reduced.

- Other studies indicate delayed or no cracking at early & latter ages

Source: EVAPORATION, SETTLEMENT, TEMPERATURE EVOLUTION & DEVELOPMENT OF PLASTIC SHRINKAGE CRACKS IN MORTARS WITH SHRINKAGE-REDUCING ADMIXTURES. Pietro Lura, Guy B. Mazzotta, Farshad Rajabipour and Jason Weiss
Early-age crack mitigation strategies (DOTs)

- SRA is recommended to be used in concrete to mitigate early-age shrinkage cracking in concrete bridge decks (Washington State DOT report)
- By incorporating a SRA the cracking resistance of concrete is increased (Oklahoma DOT Final Report SPR 728)
- California DOT (Caltrans) has selected SRAs as a method of crack control in cast-in place decks on precast girders & steel girders with headed studs for composite action. Deck-on-deck rehabilitation is especially prone to cracking due to drying shrinkage stresses
Thin White Topping (TWT), Bangalore, India
Thin White Topping (TWT), Bangalore, India

OPC = 430 kg/m$^3$
FA = 30 kg/m$^3$
W/C = 0.28
Superplasticizer
PP Fibres
Slump @ 30’ = 40mm
Flexural strength of Concrete
(Total no. of samples 60)

<table>
<thead>
<tr>
<th>No.</th>
<th>Sample size</th>
<th>28 – day strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Max: 7.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Min: 6.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Avg: 6.3</td>
</tr>
</tbody>
</table>

Compressive Strength of Concrete Cubes (Total no. of samples 936)

<table>
<thead>
<tr>
<th>No.</th>
<th>Sample size</th>
<th>1-day strength (MPa)</th>
<th>3-day strength (MPa)</th>
<th>7-day strength (MPa)</th>
<th>28 – day strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Max: 24.1</td>
<td>Max: 48.2</td>
<td>Max: 55.2</td>
<td>Max: 67.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Min: 21.1</td>
<td>Min: 38.4</td>
<td>Min: 48.4</td>
<td>Min: 57.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Avg: 22</td>
<td>Avg: 43</td>
<td>Avg: 51</td>
<td>Avg: 61</td>
</tr>
</tbody>
</table>

60 cubes per test
Concrete pavement & water curing, Rural India
4x4™ Concrete
Strength-on-Demand

Challenge: An alternative solution to expensive, rapid setting cement-based concrete

- Faster-setting, user-friendly and cost effective
- Develops 400 psi (2.8 MPa) flexural strength within 4 hours after placement
- Full depth highway, intersections and airport taxiway repairs

In response to this challenge, the 4x4 Concrete System was developed by BASF.

U.S. Patent – No. 6,858,074
**4x4™ Concrete**

**Owner and Contractor Benefits**

**Owner benefits**
- Economical - saves tax payers dollars
- Strength performance met consistently
- Open to traffic/airplanes sooner - reduced lane closure time

**Contractor benefits**
- Alternative to expensive, existing systems
- Slump/workability control
- Easy to place and finish
- No post-grinding for ride quality
I-75 Rehabilitation Project

(Kentucky / Ohio border)

- Full-depth mainline paving concrete replacement
- 26,000 yd$^3$ (19,880 m$^3$) of very high-early strength concrete
- Took 16 weekends to complete
- 1,600 yd$^3$ (1,220 m$^3$) of very high-early strength concrete placed every Saturday
Air Entrained Concrete

Variability = Cost
Microspheres: Comparison to Air-Entrainment

<table>
<thead>
<tr>
<th>Concrete Production</th>
<th>Air Entrainment</th>
<th>Microspheres</th>
<th>Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing and Transport</td>
<td></td>
<td></td>
<td>Robustness</td>
</tr>
<tr>
<td>Pumping, vibration, and finishing</td>
<td></td>
<td></td>
<td>Resilient</td>
</tr>
</tbody>
</table>
Conclusions

*SRA*
Reduces plastic cracking
Reduces the frequency and width of cracks
Reduces short as well as long-term drying shrinkage values

*Test Method*
ASTM C 1581 well gaining acceptance

*TW Topping*
Adopted for fast tracking projects in developing countries

*4 x 4*
Rapid pavement repair option

*Microsphere*
Alternate technology for Air Entrained Concrete
www.basf-cc.com.au

THANK YOU