Tony Kojundic
Silica Fume Association
c/o Elkem Materials Inc.
PO Box 266
Pittsburgh, PA 15230
(412)299-7229
tony@silicafume.org

Synopsis:
This presentation will provide a fundamental look into the definition of high-performance concretes (HPC) of today, and the technology behind silica-fume to produce HPC for bridge applications. The presentation will highlight key structural and durability properties of HPC and the life-cycle cost savings from implementing HPC into our nation’s transportation infrastructure. Included are HPC bridge applications from around the country and the latest evolving HPC designs employing the lessons learned from 20 years of bridge experiences. One such lesson is a universally accepted construction technique and curing practice to best utilize the properties HPC brings to the project. The presentation also highlights many resources for information on HPC technology, application, and practice, provided by industry and the FHWA.

About the Presenter:

Tony Kojundic is a founding Board member of the Silica Fume Association, and Business Manager for Elkem Materials in Pittsburgh, PA. The Silica Fume Association operates under a co-operative agreement with the FHWA to help provide ‘technology transfer’ on High-performance Concrete(HPC) to state and local transportation departments. He is active on numerous committees of the American Concrete Institute(ACI), the Transportation Research Board, the American Society of Testing and Materials, the National Concrete Bridge Council, and the Society of Petroleum Engineers. His ACI duties include secretary of the Silica-fume Concrete Subcommittee, and chapter author to the High-strength Concrete, Parking Structures, and Concrete Proportioning Committees. Through his employment at Elkem he’s been directly involved with silica-fume concrete research and implementation into project applications for the past 20 years. A 1975 graduate engineer from West Virginia University, Tony has published a dozen or so papers on high-performance, durable concrete and has spoken at numerous engineering and transportation conferences around the country.
Eleventh State-wide Conference on Local Bridges

Silica Fume High-performance Concrete in Bridge Applications

October 28, 2004
What is high-performance concrete?

• “HPC is a concrete in which certain characteristics are developed for a particular application and environment” - FHWA, *BridgeViews*, Issue, #1.
Examples of HPC

- Ease of placement.
- Compaction without segregation.
- Early-age strength.
- Long-term properties.
- Permeability
- Density
- Heat of hydration.
- Toughness
- Volume stability.
- Long-life.

http://www.fhwa.dot.gov/bridge/hpcwhat.htm
1999 National Bridge Inventory

- 585,000 US bridges, +210,000 are ‘deficient’.
- 7,623 (48.9%) of NY bridges.
- #1 repair area - bridge decks.
- $5 B/yr. dedicated for bridges.
Figure 4.1 Two-Stage Service Life Model Proposed by Tuutti (1982)
Ceramic: Particle Packing Theory

- 100% packing = 0% voids.
Concrete without silica fume ... with silica fume
Relative Reduction in Penetration Coefficients with Silica Fume (w/cm = 0.35)
FIGURE 5. A generalized relation between efficiency index and silica fume content of concrete.
Bridge Deck HPC Philosophy

- Implies using the least amount of cement possible!
- Judicious use of pozzolans.
  - Particle packing / reduced permeability.
  - ASR control.
  - Less water / less shrinkage.
  - Reduced heat of hydration.
  - Reduced cracking.
Typical HPC Proportions - Piles, Piers, Caps.

- **High Strength, HPC.**
  - Cement 624 pcy
  - Fly ash 120 cy (15%)
  - SF 56 pcy (7%)
  - w/cm 0.34
  - 1d 5000 psi
  - 28d 9000 psi
Hoover Dam Bypass - Box Girder Arch, 12,000psi HPC.
Deck Concrete Performance Goal

- Extended service life.
  - Reduce mortar permeability.
  - Reduce shrinkage or tendency to crack.
Extended Service Life

- **Reduce permeability.**
  - Particle packing and pozzolanic chemistry.

- **Reduced shrinkage and/or tendency to crack.**
  - Less water per volume (cubic yard) of concrete.
  - Lower cement content.
  - Greatest amount of aggregate.
  - Least amount of mortar.
  - Control evaporation.
Typical HPC Proportions - Bridge Decks.

- Low permeable, low cracking.
  - Cement 500 pcy
  - Fly ash 135 pcy (20%)
  - SF 40 pcy (6%)
  - w/cm 0.40
  - 28d 5000 psi
  - Perm. <1200 coulombs
## Bridge Deck Concrete Comparison

<table>
<thead>
<tr>
<th>Material</th>
<th>HPC vol</th>
<th>DOT AAA mix.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement, pcy</td>
<td>470</td>
<td>2.39</td>
</tr>
<tr>
<td>Fly ash, pcy</td>
<td>100</td>
<td>0.64</td>
</tr>
<tr>
<td>Silica fume, pcy</td>
<td>40</td>
<td>0.29</td>
</tr>
<tr>
<td>Water, gal</td>
<td>29.8</td>
<td>3.97</td>
</tr>
<tr>
<td>Total volume (&lt;27%)</td>
<td>7.29</td>
<td>9.05</td>
</tr>
<tr>
<td>w/cm</td>
<td>0.407</td>
<td>0.392</td>
</tr>
<tr>
<td>Crushed gravel, pcy</td>
<td>1770</td>
<td>1680</td>
</tr>
<tr>
<td>Natural sand, pcy</td>
<td>1190</td>
<td>993</td>
</tr>
<tr>
<td>Aggregate volume</td>
<td>17.96</td>
<td>16.20</td>
</tr>
<tr>
<td>Rapid Cl permeability</td>
<td>1200</td>
<td>2850</td>
</tr>
<tr>
<td>3d, psi</td>
<td>2760</td>
<td>3200</td>
</tr>
<tr>
<td>28d</td>
<td>5390</td>
<td>5160</td>
</tr>
</tbody>
</table>
Cohesive silica-fume concrete -- OK to increase slump
**Problem:** Concrete Surface Drying

If Evaporation > Bleeding $\Rightarrow$ Plastic Shrinkage Cracking
What is Plastic Shrinkage Cracking?

Cracking that occurs in the surface of fresh concrete soon after it is placed and while it is still plastic.

-- ACI 116R
Test Pours for ‘Never- evers’.

- Makes slump appear less.
- Silica-fume concrete does not bleed.
- Susceptible to plastic shrinkage cracking.
- Requires immediate evaporation protection.
- No delay in final finishing.
- Key to fast-track finishing.
- Document finishing plan.
“One-Pass” Finishing

• Under finish, over cure.

• Excessive hand finishing gains no advantage, and harms surface durability.

• Avoid tools that stick to the HPC surface.

Photos of placement
“One-Pass” Finishing.

- Steel bull floats and *Fresnos* work well.
- Curing requirements.
  - Wet cure begins 10-15 min. after placement for a minimum 7d.
  - Membrane cure after wet cure and texturing

Expedite placing, finishing, texturing and use immediate curing
Cracking Performance of HPC Bridge Decks - NY DOT
- TRB Paper No. 5B0121

- **Survey** - 84 bridges constructed between ‘95 and ‘98.
- **Class E concrete decks (‘95-’96).**
  - 60% transverse cracking.
  - 58% longitudinal cracking.
- **Class HP concrete decks ‘97-’98.**
  - 39% transverse cracking.
  - 33% longitudinal cracking.
- **The ‘98 decks** - 33% and 25% respective cracking.
- **55% of cracks appeared between 0 - 14 days.**
- **No difference steel and concrete bridge structures.**
FHWA - HPC Technology Delivery Program.

- **Innovative Bridge Research Program**
  - 240 projects, 61 HPC.

- **HPC - Technology Delivery Team**
  - [http://www.fhwa.dot.gov/bridge/hpc.htm](http://www.fhwa.dot.gov/bridge/hpc.htm)

- **Silica Fume Association.**
  - [www.silicafume.org](http://www.silicafume.org)
When the HPC Lead States Team closes its doors in September, our members and partners can look back on a five-year record of achievement. Since the AASHTO Lead States Team was established in 1996, HPC team members have documented the performance and strength advantages of HPC technology, primarily in bridge superstructures and substructures. We crafted a mission statement and developed a three-phased, 3-year program specific goals, strategies, and action plans. Our outreach initiatives included HPC Bridge Showcases, international symposia, conference and meeting presentations, and articles for various publications.

Implementation is the Foundation for Transition

The successes of the Lead States Team owe much to the tremendous cooperation of our public and private sector partners, including precast, prestressed concrete producers and trade associations, concrete suppliers, academic, the FHWA, and State DOT professionals. For example, in each State, there are Points of Contact (POCs) who champion HPC technology. One of the most valuable lessons learned is the importance of industry input. As a result, a majority of States now use conventional-strength HPC for bridge decks, almost half use high-strength HPC for girders, and others are using HPC for superstructures and substructures.

Technology plays an important role in publicizing our activities. The Team has established a website with up-to-date information on HPC technology, including project results and case histories. The Team has also established liaisons with the AASHTO, the AASHTO Subcommittee on Bridges and Structures, Materials, and Construction.

Funding sources for research into HPC permeability and resistance to chloride ion penetration must be identified.

Streamlined and open communication must be maintained with key industry, academic, and association partners to continue HPC implementation.

Research to confirm and promote the long-term benefits of HPC bridges and pavements must continue. The Team has already provided multiple test sites for the bridge lifecycle cost program developed by the National Institute of Standards and Technology.

The Future

Each Lead States Team member has contributed enthusiasm, insight, and hours of hard work. The future direction for the Team is not to retire the term high performance concrete and simply refer to concrete designed for the specific performance requirements.

FHWA - HPC Technology Delivery Program.

• National Concrete Bridge Council.
  – www.nationalconcretebridge.org

• HPC Bridge Views.

HPC LEAD STATES TEAM PLANS TRANSITION

When the HPC Lead States Team closes its doors in September, our members and partners can look back on a five-year record of achievement. Since the AASHTO Lead States Team was established in 1996, HPC team members have documented the performance and strength advantages of HPC technology, primarily in bridge superstructures and substructures. We crafted a mission statement and developed a three-phased, 3-year program specific goals, strategies, and action plans. Our outreach initiatives included HPC Bridge Showcases, international symposia, conference and meeting presentations, and articles for various publications.

Implementation is the Foundation for Transition

The successes of the Lead States Team owe much to the tremendous cooperation of our public and private sector partners, including precast, prestressed concrete producers and trade associations, concrete suppliers, academic, the FHWA, and State DOT professionals. For example, in each State, there are Points of Contact (POCs) who champion HPC technology. One of the most valuable lessons learned is the importance of industry input. As a result, a majority of States now use conventional-strength HPC for bridge decks, almost half use high-strength HPC for girders, and others are using HPC for superstructures and substructures.

Technology plays an important role in publicizing our activities. The Team has established a website with up-to-date information on HPC technology, including project results and case histories. The Team has also established liaisons with the AASHTO, the AASHTO Subcommittee on Bridges and Structures, Materials, and Construction.

Funding sources for research into HPC permeability and resistance to chloride ion penetration must be identified.

Streamlined and open communication must be maintained with key industry, academic, and association partners to continue HPC implementation.

Research to confirm and promote the long-term benefits of HPC bridges and pavements must continue. The Team has already provided multiple test sites for the bridge lifecycle cost program developed by the National Institute of Standards and Technology.

The Future

Each Lead States Team member has contributed enthusiasm, insight, and hours of hard work. The future direction for the Team is not to retire the term high performance concrete and simply refer to concrete designed for the specific performance requirements.

FHWA - HPC Technology Delivery Program.