VIRGINIA'S EXPERIENCE WITH HPC FOR BRIDGES

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Outline

- HPC
- Field applications
- Lessons learned

HPC

- Enhanced durability
- High strength
- High workability
- Low heat generation
- Crack control

More Durable Concrete!

- **Low permeability** resists infiltration of liquids
  – Water
  – Chlorides
  – Sulfates
- **Air entrainment** for resistance to freezing and thawing

Durability vs. High Strength

- High strengths may be simply a by-product of designing for low permeability
  – Supplementary cementitious materials
  – Binary, ternary systems
  – Low w/cm

Early HPC Use in Virginia

- Early efforts with supplementary cementitious materials
  – 1950s: fly ash in Louisa sidewalks
  – 1970s: Class F fly ash in bridge structures
  – 1980s: slag in Route 143 bridge over Hampton River
- Rapid chloride permeability test (1980s)
  – Verified that pozzolans and slag provide low permeability

LMC and Silica Fume

- Low permeability overlays
  - 1974: Latex-modified concrete (LMC)
  - 1980s: Silica fume

ASR Requirement

- 1992: maximum cement alkali content set at 0.40% (recently increased to 0.45%)
- If exceeded, pozzolans or slag are required
- Low permeability concrete obtained as a by-product, even at conventional w/cm ratios (0.40-0.45)

High Strength Concrete

- Reduce w/cm **below 0.40** to obtain high strength concretes (HSC)
  - 8,000 to 10,000 psi beams (w/cm around 0.30)

HPC Bridge Beams

- Route 40, 1995
- First specification of 8,000 psi concrete
- 1500 coulombs
- w/cm = 0.32

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Rte 40

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Curing

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HPC Bridge Beams

- Richlands, 1997
- First specification of 10,000 psi concrete
- 1,500 coulombs
- w/cm = 0.28

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Fibers

- To control cracking
  - 1970s: Steel fibers
  - 1990s: Synthetic fibers (8 to 9 lb/yd^3 structural fibers)

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Heat Control

- Mass concrete
  - Control maximum temperature
  - Control maximum temperature differential
  - Used 75% slag

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Lightweight HPC (LWHPC)

- Reduced dead load
- Low permeability
- Increased strain capacity
- Reduced elastic modulus
- Internal curing

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LWHPC

- 2001: Route 106 over the Chickahominy River.
- Beams: 8,000 psi, 1,500 coulombs
- Deck: 4,000 psi, 2,500 coulombs

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LWHPC

- Route 33 bridges over the Mattaponi and Pamunkey Rivers
  - Longer spans (145 ft simple span, or 240 ft with spliced girders)

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Self-Consolidating Concrete (SCC)

- 2001: Precast arch bridge
  – 5,000 psi, 2,500 coulomb

- 2005: 8 Bulb-T beams
  – 8,000 psi, 1,500 coulomb

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SCC Beams – Rte 33 (2005)

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Smooth Surface Finish

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Bugholes – Rte 33

SCC

Regular

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SCC Beams – Rte 33

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Lessons Learned - Partnership

- Agency-industry **partnership** is essential
  - Set achievable goals. Focus on incremental improvements rather than great leaps.
  - Try new materials and methods: need technology transfer.

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Lessons Learned - Cracking

- **Cracking** concern:
  - Avoid high-strength concrete if possible. It is more brittle than conventional concrete.
  - Cure properly: temperature and moisture control.
  - Replace cement with pozzolans or slag for slow early strength development and reduction in heat rise.

Lessons Learned - Cost

- **Cost!** Be patient. Benefits are there.
  - Initial cost may increase when using HPC
    - More expensive materials
    - Misconceptions and experimentation
  - BUT, HPC is more durable (longer lasting)
    - Would be cheaper based on life-cycle cost
- Cost analysis must include:
  - All phases of production (including labor)
  - Possible structural design considerations (i.e.: longer spans, smaller members/foundations)
- Competition will also lead to reduced costs.

Lessons Learned - QC

- **Quality control** becomes even more important with HPC
  - Test for the specific properties sought
  - Check sensitivity to variations in ingredients
- Determine in-place strength
  - temperature-matched curing
  - maturity method

Lessons Learned - Specifications

- Move from prescription-based **specifications** to end-result specifications (ERS) that
  - Address important properties
  - Permit innovation in:
    - Ingredients
    - Mixture proportions

Conclusions

- HPC = High workability, high strength, low permeability
- Much learning has taken place
  - Importance of industry partnerships
  - Focus on incremental improvements
  - Life-cycle cost analysis
  - Performance-based specifications
  - Enhanced quality control and testing
  - Improved construction practices

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