



# VIRGINIA'S EXPERIENCE WITH HPC FOR BRIDGES

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## Outline

- HPC
- Field applications
- Lessons learned



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## HPC

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



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### More Durable Concrete!

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



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### 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



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### 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



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## LMC and Silica Fume

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



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## 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)



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## 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)



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## 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<sup>3</sup> 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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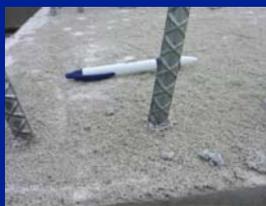
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## SCC Beams – Rte 33



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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.



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## 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.



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## 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



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## Lessons Learned - Specifications

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



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## 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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