Use of prepackaged ECC, VHPC, and UHPC in Bridge Structures

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Outline

• Introduction: High Performance Fiber Reinforced Concretes (HPFRC)
  – ECC, VHPC, UHPC
• Tests
• Prepackaged Materials
• Field Applications
• Conclusions
ECC, VHPC, UHPC

- ECC: engineered cementitious composite
- VHPC: very high-performance concrete
- UHPC: ultra high-performance concrete

<table>
<thead>
<tr>
<th>Concrete</th>
<th>Compressive Strength (psi)</th>
<th>Ductility</th>
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</thead>
<tbody>
<tr>
<td>ECC</td>
<td>4,000 at 7d</td>
<td>Y</td>
</tr>
<tr>
<td>VHPC</td>
<td>&gt; 11,500</td>
<td>Y</td>
</tr>
<tr>
<td>UHPC</td>
<td>&gt; 17,000</td>
<td>Y</td>
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</tbody>
</table>
Goal is Longevity! Build to Last!

CONCRETE IS DURABLE!
Pantheon: Roman concrete, 2,000 years old!
Year 1 002 020

Awesome stuff! I wish we had that on Mars.

Cast: 2020

Build it right! Keep it dry!
Infiltration into Concrete

• Water and solutions penetrate through poor quality concrete, joints, and cracks.

• Cause damage to reinforcement and concrete
Corrosion

- Corrosion is a major distress in reinforced concrete structures exposed to the environment.
Leaking Joints
Cracks

There are two kinds of concrete:
• One cracked
• One about to crack

Charlie Robson
Former VDOT State Materials Engineer
Crack Control with Fibers

• Synthetic fibers in low amounts, 1.5 lb/yd\(^3\) (0.1\% by volume) are used to minimize plastic shrinkage.

• Larger amounts of fibers up to 2\% needed for crack control in hardened concrete.
Fibers

• ECC
  - PVA fiber

• VHPC / UHPC
  - Steel fiber hooked end
  - OL fiber
Crack Control – FRC

- FRC: fiber-reinforced concrete
  - Improve tensile and flexural strengths
  - Increase ductility
- Keep crack width less than 0.1 mm. Crack widths ≥ 0.2 mm can be and should be sealed.
Tight Cracks (<0.1 mm)

ECC

UHPC
Tight Cracks
FRC

• Connections, short lap splices
Tests

- Compressive strength
  - Cube
  - Cylinder
- Flexural strength
- Splitting tensile strength
- Pull-out test
Tests

Cube Compressive Strength

Cylinder Compressive Strength
Flexural Test
Flexural Test

Deflection Hardening

Deflection Softening

No fiber
Tests

Splitting Tensile Strength

Pull-out
Pull-out Specimen
Typical pullout test graph
Prepackaged Materials

• Ingredients blended and stored in a bag or super sack
• Generally only water is added on site
• Fibers can be in the bags or added separately
• Expect quality and convenience
List of Prepackaged Material

• ECC: Three materials in VDOT SPEL (special products evaluation list).

• VHPC: Two materials in VDOT SPEL.
• UHPC: Three materials ready for inclusion in SPEL.

• Continuing evaluation of ECC, VHPC, and UHPC materials.
Mixing FRC

- FRC: Mortar mixers, RMC trucks

- HPFRC: efficient mixers

Fibers added manually
HPFRC - Mixing Small Amounts

- Dual paddle drill mixer

- Mortar mixer
HPFRC - Mixing Larger Amounts

Planetary mixer (UHPC)

Drum and mortar mixers (VHPC)
HPFRC Applications in VDOT

• ECC is also known as bendable concrete used in shear keys, closure pours, and culvert repairs.

• VHPC is used in block-outs.

• UHPC is used in beams. It can meet VHPC requirements at early ages.
ECC, Kents Store - 2019
ECC Test Results

7-day flexural strength
VHPC Applications

Block-outs in new construction or repair projects
VHPC, Sperryville - 2019
VHPC Test Results

7-day flexural strength with hooked-end steel fiber
UHPC - Route 624 - 2007
Flexural Strength

4-in-thick beams at 2 months
New UHPC - 2019

Prepackaged material
Planetary mixer
28-d compressive strength ≥ 17,000 psi
Flexural Strength – New UHPC

28d flexural strength
Conclusions

• Fibers in concrete can reduce the width and length of cracks and shorten the lap splices.
• The type and amount of fibers are important in crack control.
• Concretes with high amounts of PVA or steel fibers can achieve crack widths of less than 0.1 mm.
• Prepackaged materials are available to control cracks and provide short lap splices.
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