Repair of Metal Culverts Using ECC “Bendable Concrete”

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Outline

• Corrugated metal pipes
• Repairs
• Invert Lining: engineered cementitious composite (ECC)
  ➢ Laboratory investigation
  ➢ Field investigation
Culvert

Corrugated metal pipe (CMP) culverts made of galvanized steel are subject to abrasion and corrosion.
Existing Repair Methods

**Slip-lining**
That involves inserting a pipe liner of smaller diameter directly into a deteriorated culvert

**Cured-in-place pipe liner**
That involves the insertion of a felt or fiber tube saturated with resin (ASTM F1216)
Existing Repair Methods

- Spin casting: spraying cementitious material to cover the inside
- Invert lining: repairs the most worn part; the bottom part that sees water. Usually 4 inch thick concrete with a wire mesh at the middle
Concerns

- Decrease in cross-sectional area; reduced flow quantity
- Harmful chemicals
- Cost
Invert Lining with ECC

- Engineered cementitious composite (ECC)
- Thickness (≤ 1”)
- Reinforcement
  - PVA Fibers in ECC
  - Geogrid (PVA, PP)
ECC

Slump flow ranged from 18 to 21 inches
## Typical ECC Mixture (lb/yd$^3$)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland cement (I/II)</td>
<td>961</td>
</tr>
<tr>
<td>Fly ash</td>
<td>1153</td>
</tr>
<tr>
<td>Water</td>
<td>571</td>
</tr>
<tr>
<td>Air</td>
<td>2%</td>
</tr>
<tr>
<td>Mortar sand*</td>
<td>676</td>
</tr>
<tr>
<td>Fibers (PVA)</td>
<td>33 to 44 (1.5 to 2%)</td>
</tr>
<tr>
<td>w/c</td>
<td>0.27</td>
</tr>
</tbody>
</table>

*Also concrete sand; admixture: HRWRA*
ECC in Shear Keys

Route 645, 2013
ECC in Shear Keys

Route 645, 2013

After 3 months, only ECC did not leak
I-64 over Dunlap Creek, 2014

Closure Pours
ECC in Closure Pours, I-64

Self consolidating
ECC
Flexure Test - Deflection Hardening ECC
ECC

Deflection

Tight cracks
(<0.1 mm)
Initial Mixtures

• 15 mixtures, 14 in the laboratory and 1 in RMC truck
• Same cement and fly ash contents
• w/cm
  ➢ B1-B13: 0.27
  ➢ B14: 0.30
  ➢ B15: 0.25
• Mortar or concrete sand
• PVA at 1.8% and 1.5% by volume
• Admixtures: HRWRA, hydration controlling, VMA, workability retaining
Compressive Strength

7-day flexural (first peak) strength ranged from 632-1095 psi
Permeability

- First two laboratory batches: 330 and 237 coulombs
- Batch at the Culpeper plant: 117 coulombs.
Flexural Test Data

![Graph showing force vs. deflection for two fiber content levels (1.8% and 1.5%)](image-url)
Geogrid and Spacers
Laboratory Investigation
Culpeper District

Planning to repair a 60-ft long pipe.

A trial at the District Office:

• 1.8% PVA Fiber (40 lb/yd$^3$)
• Admixtures: HRWR, workability-retaining, hydration controlling, and viscosity-modifying (VMA).
• Concerns:
  ➢ concrete was flowing down on the sides.
  ➢ mixture was still plastic until next morning.
ECC in Truck
Culpeper District
Lynchburg District

✓ A trial to repair 6 feet section of 70-ft long culvert south of Farmville
  • Two 2 ft$^3$ of concrete made in the mortar mixer
  • 1.8% PVA Fiber (40 lb/yd$^3$)
  • Admixtures: HRWR, Workability-Retaining Admixture
Culvert with Asphalt Coating
Mixing and Placement

Mortar Mixer

Manual Placement
Flowing Down on the Sides
Completed 6-ft Repair
Trials for Field Placement of ECC

- Manual placement would not be practical
- Pumping methods were investigated:

Piston type and Rotary type pumps
Trials for Field Placement of ECC

- Pump clogging with 1.8% of fiber in the mix
- Spraying of ECC with 1.4% fibers using rotary pump

Larger pump with larger hose would make spraying much easier
Invert Repair in Farmville (11-28-2017)

• 70-ft long culvert was repaired with 2 cubic yards of ECC (with 1.4% PVA fibers) prepared in truck
• Trailer pump with more horsepower and larger hose diameter
Trailer Pump with Nozzle

For enhanced spraying:
• High slump flow
• Reduced fiber amount (1.4%)
• HRWRA and workability retaining admixture
• Concern:
  ➢ Wet mix caused flowing down on the sides
Spraying ECC
Finished Repair

The 1d and 7d compressive strength were 3250 and 4490 psi, respectively.
ECC – 5 weeks after
Conclusions

- ECC can be prepared with locally available materials including mortar or concrete sand
- Mortar mixer and RMC trucks both can be used for mixing ECC
- ECC is self-consolidating
- ECC shows deflection hardening
- ECC can be applied at thicknesses of less than 1 inch with embedded geogrid
- ECC is easily sprayed with a trailer pump
- ECC provides good bonding with metal
Thank You.