

# 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 ( $\leq 1''$ )
- Reinforcement
  - PVA Fibers in ECC
  - Geogrid (PVA, PP)



# ECC



Slump flow ranged from 18 to 21 inches



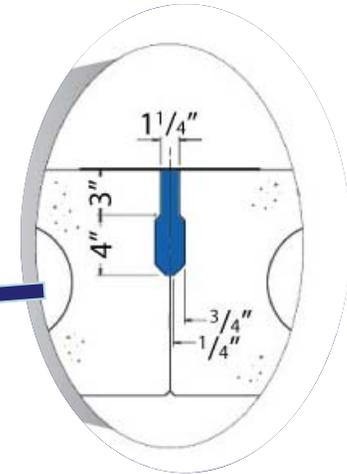
# Typical ECC Mixture (lb/yd<sup>3</sup>)

Portland cement (I/II)	961
Fly ash	1153
Water	571
Air	2%
Mortar sand*	676
Fibers(PVA)	33 to 44 (1.5 to 2%)
w/c	0.27

\*Also concrete sand; admixture: HRWRA



# ECC in Shear Keys



Route 645, 2013



# ECC in Shear Keys

Route 645, 2013

**Non-shrink grout**



**UHPC**



**ECC with PVA fibers**



**After 3 months, only ECC did not leak**



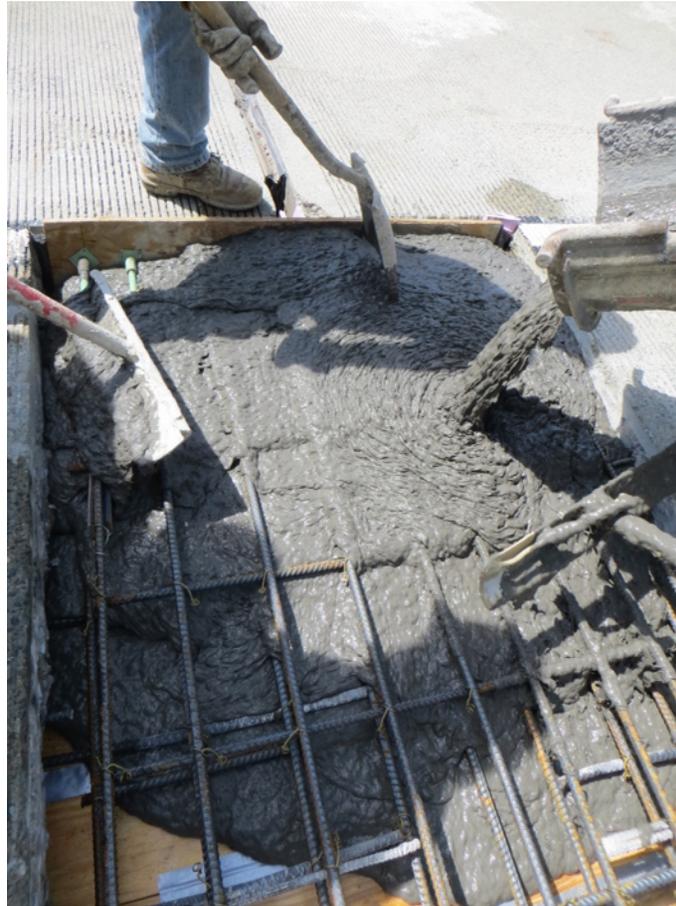
# I-64 over Dunlap Creek, 2014



Closure Pours



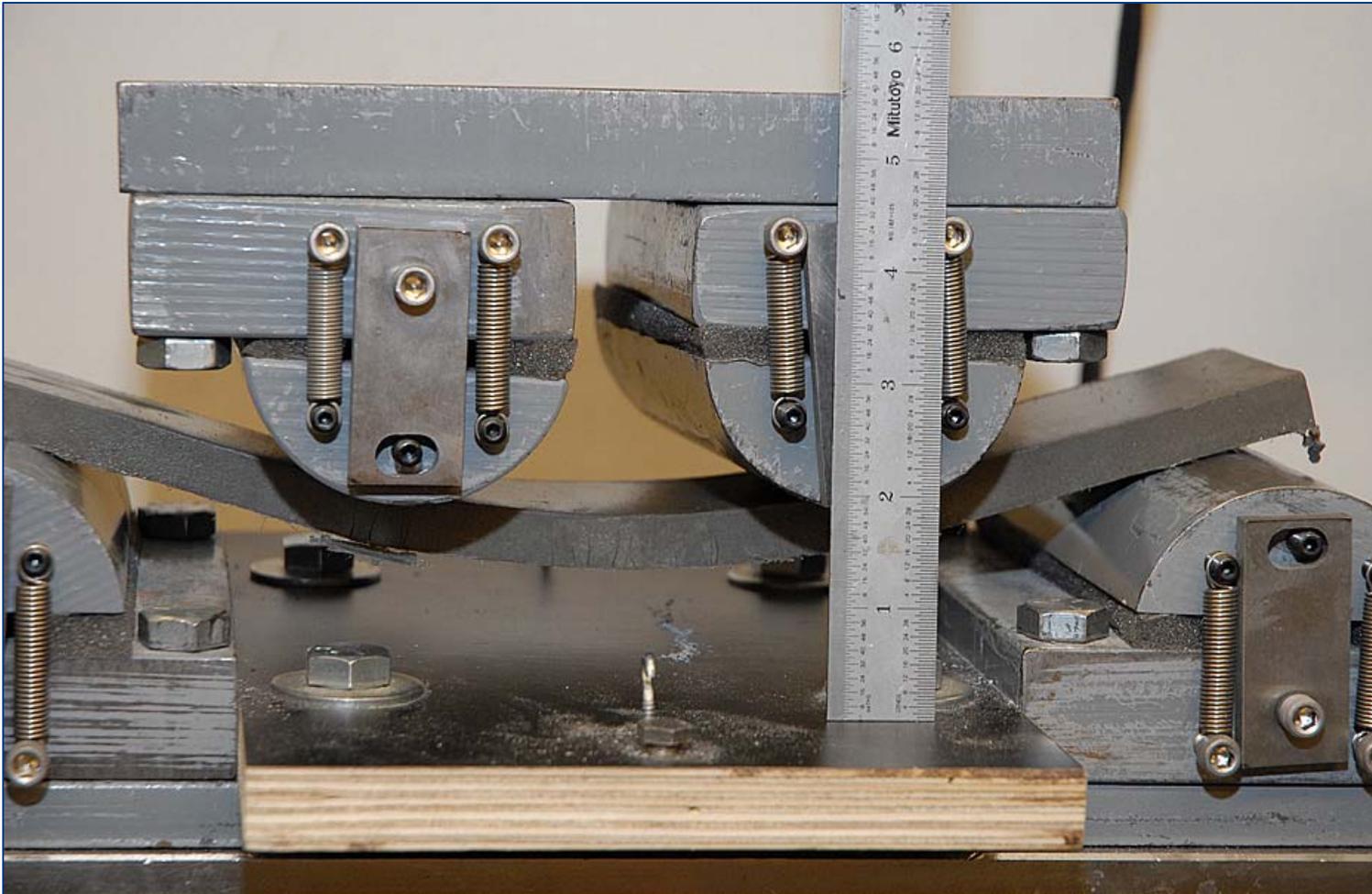
# ECC in Closure Pours, I-64



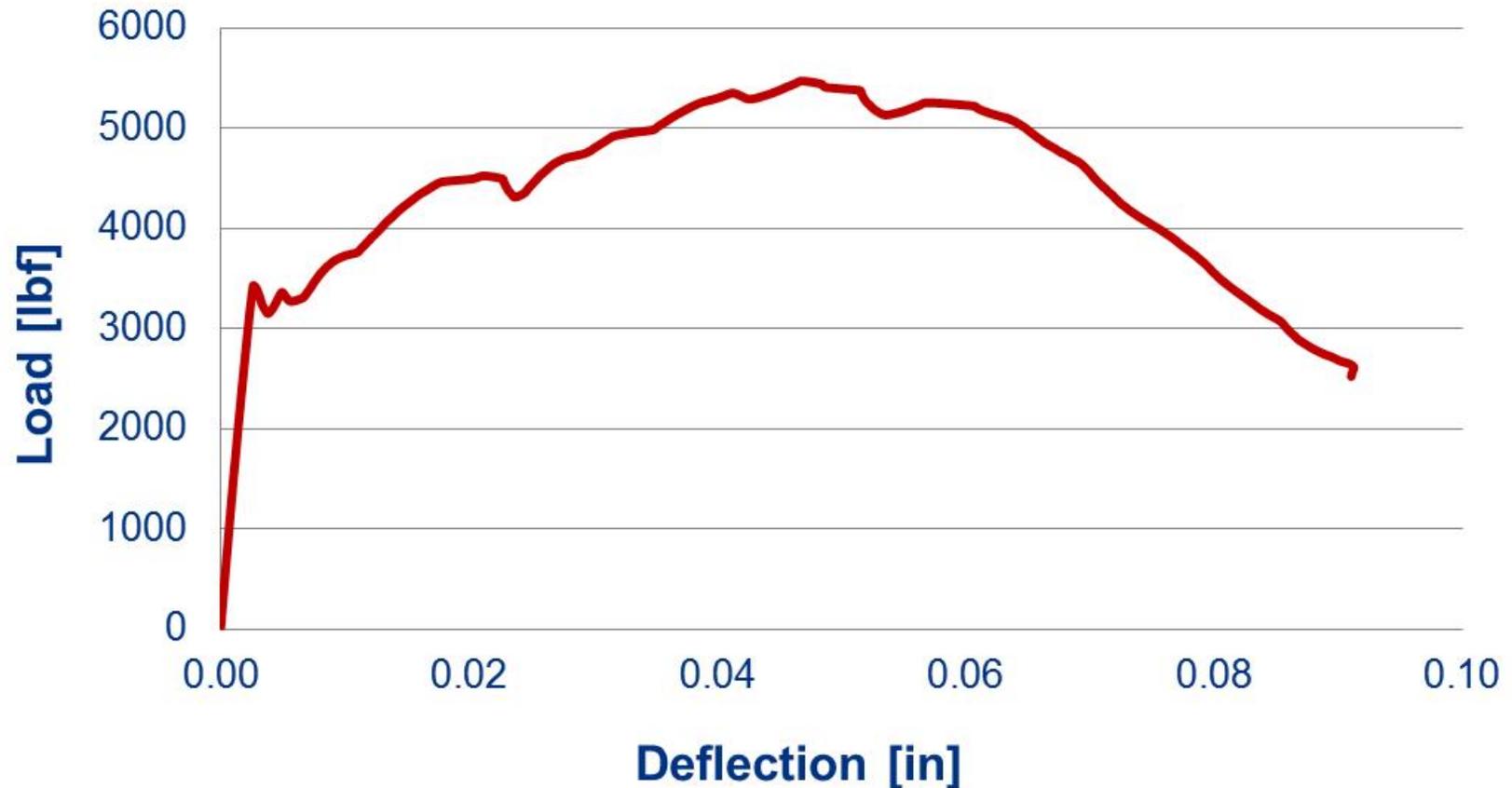
Self consolidating



# ECC



# Flexure Test - Deflection Hardening ECC



# ECC

## Deflection



## Tight cracks (<0.1 mm)

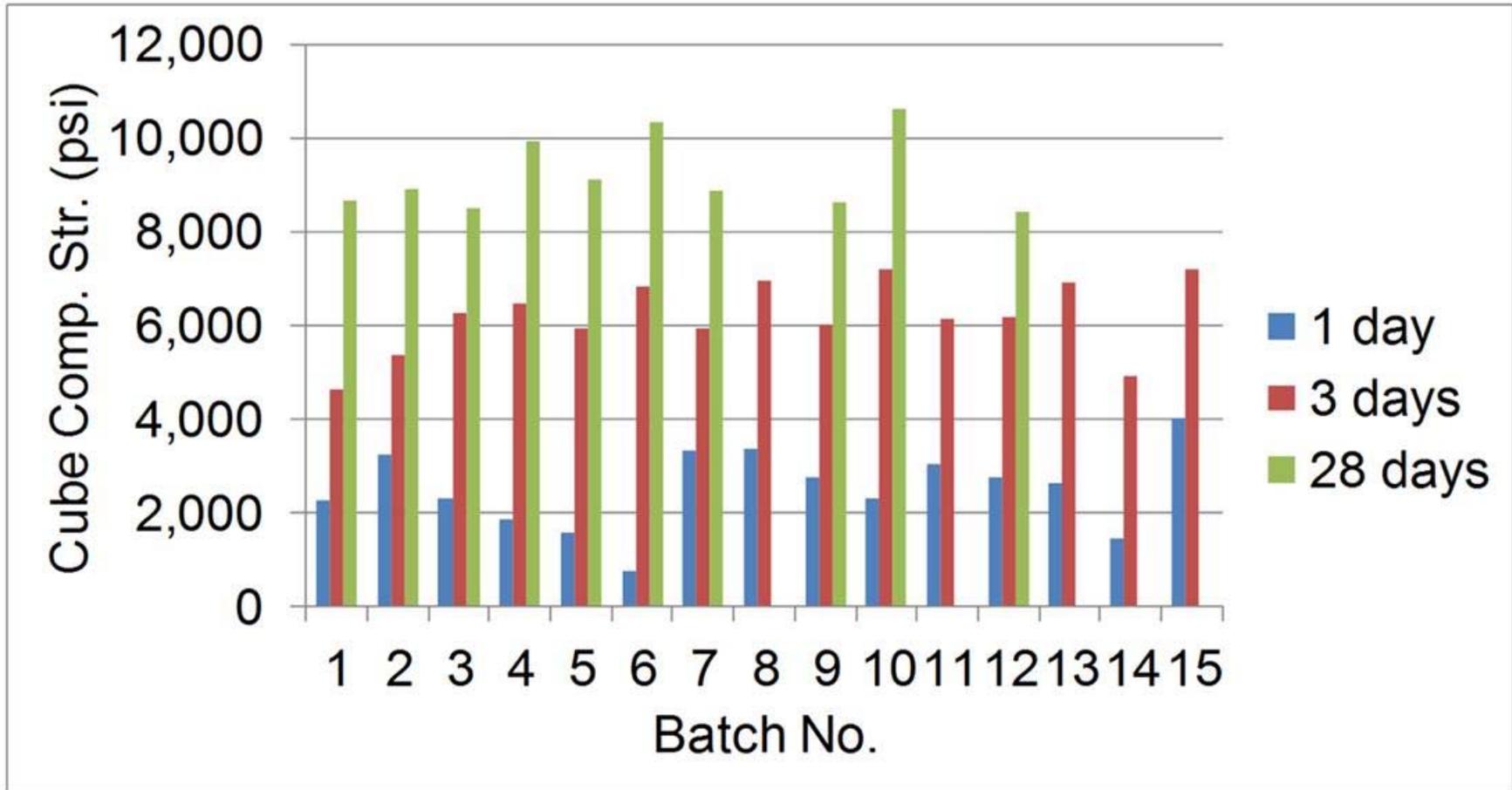


# Initial Mixtures

- 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

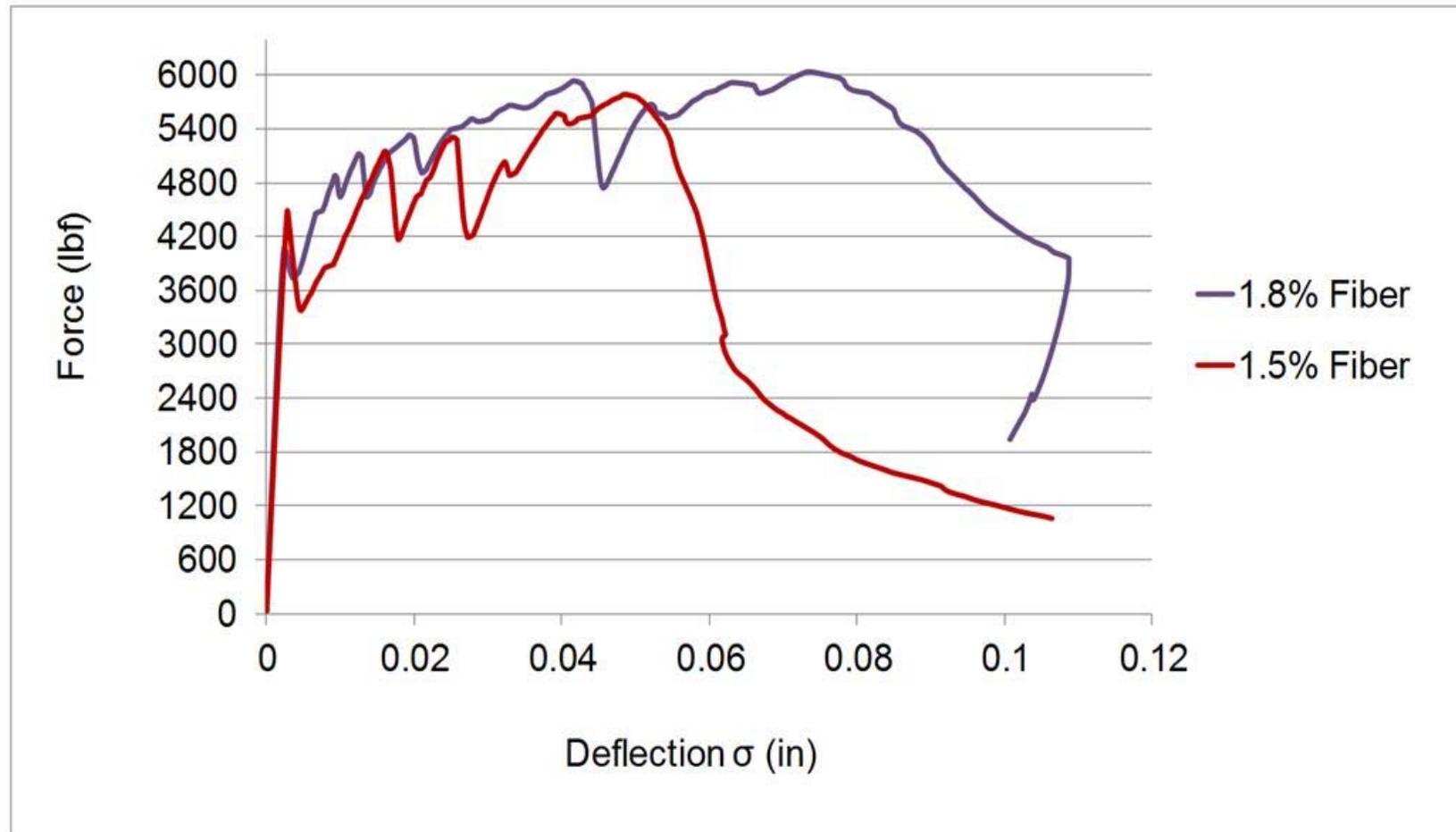


# Permeability

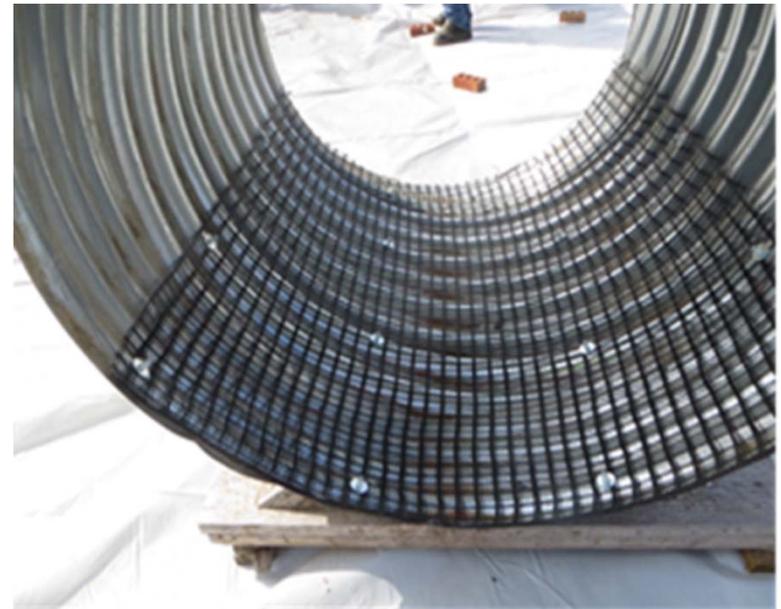
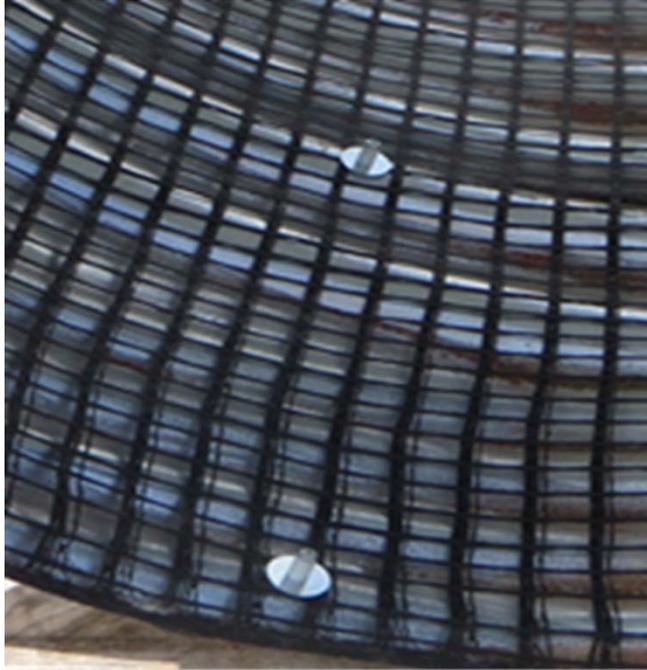
- First two laboratory batches: 330 and 237 coulombs
- Batch at the Culpeper plant: 117 coulombs.



# Flexural Test Data



# 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<sup>3</sup>)
- 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<sup>3</sup> of concrete made in the mortar mixer
- 1.8% PVA Fiber (40 lb/yd<sup>3</sup>)
- 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





*We bring innovation to transportation.*

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**Thank You.**

