Geopolymer Lining Rehabs
Colorado DOT
Large-Diameter Culvert

Joe Royer, PhD – Milliken Infrastructure – joe.royer@milliken.com
Collis Parrish – IPR – cparrish@teamipr.com
What is a Geopolymer?

Not a Plastic
- Not HDPE/PVC/Epoxy

Looks and feels like cement
- Workability
- Material Properties
- Service Life

Chemical structure like natural stone
- Monolithic
- Durable
- Corrosion Resistant
Geopolymer Chemistry Primer

Typical Hydrated OPC Structure

Typical Geopolymer Structure
Spray-Applied Geopolymer Technology
Colorado DOT – Project Overview

- Colorado DOT - Special Provision 603 “Spray Applied Culvert Linings”
  - Project included 7 individual pipes spread across 3 counties in central Colorado (Region 2)
    - Jefferson
    - Douglas
    - Arapahoe

- Federal Aided Project Funding
Why Rehabilitate

**Issues**
- Significant CMP corrosion
- Spaulding / Steel Loss
- Abrasion

**Why no Dig?**
- Major highways/Interstates
- Fully Structural Rehab
Why Spray Applied Liners

CIPP
• Several short runs
• Higher Costs
• Difficult sizes and access
• Larger footprint

Sliplining
• Non-round damage
• Reduced diameter
Colorado DOT – Project Overview

Summary of Specific Pipes:

1) 524 linear ft of 60” CMP - Hwy 70
2) 252 linear ft of 50” CMP - Hwy 391
3) 191 linear ft of 48” CMP - Hwy 121
4) 534 linear ft of 48” CMP - Hwy 83
5) 374 linear ft of 60” CMP - Hwy 6
6) 375 linear ft of 48” CMP - Hwy 6
7) 124 linear ft of 6’ x 7’ Box Culvert - Hwy 105

Contractors were required to be prequalified
Lining products were required to be listed on the CDOT Approved Products List
Colorado DOT – Project Timeline

Project Bid in March 2016

Contract was Awarded May 2016

Construction began July 2016

Construction took approximately 6 Week with 2 crews working on the different pipes typically 2 sites were under construction at a time.

<table>
<thead>
<tr>
<th>Contractor</th>
<th>Total Bid</th>
<th>% of Engineering Estimate</th>
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<tr>
<td>Inland Pipe (IPR)</td>
<td>$954,008.00</td>
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Engineering Estimate: $1,170,995.70
Design

The design methodology uses the bending moment at the crown of the pipe and conservative assumptions, verified by actual pipe testing:

\[ t = \sqrt{\frac{0.0744 \cdot P \cdot r^2 \cdot N}{S_F \cdot C}} \]

Source - Structural Mechanics of Buried Pipes - Watkins & Anderson
Design

• All CMP pipes were designed to be “Stand-Alone” Fully Structural Liners:

• 48” pipes had a 1” thickness based on the design conditions

• Pipes between 50” - 60” required a 1.5” thickness based on design conditions

• The box structure was designed as a “Structural Enhancement” with a 1.5” liner and replacing corroded steel to return structure to its original service condition.
Examples of Site Conditions
Examples of Site Conditions
Examples of Site Conditions
Example of Contract Details

NOTES:
1) SEE GENERAL NOTES FOR EQUIPMENT AND MATERIAL STORAGE LIMITATIONS
2) NO WORK SHALL BEGIN UNTIL THE CONTRACTOR NOTIFIES THE PROJECT ENGINEER.
3) THE CONTRACTOR SHALL NOT INTERFERE WITH TRAVEL LANES OF TRAFFIC.
4) PRIOR TO CONSTRUCTION, THE CONTRACTOR WILL VERIFY LIMITS OF DISTURBED AREA WITH THE PROJECT ENGINEER AND CLEARLY MARK.
5) SPRAY LINER APPLICATION METHODS & MATERIALS MUST MEET MANUFACTURER SPECIFICATIONS AT ALL TIMES.
6) ANY DEWATERING SCHEDULED AND CONDUCTED BY THE CONTRACTOR PRIOR TO AND DURING THE WORK SHALL BE TO THE SATISFACTION OF THE ENGINEER. DEWATERING PLAN MUST BE SUBMITTED FOR APPROVAL BY ENGINEER.
7) THE CONTRACTOR SHALL CLEAN THE ENTIRE INTERIOR SURFACE TO BE REPAIRED WITH HIGH PRESSURE WATER JET AND/OR WET SAND BLASTING, AND THE SURFACE SHALL BE FREE OF RUST FLAKES TO THE SATISFACTION OF THE ENGINEER.
8) NO WATER WILL BE ALLOWED TO FLOW THROUGH THE CULVERT UNTIL THE MANUFACTURER’S SPECIFICATIONS ARE FULLY MET FOR CURING TIME/CONDITION.
9) FINISHED LINING MUST HAVE A MANNING’S N (ROUGHNESS) COEFFICIENT OF LESS THAN OR EQUAL TO 0.024 AND REDUCE THE INTERIOR DIAMETER NO MORE THAN 6 INCHES MEASURED FROM THE EXISTING PIPE INTERIOR SURFACE TO THE PROPOSED SPRAY LINING FINISHED SURFACE. (NO MORE THAN 3 INCH INTERIOR RADIUS LOSS)
10) SPRAY LINING WILL BE APPLIED TO A THICKNESS RECOMMENDED BY THE MANUFACTURER IN ORDER TO ACHIEVE THE PERFORMANCE SPECIFICATIONS.
11) THE WILLOW CREEK TRAIL AND THE CENTENNIAL TRAIL SHALL REMAIN OPEN AT ALL TIMES AND CONSTRUCTION ACTIVITIES SHALL NOT CAUSE ANY TRAIL TRAFFIC DELAYS OR HAZARDS.
Pipe Conditions:
Pipe Conditions:
Pipe Conditions:
Box Pipe Conditions
Equipment Set Up
Spraying Hand/Sled
Equipment Set Up
Completed Pipes
Completed Pipes
Box Culvert Lining – Handlining
Quality Control

Sample Details

- Date Cast: 5/6/2015
- No. of Specimens: 6
- Slump: 1" Admixtures: -
- Air Content: - Water: -
- Design Strength: - Supplier: IPI
- Material Temperature: 63.0° Ticket Number: -
- Ambient Temperature: 63.0° Technician: MC
- Location: -

Laboratory Test Results

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<th>Set ID</th>
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<th>Age (Days)</th>
<th>Length</th>
<th>Surface Area</th>
<th>Load (lb)</th>
<th>Strength (psi)</th>
<th>Density (pcf)</th>
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Notes

- Samples Initial G cruciform were taken at each type of fracture in laboratory SPURH storage
- Type 1 Type 2 Type 3 Type 4 Type 5

Distributor

- Troy Shinn

- Lab Technician: Elizabeth Butler Date: 6/20/2015
- Project Manager: Jack Parisi Date: 6/20/2015

Designation: C804/C345M - 12a

Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

1. Scope

   1.1 This test method covers determination of compressive strength of cylindrical concrete specimens such as molded cylinders and drilled cores. It is limited to concrete having a density of an excess of 800 kg/m³ (50 psf). 1.2 The values stated in either SI units or inch-pound units are to be regarded as standard. The inch-pound units are shown in brackets. The values stated in such system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in非有效的 results.

   1.3 The standard does not purport to address all the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Summary of Test Method

   2.1 This test method consists of applying a compressive load to a cylindrical or drilled core or core in a manner that is in accordance with the procedure specified in this test method. The compressive strength of the specimens is calculated by dividing the maximum load observed during the test by the cross-sectional area of the specimens.

3. Referred Documents

   3.1 ASTM Standards:

   3.1.1 C192M/C192M-13 Practice for Making and Curing Concrete Test Specimens in the Laboratory

   3.1.2 C424M/C424M-12 Test Method for Obtaining and Testing Drilled Cored and Sawed Beams of Concrete

4. Significance and Use

   4.1 This test method is used to determine compressive strength of cylindrical concrete specimans prepared and used in accordance with Practice C192M/C192M-13, C424M/C424M-12, and C2242M/C2242M-12 and Test Methods C424M and C424M-12.

   4.2 The results of this test method are used as a basis for quality control of concrete proportioning, mixing, and placing.
6-months in Service
Questions?