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Geopolymer Lining Rehabs Colorado DOT Large-Diameter Culvert

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MILLIKEN INFRASTRUCTURE
A Milliken COMPANY

IPR

What is a Geopolymer?

Not a Plastic

- Not HDPE/PVC/Epoxy

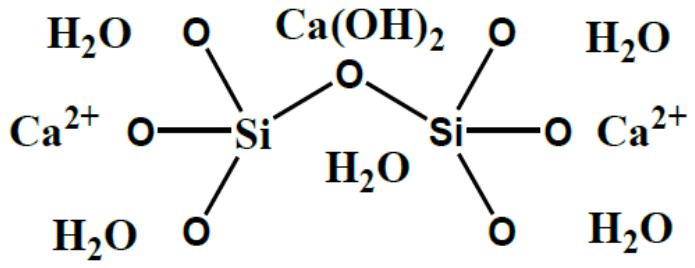
Looks and feels like cement

- Workability
- Material Properties
- Service Life

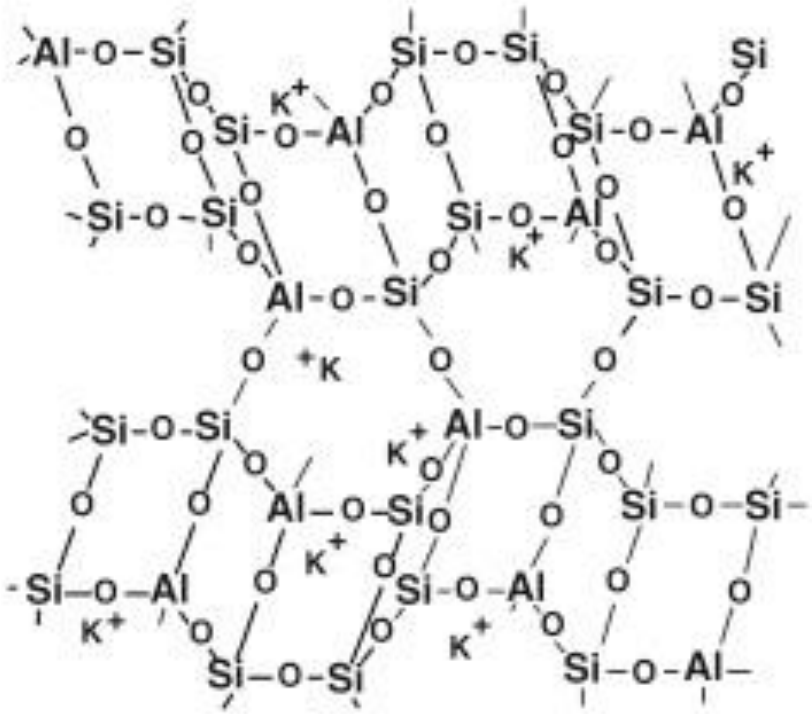
Chemical structure like natural stone

- Monolithic
- Durable
- Corrosion Resistant

Geopolymer Chemistry Primer

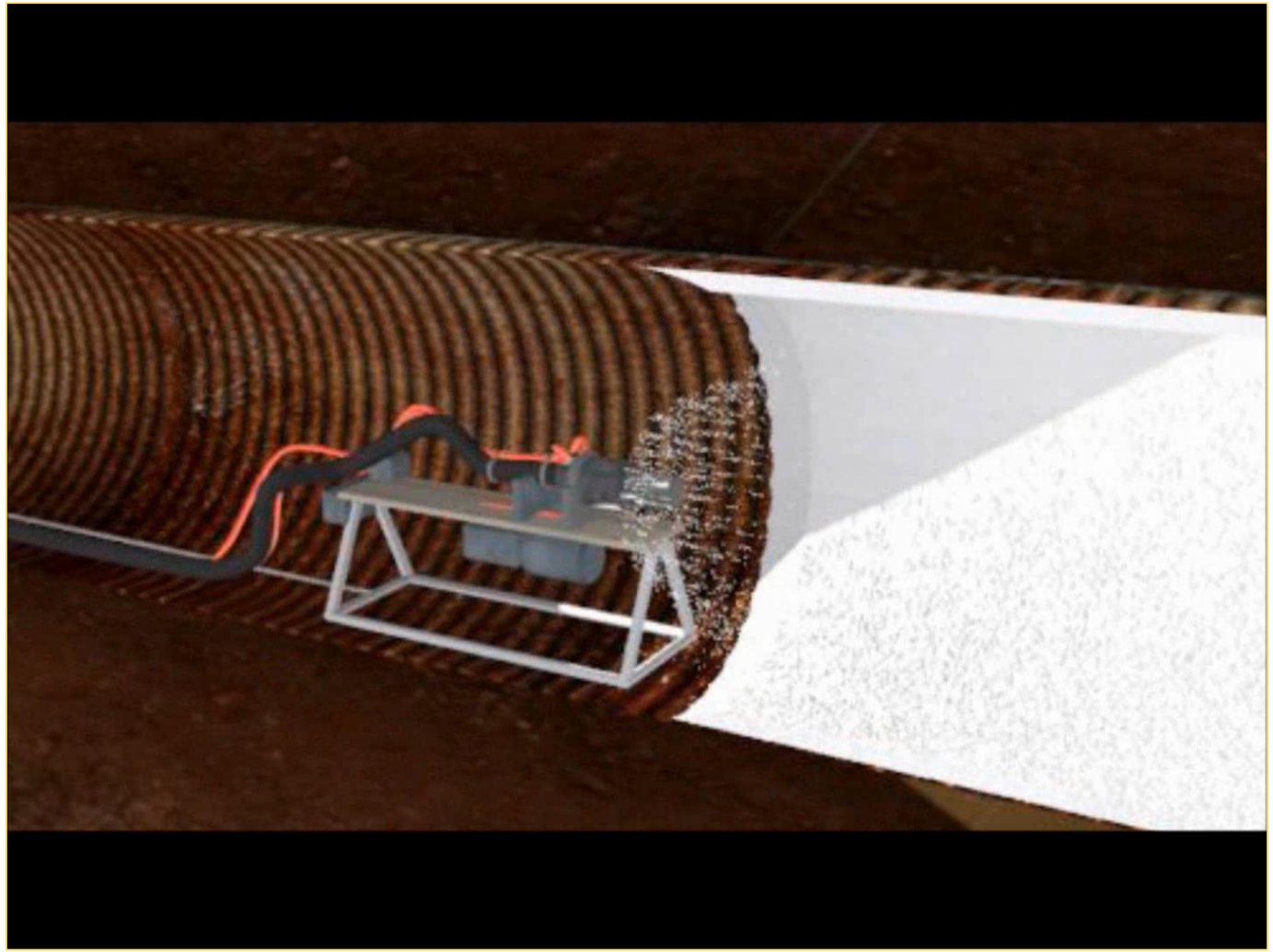


Typical Hydrated OPC Structure



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
  - Dougal
  - Arapahoe

- Federal Aided Project Funding

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REVISION OF SECTION 603
SPRAY APPLIED CULVERT LINING

Section 603 of the Standard Specifications is hereby revised for this project as follows:
Subsection 603.01 shall include the following:
This work consists of placing spray applied liner in an existing culvert in accordance with manufacturer's recommendations, requirements, design, and the plans. This specification applies to all sections (round, elliptical, rectangular, etc) of culverts.

Subsection 603.02:
The spray liner shall not reduce the total existing culvert pipe interior effective interior radius by more than 6 inches or as stated on the drawings, and shall have a finished surface manning's roughness coefficient of 0.024 or less. The spray applied liner shall not contain styrene or any leachable toxins. The spray applied liner shall be high strength and ultra-low porosity. Spray applied liner thickness will be determined by the manufacturer's specification in order to achieve the minimum warrantied performance characteristics. The liner shall be selected from the options listed in the CDOT approved products list. (APL)

Subsection 603.03 shall include the following:

Prior to installing the liner, the Contractor shall dewater the pipe and remove all loose rock, dirt, and debris from both the inlet and outlet of the culvert, and fill any voids in the area adjacent to the pipe with grout. Grout shall be an approved material that meets manufacturer's recommendation for this installation. The grout shall be placed through existing holes in the pipe or tool cut openings upon approval from the project engineer. The Contractor shall thoroughly clean the pipe, and remove all sharp protrusions from the inlet and outlet that may potentially reduce the homogeneity or performance of the liner.

The Contractor shall make all necessary arrangements to have a representative of the manufacturer on site to ensure the proper preparation of materials and installation of the culvert liner. A manufacturer's letter of compliance shall be provided to the PE ensuring certification and verification of the correctly installed product by the manufacturer. Design Calculations and Lift (installation) Plan stamped by a Colorado Licensed Professional Engineer.

The contractor will provide no less than one (1), half inch (1/2") wide hole drilled through the finished liner to the interior of the host pipe surface, perpendicular to the host pipe interior surface, in the pipe crown ('top'), if the host pipe is CMP, this will be on the most interior ridge of a corrugation, for liner thickness verification, per every 25' of lined pipe, at locations randomly selected by the PE or Inspector who may or may not elect to do so. The hole will be re-drilled until the interior ridge of the CMP is located. Following the PE or Inspector liner thickness measurement, the contractor will then patch the holes with the liner material or manufacturer accepted patch method. This shall not be paid for separately but shall be included in the cost of the work. This process must be explained and detailed in the contractor's method statement.

Subsection 603.11 shall include the following:
Culvert liner will be measured by the actual number of linear feet that is installed and accepted. Culvert lining will be measured by the foot along the bottom (invert) centerline of the culvert.

Subsection 603.11 shall include the following:

Pay Item	Item Number	Pay Unit
Culvert Lining (36 Inch)(Spray Applied)	603-00045	Linear Feet
Culvert Lining (48 Inch)(Spray Applied)	603-00052	Linear Feet
Culvert Lining (54 Inch)(Spray Applied)	603-00058	Linear Feet
Culvert Lining (60 Inch)(Spray Applied)	603-00065	Linear Feet
Culvert Lining (84 Inch)(Spray Applied)	603-00088	Linear Feet

Payment will be full compensation for all labor, materials, and equipment required to complete the work.
All costs associated with having a manufacturer's representative on site will not be measured and paid for separately, but shall be included in the work. Grout and dewatering will not be measured and paid for separately, but shall be included in the work.

Why Rehabilitate

Issues

- Significant CMP corrosion
- Spaulding / Steel Loss
- Abrasion

Why no Dig?

- Major highways/Interstates
- Fully Structural Rehab

Why Spray Applied Liners

CIPP

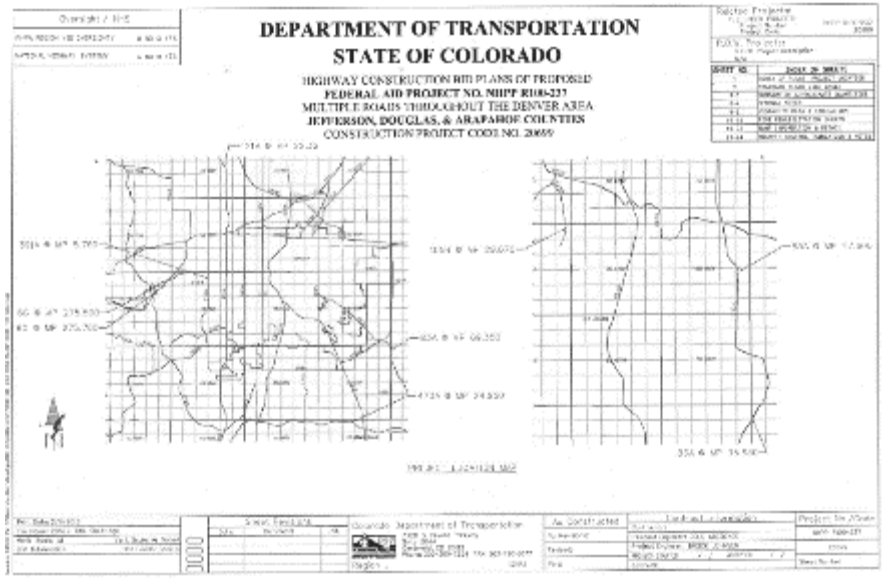
- Several short runs
- Higher Costs
- Difficult sizes and access
- Larger footprint

Sliplining

- Non-round damage
- Reduced diameter

Colorado DOT – Project Overview

Summary of Specific Pipes:


DEPARTMENT OF TRANSPORTATION
STATE OF COLORADO
HIGHWAY CONSTRUCTION BID PLANS OF PROPOSED
FEDERAL AID PROJECT NO. NHPP R100-237
MULTIPLE ROADS THROUGHOUT THE DENVER AREA
JEFFERSON, DOUGLAS, & ARAPAHOE COUNTIES
CONSTRUCTION PROJECT CODE NO. 20659

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

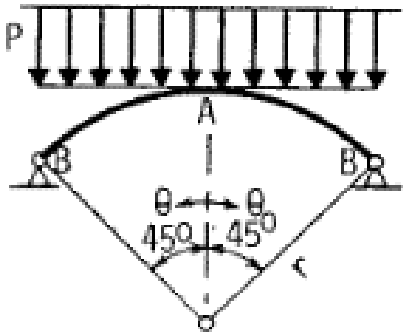
Construction took approximately 6 Week with 2 crews working on the different pipes typically 2 sites were under construction at a time.

Engineering Estimate:	$1,170,995.70

Contractor	Total Bid	% of Engineering Estimate
Inland Pipe (IPR)	$ 954,008.00	81.47%

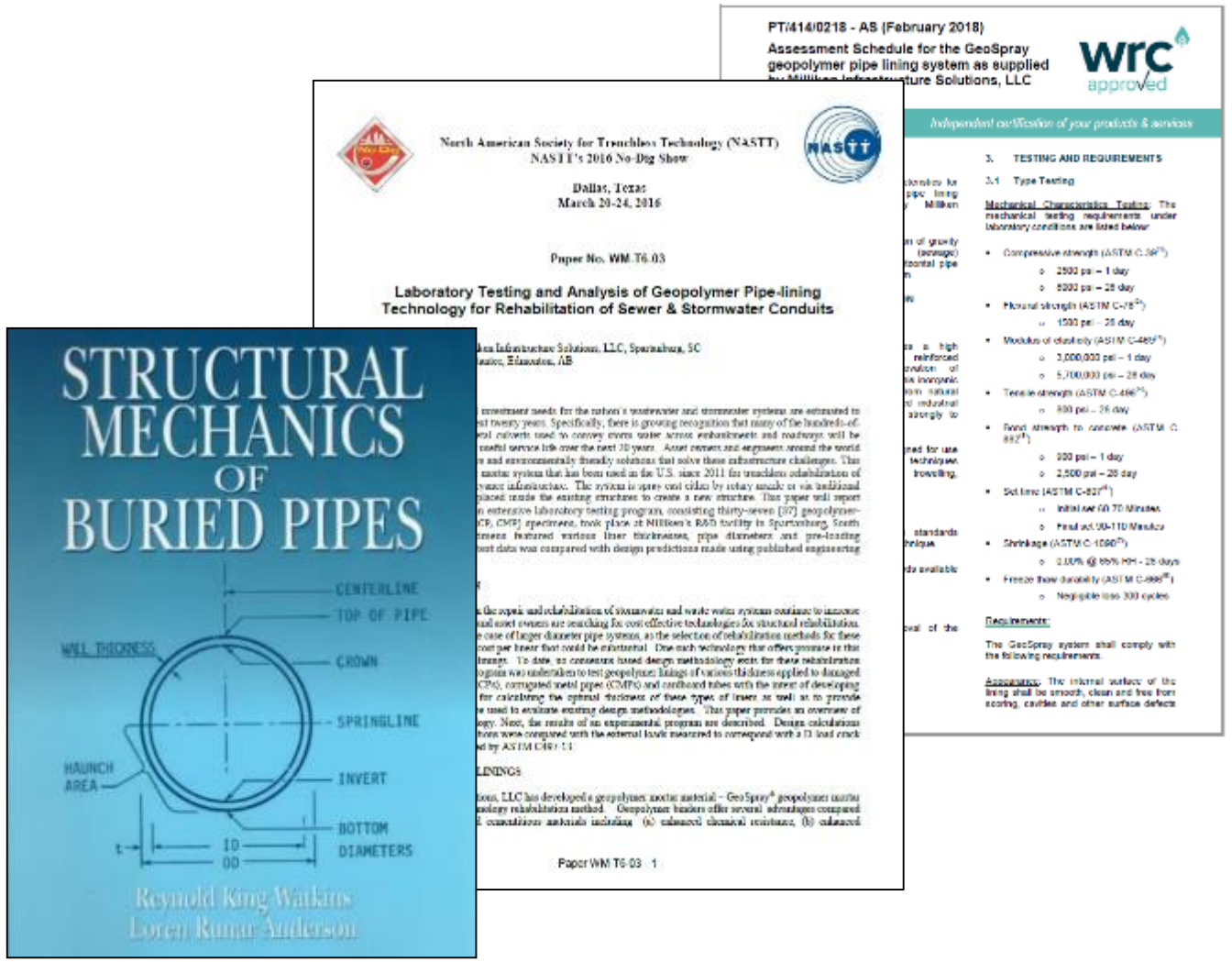
Design

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



$$T_A = 0.8323Pr$$
$$M_A = 0.0062Pr^2$$

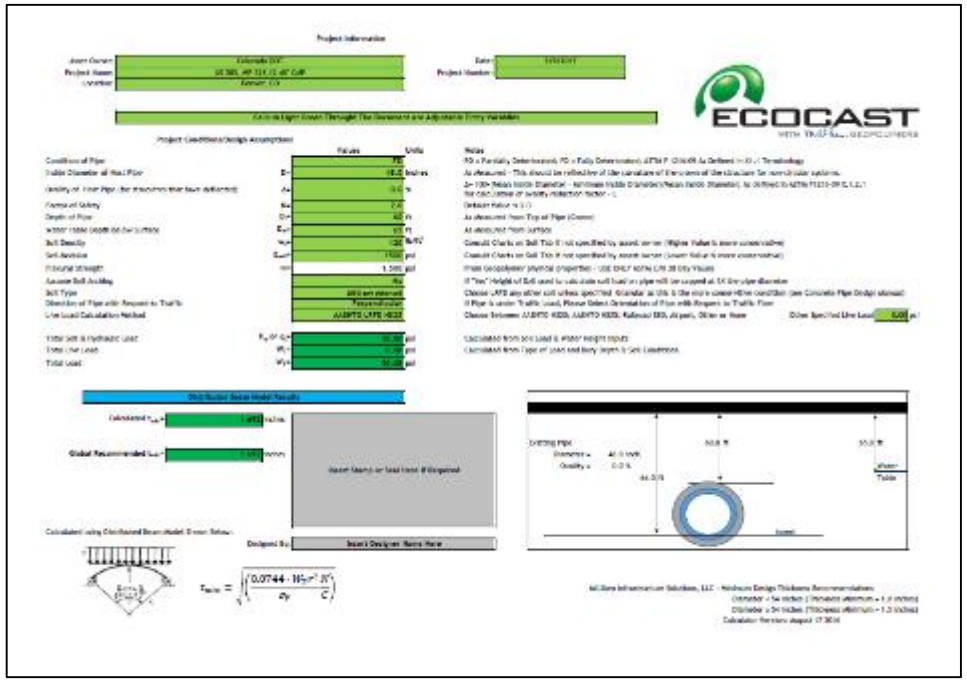
$$t = \sqrt{\frac{0.0744\,P\,r^2}{S_F}\frac{N}{C}}$$



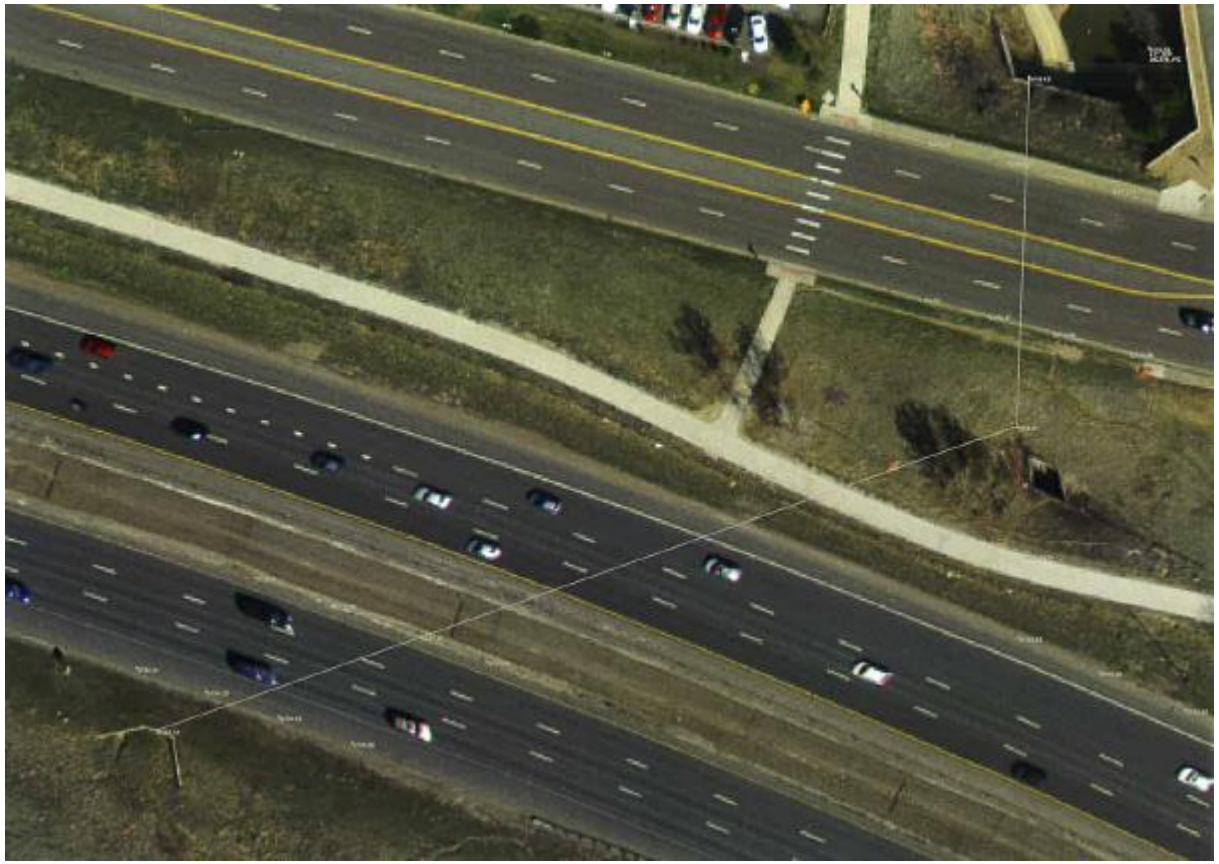
Source – Structural Mechanics of Buried Pipes – Watkins & Anderson

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



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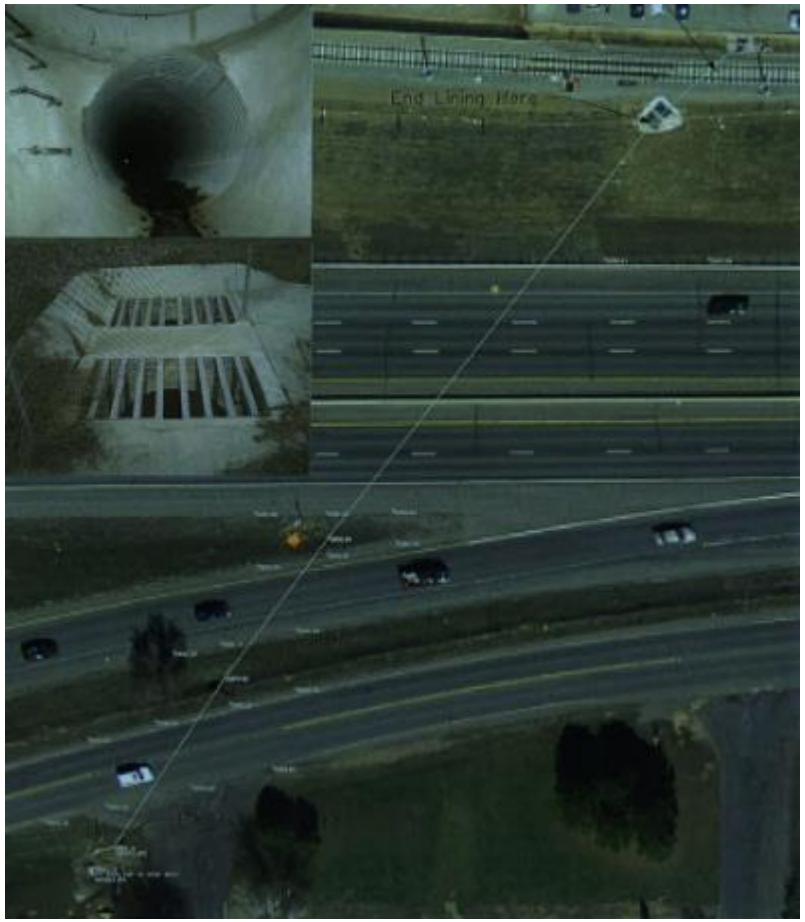
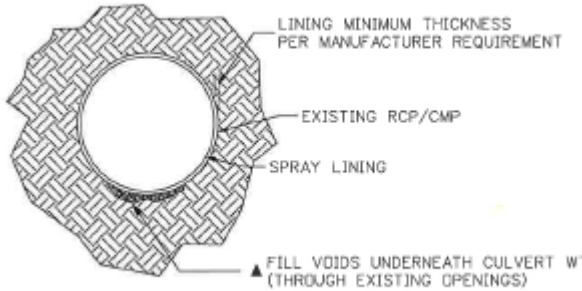


Example of Contract Details

SPRAY LINING DETAIL



▲ WILL NOT BE PAID FOR SEPARATELY, BUT SHALL BE INCLUDED IN THE WORK.

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 UNITL 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:

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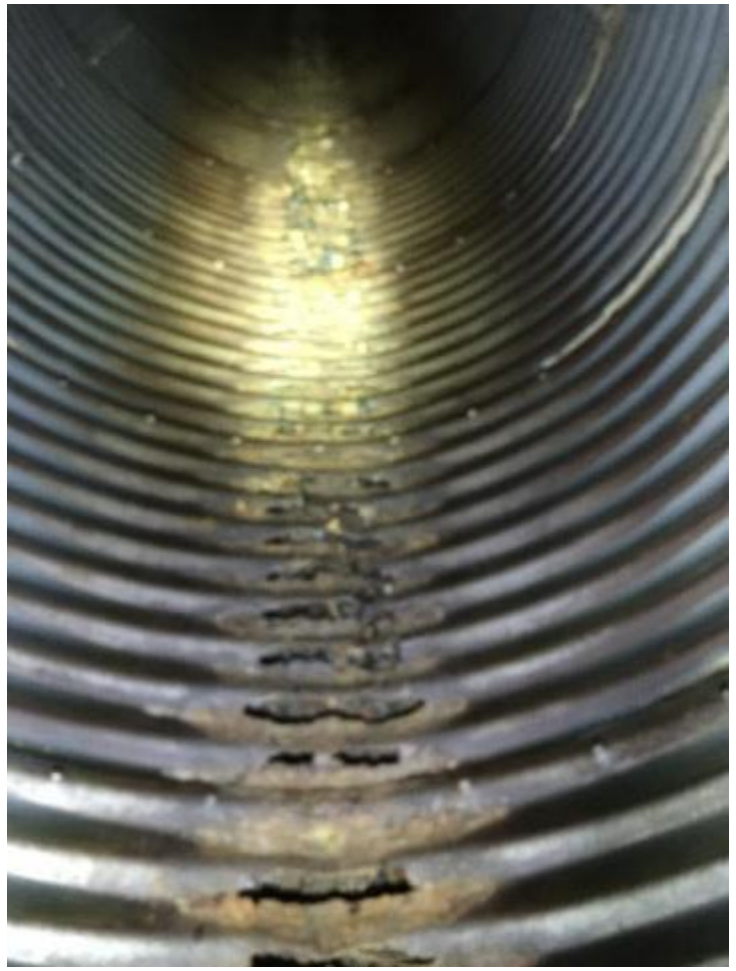
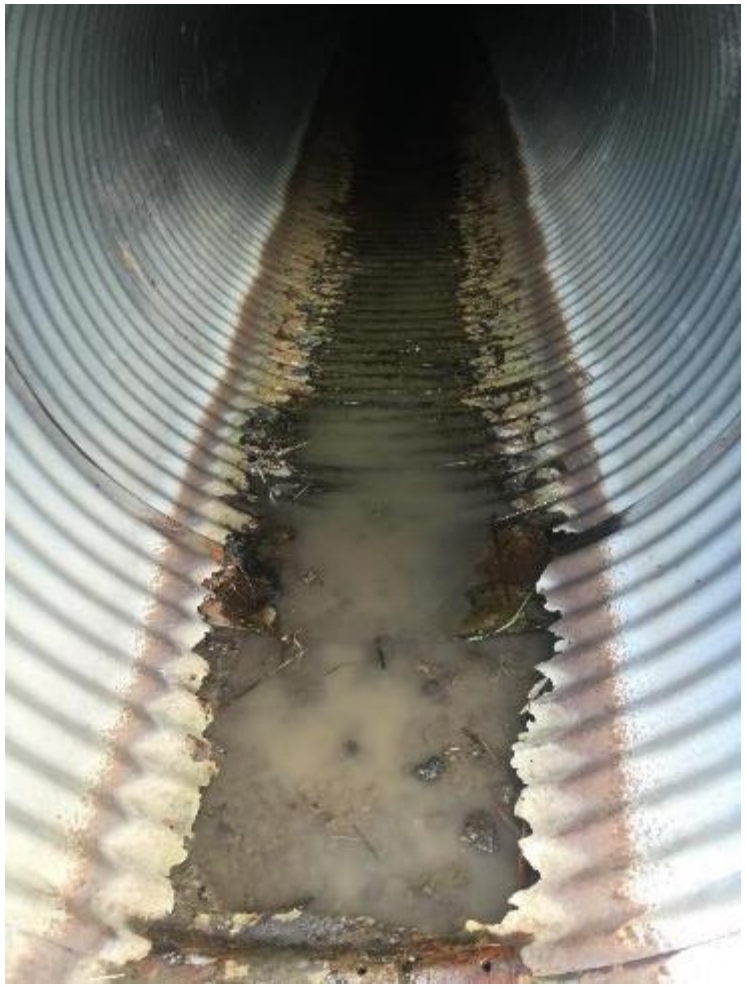
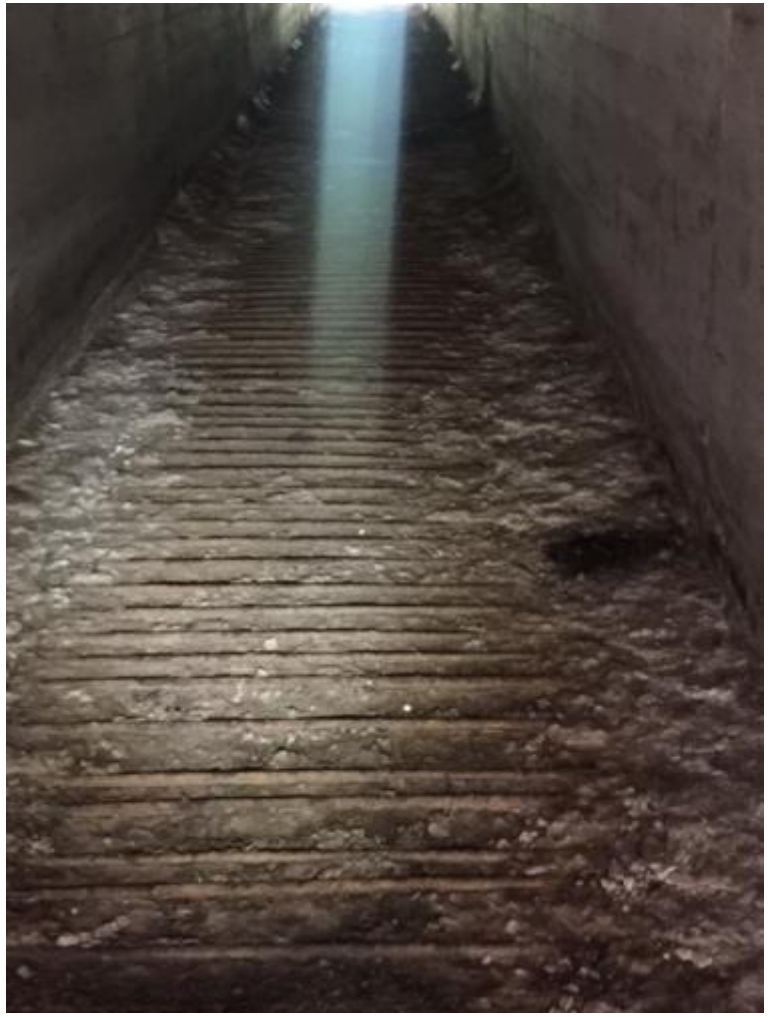


Pipe Conditions:



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:	5/5/2016	No. of Specimens:	6
Slump:	1"	Admixtures:	-
Air Content:	-	Water:	-
Design Strength:	-	Supplier:	IPR
Material Temperature:	83.0	Ticket Number:	-
Ambient Temperature:	69.0	Technician:	MC
Location:	Pipe		

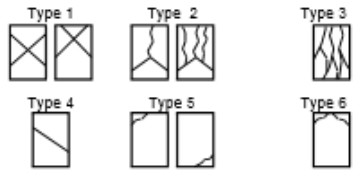
Laboratory Test Results

Set ID	Date Tested	Age (Days)	Length	Surface Area	Load (lb)	Strength (psi)	Density (pcf)	Type of Fracture
16139050511	5/12/2016	7	8.05	12.84	81,070	6,320	131.2	3
16139050512	5/12/2016	7	8.08	12.84	87,240	6,800	130.6	3
16139050513	6/2/2016	28	7.90	12.566	107,850	8,580	134.0	3
16139050514	6/2/2016	28	8.02	11.946	109,770	9,190	139.3	3
16139050515	6/2/2016	28	7.99	12.692	115,190	9,080	132.9	3
16139050516	6/30/2016	56	8.00	12.629	138,300	11,000	134.9	3

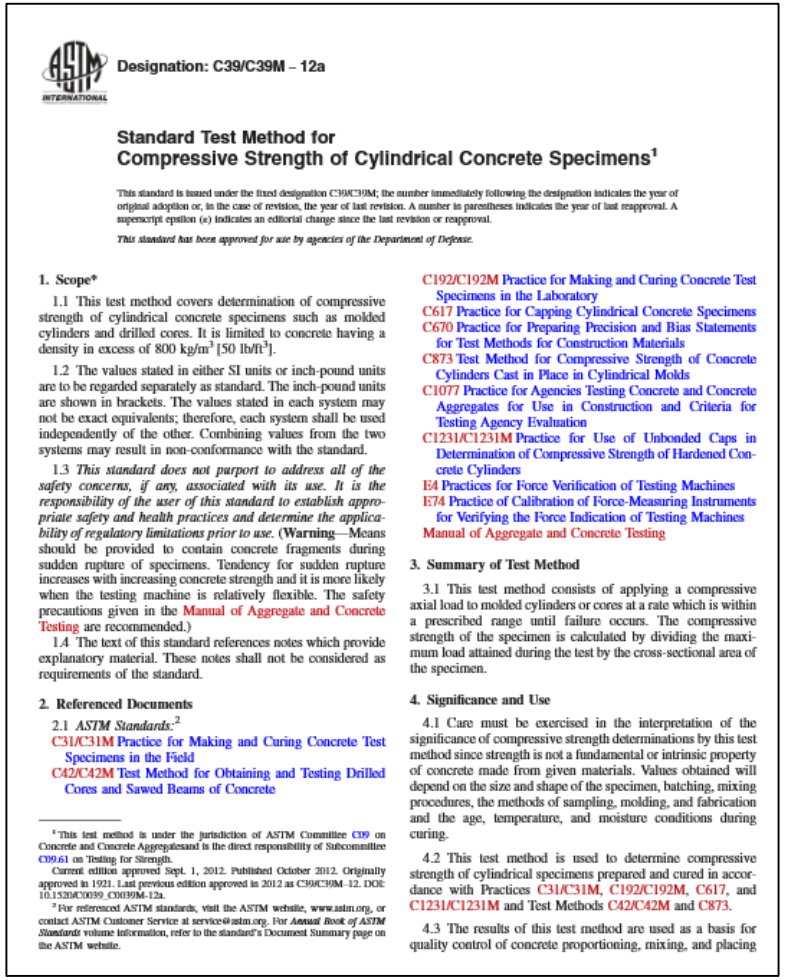
Notes

Set: No.1 of 1
Samples received at laboratory 5/6/16
Samples Initial Cured onsite in cooler
Sample Final Cured in laboratory in 50%RH storage

Types of Fracture



Distribution				
Troy Stroman	Lab Technician:	Elizabeth Butler	Date:	6/30/2016
	Project Manager:	Jack Parisi	Date:	6/30/2016



Designation: C39/C39M – 12a

Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens[1]

This standard is issued under the fixed designation C39/C39M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

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 in excess of 800 kg/m^3 [50 lb/ft^3].

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The inch-pound units are shown in brackets. The values stated in each 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 non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, 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.* (**Warning**—Means should be provided to contain concrete fragments during sudden rupture of specimens. Tendency for sudden rupture increases with increasing concrete strength and it is more likely when the testing machine is relatively flexible. The safety precautions given in the Manual of Aggregate and Concrete Testing are recommended.)

1.4 The text of this standard references notes which provide explanatory material. These notes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field
C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C617 Practice for Capping Cylindrical Concrete Specimens
C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
C873 Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds
C1077 Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
C1231/C1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders
E4 Practices for Force Verification of Testing Machines
E74 Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines
Manual of Aggregate and Concrete Testing

3. Summary of Test Method

3.1 This test method consists of applying a compressive axial load to molded cylinders or cores at a rate which is within a prescribed range until failure occurs. The compressive strength of the specimen is calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen.

4. Significance and Use

4.1 Care must be exercised in the interpretation of the significance of compressive strength determinations by this test method since strength is not a fundamental or intrinsic property of concrete made from given materials. Values obtained will depend on the size and shape of the specimen, batching, mixing procedures, the methods of sampling, molding, and fabrication and the age, temperature, and moisture conditions during curing.

4.2 This test method is used to determine compressive strength of cylindrical specimens prepared and cured in accordance with Practices C31/C31M, C192/C192M, C617, and C1231/C1231M and Test Methods C42/C42M and C873.

4.3 The results of this test method are used as a basis for quality control of concrete proportioning, mixing, and placing

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregatesand is the direct responsibility of Subcommittee C09.61 on Testing for Strength.
Current edition approved Sept. 1, 2012. Published October 2012. Originally approved in 1921. Last previous edition approved in 2012 as C39/C39M–12. DOI: 10.1520/C0039_C0039M-12a.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

6-months in Service

Questions?