SPRAY APPLIED GEOPOLYMER STRUCTURAL REPAIR MORTAR ON US 23 UNDERPASS

David Keaffaber, P.E.
GeoTree Region Manager

Jason DeRuyver, P.E. MDOT
Engineering Manager, Region Support

Michigan Department of Transportation

BUREAU of BRIDGES and STRUCTURES
SPANNING SAFETY CONNECTING EFFICIENTLY

GEOTREE

WELCOME TO GEOTREE'S AND MDOT'S MAINTENANCE TRIAL

David Keaffaber, P.E. - PRESENTER

- Midwest Region Manager for GeoTree, a division of ClockSpring|NRI, specializing in the technical sales of **GeoSpray®** lining mortars
- B.S. in Agricultural and Biological Engineering from Purdue University, West Lafayette, Indiana
- Over 30+ years of direct experience in drainage/hydraulic design, erosion control, and storm and sanitary conveyance structures
- Overview of Geopolymer material:
  - What is a geopolymer
  - Application and benefits
  - Advantages over other trenchless methods
  - Project case studies

GEOTREE

BUREAU of BRIDGES and STRUCTURES

Structure Maintenance

Brian Zakrzewski, Structure Preservation Section Engineer
517-243-9473

Preservation, RFA, Structural Design/Maintenance, Technology, and Materials & Equipment Support

Provides technical expertise to MDOT regions, local agencies, and consultants for structural maintenance, structure design for Request for Action, trials for new technologies in equipment and materials for structure maintenance, and training.

Jason DeRuyver, Priority Preservation and Maintenance Support Unit Engineer
517-242-2988

Andrew Zevchak, Priority Preservation Engineer
517-256-8439

Jacob Creisher, Structure Maintenance Engineer
517-243-7821

Aaron Porter, Structure Maintenance Support Coordinator
517-242-5788

BUREAU of BRIDGES and STRUCTURES

Structure Maintenance

- Maintenance Resource
- Develop Standards and Specifications
- Provide Technical Support
- Develop Contracts
- Investigate New Materials and Methods
- Design and Detail Complex Repairs
- Liaisons with Industry Partners

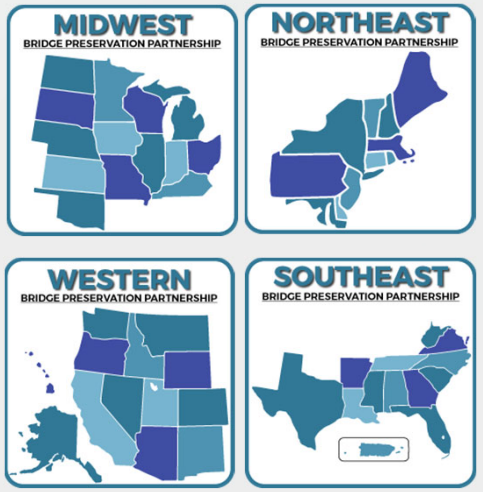
AASHTO Transportation System Preservation Technical Services Program (TSP2)

- 4 Regional Partnerships

  Monthly Teleconference Meetings
  - Business – MWBPP 1st Tuesday @1:30 pm EST
  - Technical Presentations/Discussion – 2 pm EST
    - Innovative Products/Practices
    - Preservation Challenges
    - Current Topics
    - Best Practices

  Regional Partnership Meetings
  - Annual

  National Bridge Preservation Partnership Meeting
  - Every 4 years (or so . . .)



AASHTO TSP2 Bridge Preservation Program

Principal mission is to serve as a clearinghouse with comprehensive and up-to-date information on efficient and effective preservation measures that enhance highway performance and extend useful life.

TSP2 AASHTO

Partnerships

Collaboration & Cooperation

- State Departments of Transportation
- Local Agencies
- FHWA
- Academia
- Industry
- Consultants

Officers

Name	Organization	Office
Sarah Wilson	Illinois DOT	Chair (State Rep)
Jason DeRuyver	Michigan DOT	Vice-Chair (State Rep)
Drew Storey	Clark Dietz	Vice-Chair (Industry)
Mike Brokaw	Ohio DOT	Secretary / Treasurer (State Rep)

Directors

Name	Organization	Representation
Mike Brokaw	Ohio DOT	State Agency Director
Matthew Keilson	EMSEAL	At-Large Director
Patrick Conner	Indiana LTAP (Purdue)	Local Agency Director
Trina Davidson	South Dakota DOT	State Agency Director
Jason DeRuyver	Michigan DOT	State Agency Director
Nick Graziani	Watson Bowman	Industry Director
Joe Stanisz	Iowa DOT	State Agency Director
Drew Storey	Clark Dietz	Industry Director
Glenn Washer	University of Missouri – Columbia	Academic Director
Sarah Wilson	Illinois DOT	State Agency Director

Transportation System Preservation
Technical Services Program

Bridge Preservation Blog

"A Conversation About Bridge Preservation"

https://blog.pavementpreservation.org/

A Conversation with Wayne Harrall, Kent County, and Jason DeRuyver, Michigan DOT

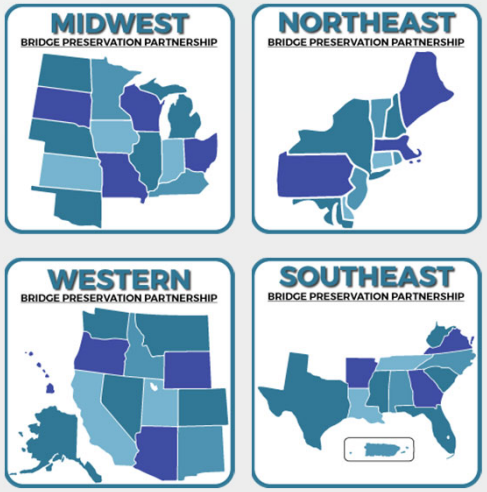
WESTERN MIDWEST NORTHEAST SOUTHEAST

Current Working Groups

- Regional Working Groups
- Bridge Inspection Program Managers

National Working Groups

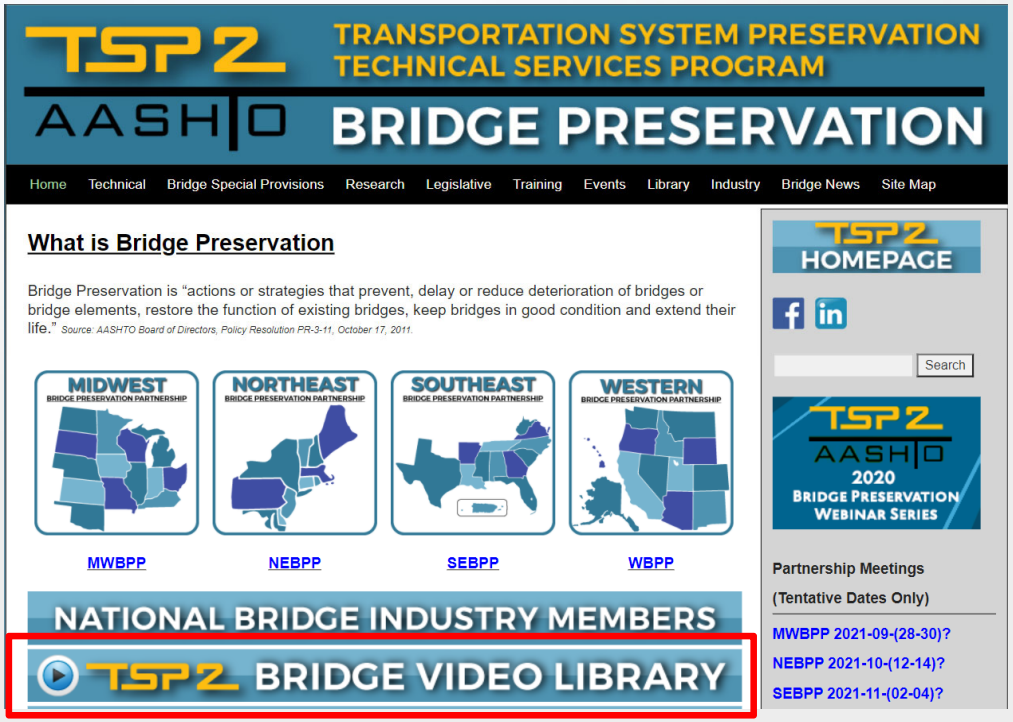
- Bridge Deck Preservation NWG
- Bridge Preservation BMS NWG
- Bridge Preservation Outreach & Communication
- Construction Quality of Bridge Preservation NWG
- Innovative Technology Demonstration (ITD) NWG
- Local Agency Outreach NWG



Local Agency Outreach Working Group

- Increase preservation of Local Infrastructure Assets.
- Provide education opportunities to Local Agencies.
- 40+ members composed of DOTs, County and City Engineers, FHWA, LTAPs, Academia and Industry.

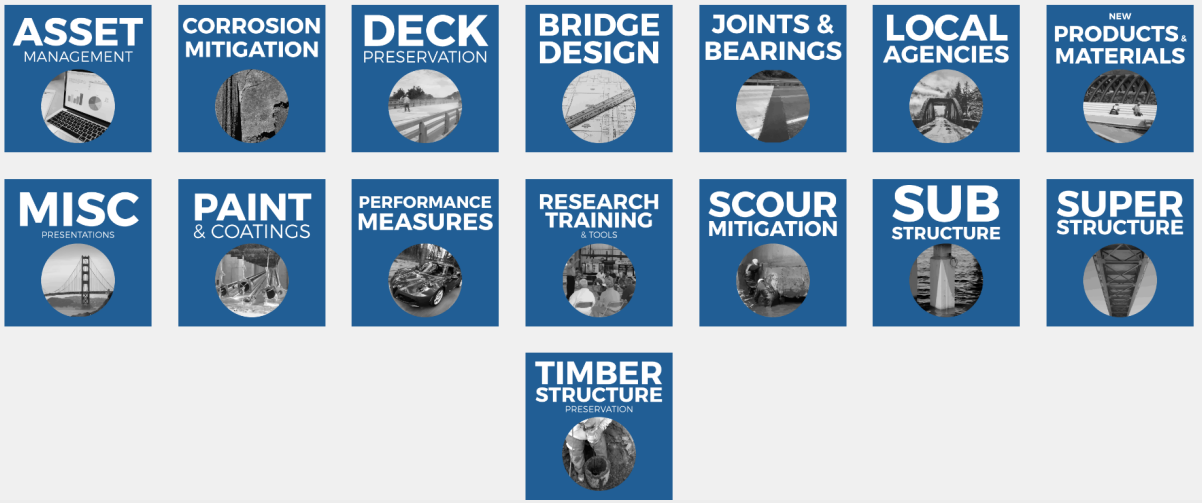
TSP2.ORG


TSP2
TRANSPORTATION SYSTEM PRESERVATION
TECHNICAL SERVICES PROGRAM
AASHTO
BRIDGE PRESERVATION
Home
Technical
Bridge Special Provisions
Research
Legislative
Training
Events
Library
Industry
Bridge News
Site Map
What is Bridge Preservation
Bridge Preservation is "actions or strategies that prevent, delay or reduce deterioration of bridges or bridge elements, restore the function of existing bridges, keep bridges in good condition and extend their life." Source: AASHTO Board of Directors, Policy Resolution PR-3-11, October 17, 2011.
MIDWEST
NORTHEAST
SOUTHEAST
WESTERN
MWBPP
NEBPP
SEBPP
WBPP
NATIONAL BRIDGE INDUSTRY MEMBERS
TSP2 BRIDGE VIDEO LIBRARY
TSP2 HOMEPAGE
Search
TSP2 AASHTO 2020 BRIDGE PRESERVATION WEBINAR SERIES
Partnership Meetings
(Tentative Dates Only)
MWBPP 2021-09-(28-30)?
NEBPP 2021-10-(12-14)?
SEBPP 2021-11-(02-04)?


WESTERN
MIDWEST
NORTHEAST
SOUTHEAST

TSP2.ORG

Archived video presentations from annual meetings



Sealing Panel Discussion	Sondag, Sarah; Peters, Walt	2019-10-17	
Installation of very early strength LMC overlays	Martens, Pat	2019-10-16	
MidWest Bridge Deck DeteriorationTPF 5(432)	Oliva, Bill	2019-10-16	
Chloride Testing & Hydro Demolition	Pilarski, Paul	2019-10-16	
Protocols for Concrete Bridge Deck Protections & Treatments	Bektas, Basak	2019-10-15	
Installation of very early strength LMC overlays	Martens, Pat	2019-10-15	
Sealing Panel Discussion Sarah Sondag (Minnesota DOT)	Peters, Walt	2019-10-15	
Bridge Deck Preservation Working Group	Welch, Ed	2019-09-11	
Bridge Deck Chloride Testing	Blower, Andrew	2019-09-10	
Installation of Very Early LMC Overlays	Martens, Pat	2019-09-10	
UHPC Overlay Solutions	Nault, Gregory	2019-09-10	
NDE & Materials Testing for Bridge Deck Condition & Service Life Assesment for Asset Planning	Boone, Shane	2019-05-15	
Panel Discussion: Deck Preservation Treatments	Henning, Brandon; McDowell, Herbert; Hardan, Chris	2019-05-15	
National Working Group: Bridge Deck Chloride Testing	Kinney, Travis	2019-05-15	

OVERVIEW

GEOSPRAY

High-Performance Geopolymer Mortar

WATER/WASTEWATER

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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

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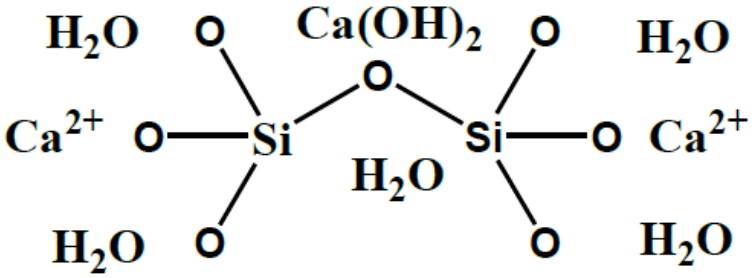
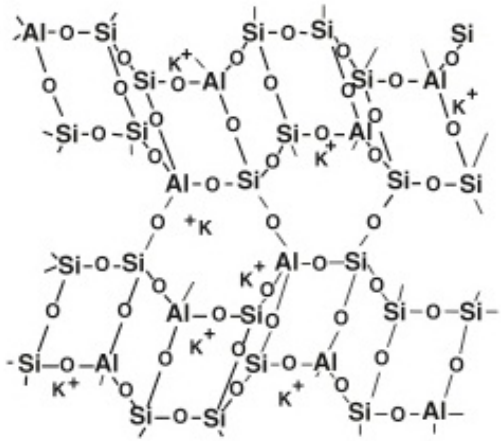
CHEMISTRY PRIMER: OPC VS GEOPOLYMERS



Typical Hydrated OPC Structure



Typical Geopolymer Structure

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GEOSPRAY ADVANTAGES: SUMMARY

Geopolymer material solutions offer significant chemical, physical, environmental, and economic advantages over traditional materials.

	Portland Cement	Competing Geopolymers	GeoSpray®
Specific Strength	Variable	Excellent	Excellent
Early Strength	Low	High	High
Acid Resistance	Poor	Very Good	Very Good
Self-Adhesion	Low	Low	High
Flexural Strength	Low	Low	High
CO_2 Emissions	High	Low	Low
Single Pass Thickness	X	X	2X-3X
Total Installed Cost	$$	$$	$

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GEOPOLYMER MARKETS

Pipe Rehabilitation

- Storm Water - Culverts
- Sewers & Manholes
- Potable Water

Transportation

- Tunnels and Bridges

Buildings and Structures

- Commercial
- Industrial

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GEOSPRAY MORTAR

GeoSpray geopolymer is a high-performance fiber reinforced mortar specifically designed for structural rehabilitation.

- This high strength, ultra-low porosity material is made from natural mineral polymers and recycled industrial waste streams.
- It is designed for use through multiple application techniques including pouring, placing, troweling, spraying, or centrifugal casting.

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GEOSPRAY GEOPOLYMER MORTAR: PHYSICAL PROPERTIES

Test Method	Duration	GeoSpray	Conventional Repair Mortar
Compressive Strength ASTM C-39/C-109	1 Day 28 Days	Min. 2,500 psi / 17 MPa Min. 8,000 psi / 55 MPa	5000 psi / 34 MPa
Flexural Strength ASTM C-78	7 Day 28 Days	750 psi / 5.2 MPa 1500 psi / 10.3 MPa	500 psi / 3.4 MPa
Modulus of Elasticity ASTM C-469	1 Day 28 Days	3,000,000 psi / 20700 MPa 5,800,000 psi / 40000 MPa	3,000,000 psi / 20700 MPa
Bond Strength to Concrete ASTM C-882	1 Day 28 Days	Min 900 psi / 6.2 MPa Min. 2,500 psi / 17 MPa	N/A
Set Time ASTM C-807 Initial Cure Time	Initial Set Final Set	60 - 75 Minutes 90 - 110 Minutes	120 Minutes 300 minutes
Freeze Thaw Durability ASTM C-666	300 Cycles	100% Zero loss	80% to 90% 10% to 20% degradation
Shrinkage ASTM C-1090	28 Days	0.00% @ 65% R. H.	0.35% to 0.50% Shrinkage
Tensile Strength ASTM C-496	28 Days	Min. 800 psi / 5.5 MPa	400 psi / 2.7 MPa
Abrasion Resistance ASTM C-1138	5 Cycles @ 28 Day Maturity	2.7% Loss	4.7% Loss
Rapid Chloride Ion Permeability ASTM C-1202	28 Days	Very Low	N/A

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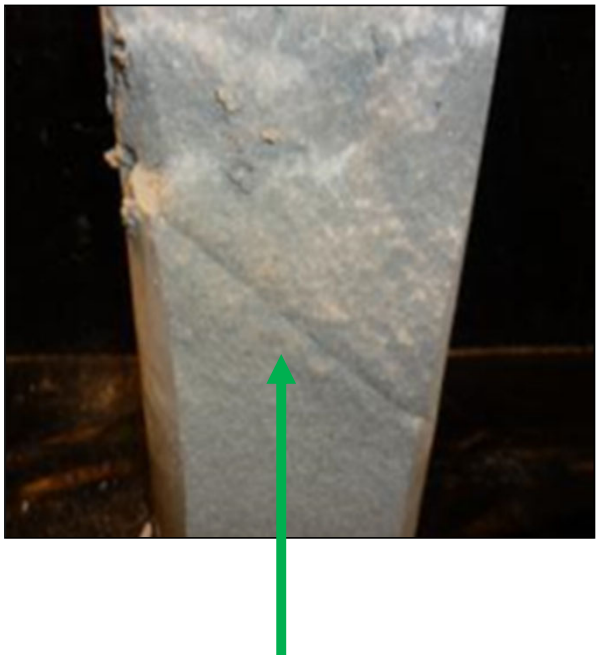
GEOSPRAY MORTAR ADVANTAGES:

Self Bonding

Experimental Parameters:

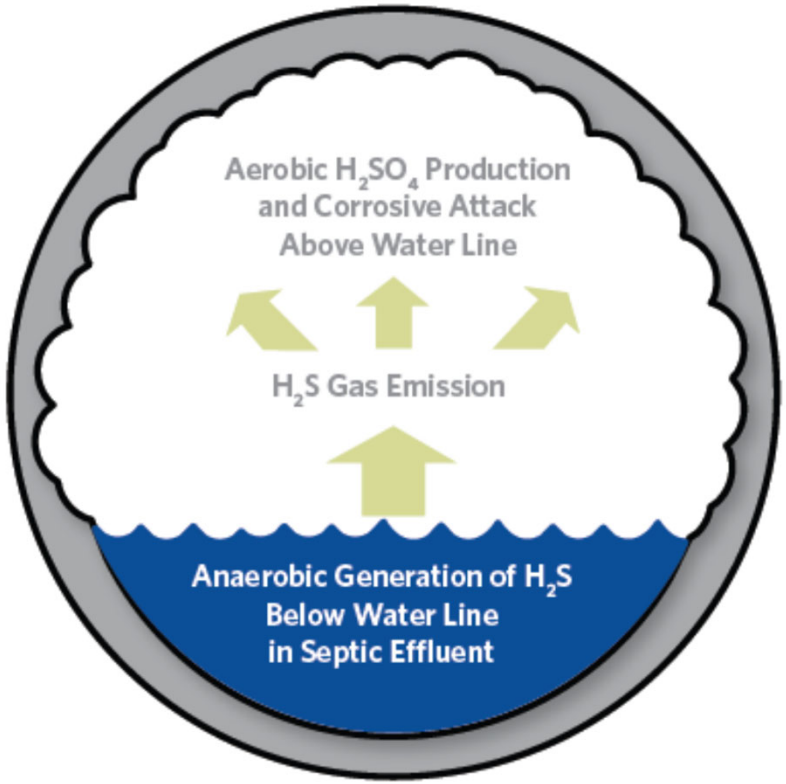
- On the first day a series of 2” by 4” cylinders were cast half full and cured with on an approximately 45 angle.
- On subsequent days (1, 7, 14 and 28) the top half of the cylinders were cast and filled creating a 45 angled joint in the center of the cylinders
- Compressive strength tests were conducted 28 days after the top half of the cylinders were cast.



Joint in Tested Sample

GEOSPRAY MORTAR ADVANTAGES:

Corrosion Resistance



Microbial-Induced-Corrosion (MIC) Mechanism

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GEOSPRAY MORTAR ADVANTAGES:

Corrosion Resistance

- The chemical make-up of GeoSpray geopolymer makes it *inherently acid resistant* to the MIC mechanism found in many sewer environments.

- Geopolymers (dependent on the exact formulation) will contain greatly reduced concentrations of $Ca(OH)_2$ (calcium hydroxide) essentially the acid corrosion mechanism found in many typical cements.

- GeoSpray and GeoSpray HCE geopolymer mortars have been tested to ASTM C267 and certified to German Standard DIN19573 - the most controlled and stringent testing for microbial induced corrosion standard in practice today.

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DESIGN METHODOLOGY

GEOSPRAY: A NEW PIPE WITHIN AN OLD PIPE

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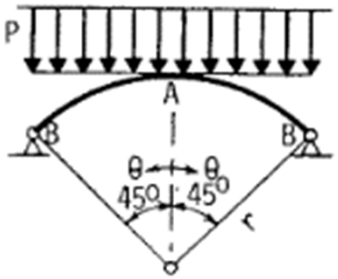
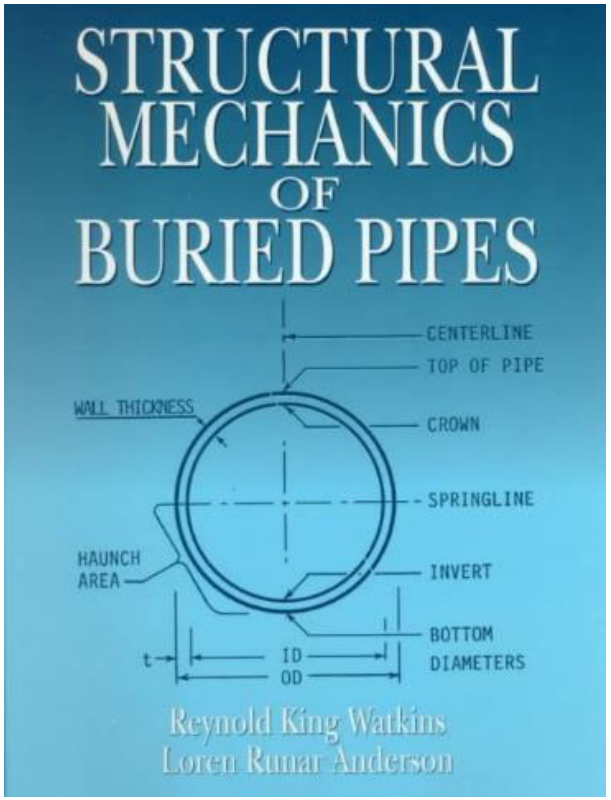
DESIGN METHODOLOGY: BASIC ASSUMPTIONS



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

The resultant solution for this case is:

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

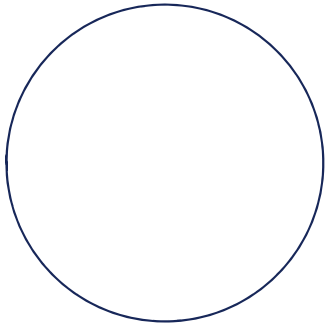


Return

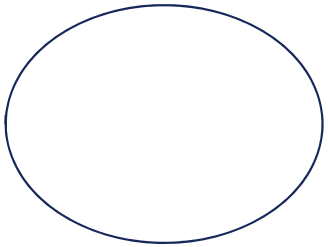
GEOTREE

DISTRIBUTED LOAD ACROSS A FIXED ARCH

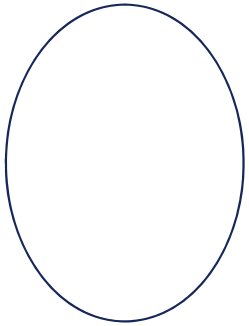
The Design Method is not specific to Round, but valid for any arched structure



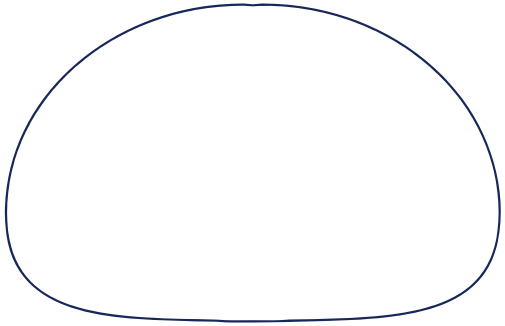
Circular/Round



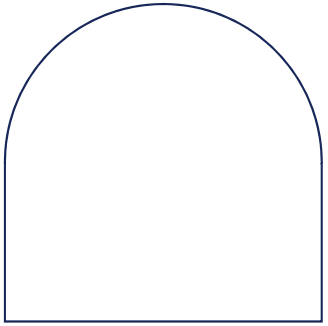
Horizontal Ellipse



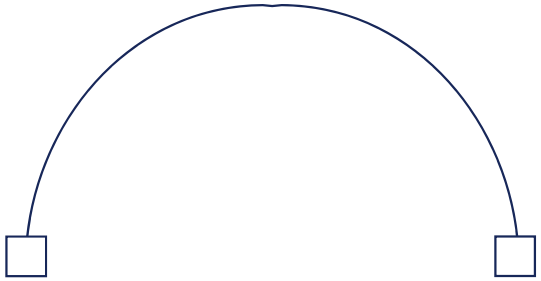
Vertical Ellipse/Egg



Pipe Arch



Horseshoe



Arches

GEOTREE

LA TECH – TTC: EXPERIMENTAL PARAMETERS

The pipes were then rehabilitated using GeoSpray geopolymer via a spin casting method; vertical application was used to keep sonotubes in shape

Source – NASST No DIG 2016, Dallas TX – Paper No WM-T6-03 (Royer & Allouche)

GEOTREE

LA TECH – TTC: EXPERIMENTAL PARAMETERS

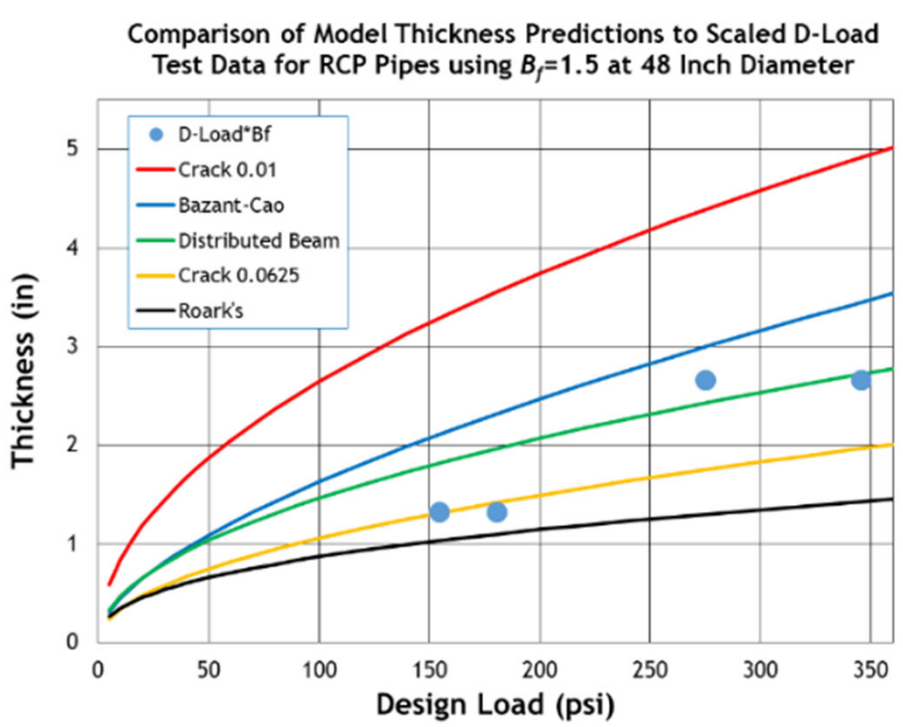
The full suite of rehabilitated pipes

LA TECH – TTC: EXPERIMENTAL PARAMETERS

Each pipe was then pre-stressed until a D-Load crack was present in the crown, invert and the external side of both spring-lines

Source – NASST No DIG 2016, Dallas TX – Paper No WM-T6-03 (Royer & Allouche)

RCP DATA –VS- 5 MODEL PREDICTIONS - 48” PIPE



Distributed Beam Model
- best choice - not over or under conservative

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PIPE REHABILITATION WITH GEOSPRAY MORTAR

GEOTREE

AVOID COSTLY AND DISRUPTIVE ROAD CLOSURES WITH GEOSPRAY TRENCHLESS CULVERT REMEDIATION

GEOTREE

GEOPOLYMERS: SPIN CASTING PROCESS

Spin Casting of GeoSpray

- Rapidly distributes material within the pipe's internal circumference .
- Forms a strong, low permeability, mortar lining.
- Depending upon design & thickness, creates a "pipe within a pipe"
- Typical engineering design does not rely on the integrity of the host structure.
- Compatible with most common reinforcement technologies.

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GEOPOLYMERS: CENTRIFUGAL CASTING EQUIPMENT

Air Driven

Mechanical / Electrical

GEOTREE

GEOPOLYMERS: HAND SPRAY APPLICATION

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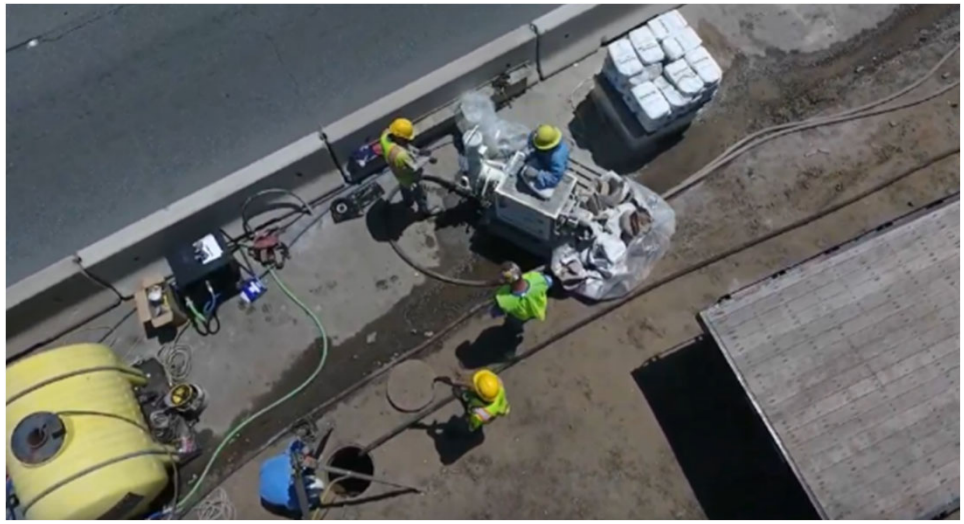
GEOPOLYMERS APPLICATION ADVANTAGE:

Footprint



Small equipment footprint allows for flexibility & planning around client needs.

CIPP OVER THE HOLE WET OUT:
Footprint

10’ Diameter CIPP Wet Out Footprint – 3 to 4 traffic lanes

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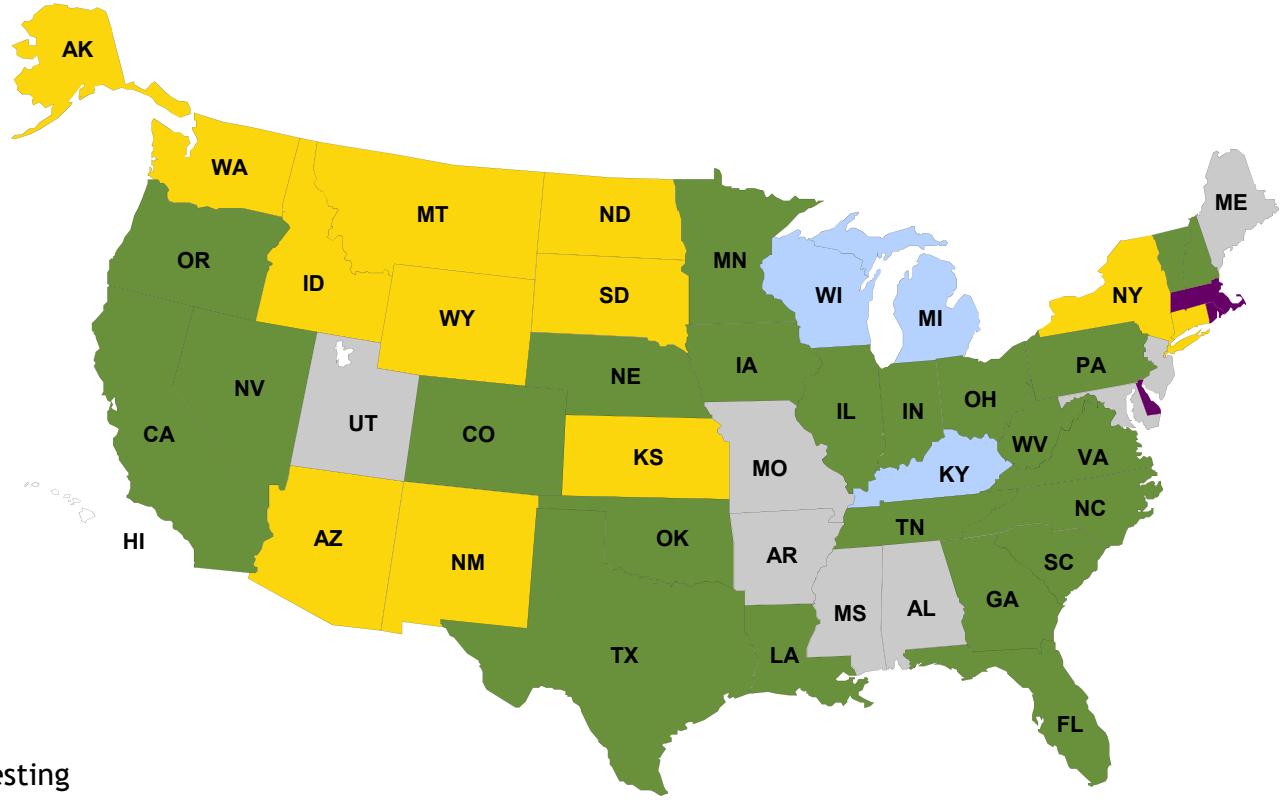
GEOSPRAY DOT APPROVALS: JANUARY 2022



- Approved
- Conditional Approval
- Approved for Field Testing
- Pending Application
- No Formal Approval Process

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SPRAY APPLIED CONDUIT APPLICATIONS

ROUND 9’ DIAMETER CMP CULVERT

Existing Culvert Condition

After 2” Lining

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14’ SPAN MULTIPLATE ARCH CULVERT

Existing Arch on Spread Footings

Completed 5” Lining

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12’ SPAN MULTIPLATE PIPE ARCH

Existing Condition

Completed 2.75” Lining

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5’ MASONRY ARCH CULVERT

Initial Culvert Conditions

Completed 1.75” Lining

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84” ELLIPTICAL RCP CULVERT

Pipe was in Moderate Condition

Completed 1.5” Lining

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8’X8’ CONCRETE BOX CULVERT

Initial Condition

Completed 1.5” Lining

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FEDERAL PRISON ROAD STRUCTURE UNDER US-23 MILAN, MICHIGAN

STRUCTURAL PLATE ARCH UNDERPASS

COMPLETED – OCTOBER 2022

US 23 REPAIR CASE STUDY: MILAN, MI

Project Details:

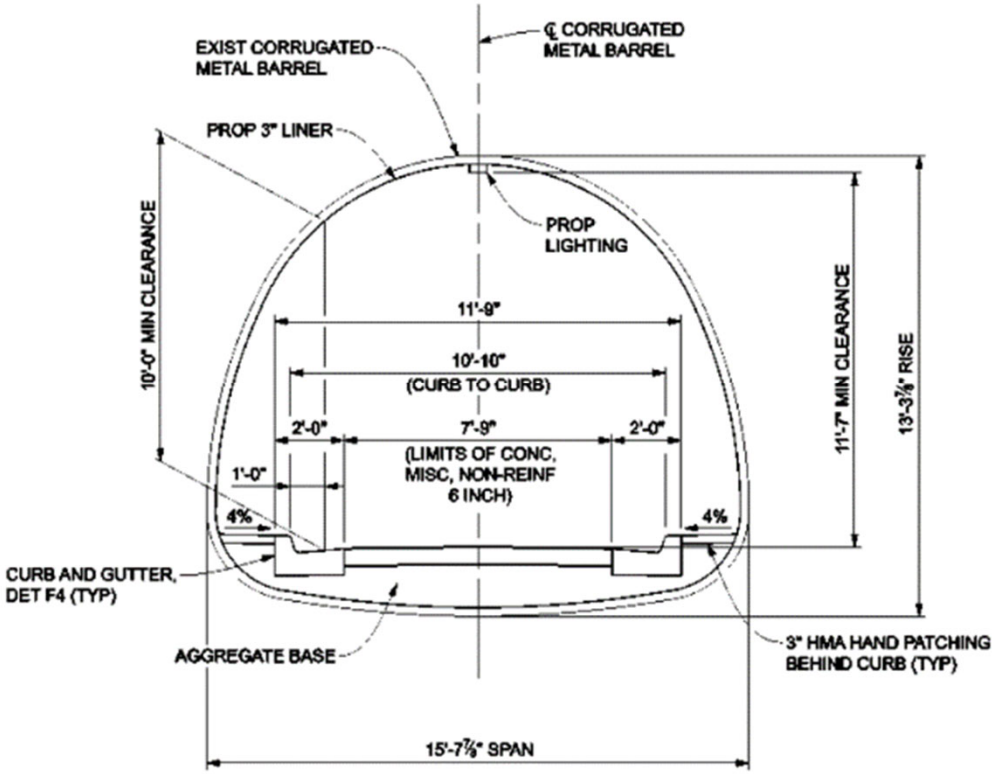
Federal Prison Road under US 23 in Washtenaw County

- Multi-Plate Pipe Arch
  - 170 Linear Feet of Structural Metal Plate
  - 15 ft - 8 inches Span
  - 13 ft - 4 inches Height
- Originally Constructed in 1962
- Sever Corrosion in Invert and Haunch Areas
- Single Lane Vehicular Underpass

- Contractor – MCSP

US 23 REPAIR CASE STUDY: MILAN, MI

Cross Section of Proposed Multiplate Arch Repair:



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BUREAU of BRIDGES
SPANNING CONNECTING
SAFELY EFFICIENTLY
and STRUCTURES

US 23 Repair case study: milan, mi

BUREAU of BRIDGES
SPANNING CONNECTING
SAFELY EFFICIENTLY
and STRUCTURES

US 23 Repair case study: milan, mi

BUREAU of BRIDGES and STRUCTURES

Unofficial Request for Action Project Process

- Oh No! How are we going to fix this?
- Ask the Region Support Unit
- Ask the TSP2 Partners
- Reach out to Industry
- Develop Repair Estimates
- Program
- Develop Unique Special Provisions

BUREAU of BRIDGES
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SAFELY EFFICIENTLY
and STRUCTURES

Develop a Unique Special Provision

- Ask Industry for a sample specification
- Ask the TSP2 Partners if they have an SP
- Write the Special Provision with Chapter 11 of the Road Design Manual Open
- Read every quoted ASTM
- Review, Review, Review
- 20SM401(A005) – Geopolymer Spray Applied Structural Liner for Job Number 210422

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Develop a Unique Special Provision

c. Construction. Obtain from the manufacturer the design for the geopolymer liner, that meets the following conditions:

1. HS-20 live loading.
2. A thickness assuming a fully deteriorated pipe condition with no bonding to the original pipe wall.
3. Water table is assumed at the ground surface above the pipe.
4. All design calculations sealed by a Professional Engineer licensed in the State of Michigan. Base the design on a factor of safety of at least 2.0.

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Develop a Unique Special Provision

5. Chemical analysis report.
6. Written installation plan approved by the manufacturer.
7. Method to verify applied thickness during installation.
8. Verification that applicators are certified by the manufacturer for installation of the geopolymer liner on large diameter corrugated metal pipes of similar size. Applicators must have worked on at least five projects of similar scope and complexity.
9. Certification that the proposed liner will have a design life of at least 50 years.

US 23 REPAIR CASE STUDY: MILAN, MI

Existing Corrosion & Pitting in Invert Haunch Areas:

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US 23 REPAIR CASE STUDY: MILAN, MI

Exposing Pipe Invert after Removal of Existing Roadway Pavement:

GEOTREE

US 23 REPAIR CASE STUDY: MILAN, MI

Spray Lining of Underpass Walls:

GEOTREE

US 23 REPAIR CASE STUDY: MILAN, MI

Spray Lining of Underpass Invert:

GEOTREE

US 23 REPAIR CASE STUDY: MILAN, MI

Installed Sub-Pavement Geotextile

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US 23 REPAIR CASE STUDY: MILAN, MI

Rehabilitated Underpass with Poured Concrete Pavement:

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BUREAU of BRIDGES and STRUCTURES

MDOT Lessons Learned

- Construction Office Questions not addressed in Special Provision
  - Testing Frequency?
  - Testing Type?
  - Sampling Requirements?
  - Mitigation Requirements for a failed test? (No test failed during trial project)
  - Do we need a geotextile separator between new concrete road and geopolymer? (One was added to job)
  - What about other defects, such as allowable cracking? Seepage? Honeycombing?
- Set clear project expectations with manufacturer
- Follow up with CSD before advertisement. Spray applied liners have no prequalification classification. (Initial Advertisement was Fa – Bridge and Ea – Grading, Drainage Structure and Aggregate).

BUREAU of BRIDGES
SPANNING CONNECTING
SAFELY EFFICIENTLY
and STRUCTURES

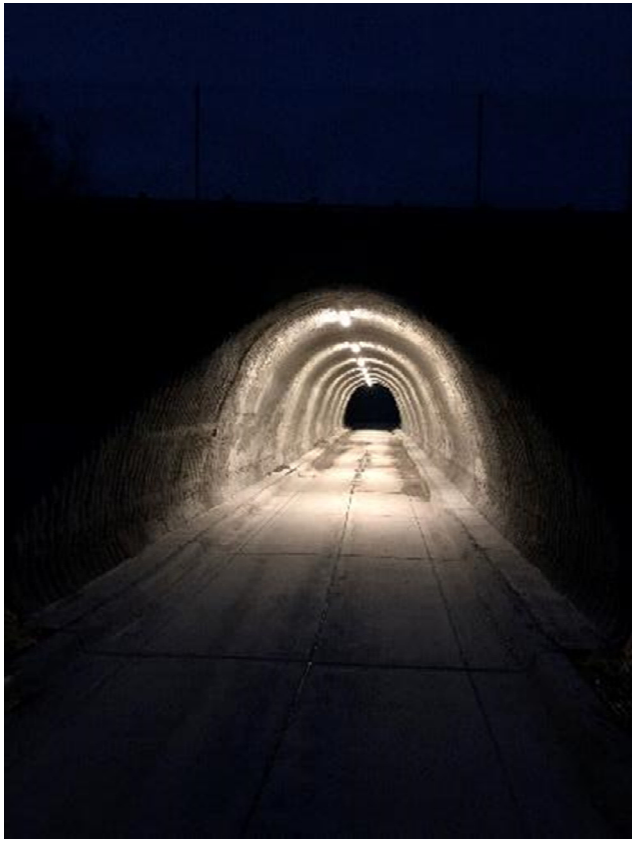
MDOT Lessons Learned

- Set clear project expectations with manufacturer
- Follow up with CSD before advertisement. Spray applied liners have no prequalification classification. (Initial Advertisement was Fa – Bridge and Ea – Grading, Drainage Structure and Aggregate).

US 23 REPAIR CASE STUDY: MILAN, MI

Challenges and Lessons Learned:

- Active Infiltration Control
- Invert Patching and Infiltration Sealing
- Post Lining Infiltration Sealing
- Suggest Requiring Broom Finish on Future Vehicular or Pedestrian Underpass Linings



GEOTREE

GEOTREE

THANK YOU