Laboratory and Field Performance of Asphalt and Concrete Patching Materials and Techniques

Robert Kostick and Jay Dailey

Eshan Dave

Eric Musselman

UMD University of Minnesota Duluth Driven to Discover

University of New Hampshire

Villanova University

Minnesota Department of Transportation

Motivation for the Research

- Minnesota Department of Transportation (MnDOT) patch failure rates are high (….so are for others)
  - The annual roadway condition report indicates that on an average basis patches have been failing within one year.

Two Projects

- Partial Depth Patching Materials
  - 2012 - 2014
  - Lab testing based acceptance system for partial depth patching mixtures
  - Final Report: http://www.dot.state.mn.us/research/TS/2014/201441.pdf

- Pothole Patching Materials and Techniques
  - 2014 - 2016
  - Field evaluation of patching materials and techniques
  - Outcomes:
    - *Best practices manual and decision tree*
    - *Slurry mix design, equipment modifications*

Concrete Rapid Patching Material Acceptance Criteria

State (Northern US)	**Material Acceptance Specification**
Minnesota	ASTM C928 (required tests only)
North Dakota	ASTM C928 (required tests only)
South Dakota	Material must reach 4000 psi compressive strength in 6 hours
Michigan	*Presentation by John Staton*
Idaho	Type III Portland cement concrete required
State (Southern US)	
Arizona	Material must reach 2000 psi compressive strength in 6 hours
Florida	ASTM C928 (required tests only)
Georgia	ASTM C928 and Freeze Thaw Durability Factor must be within 75% of the reference concrete @ 300 cycles

Summary of State DOT Practices

- Many states follow the ASTM requirements for the approval of mixes
- Most do not require any of the additional (recommended) ASTM tests
- ASTM C928, Required testing includes:
  - Compressive Strength Gain
  - Bond Strength by Slant Shear
  - Length Change, in air and water
  - Consistency of Concrete, workability
  - Scaling Resistance to Deicing Chemicals, the only cold weather related test

Recommended ASTM C928 Testing

- The optional tests include:
  - ASTM C403, Time of setting
  - ASTM C78, Flexural strength
  - ASTM C666, Freeze-thaw durability
  - ASTM C1012, Sulfate expansion




Previous Research

- Laboratory evaluation:
  - AASHTO/NTPEP
  - FHWA (Federal Highway Administration)
  - SHRP (Strategic Highway Research Program)
  - Penn State University
  - TTI (Texas Transportation Institute)

- Field performance testing:
  - MnROAD Evaluation of Patching Materials (2011)
  - NTPEP conducted a tests on a bridge deck in Ohio using 6 products in 3 ft. X 9 ft. patches
  - SHRP had a similar test but ranged over 4 states; Utah, Arizona, Pennsylvania and South Carolina

Why Cold Climate Specific Testing

- Cold climates present unique challenges for patching materials: greater slab curling, snow plow damage, deicing chemicals etc.
- The goal is to identify materials in the lab that will perform better and last longer once in the field.

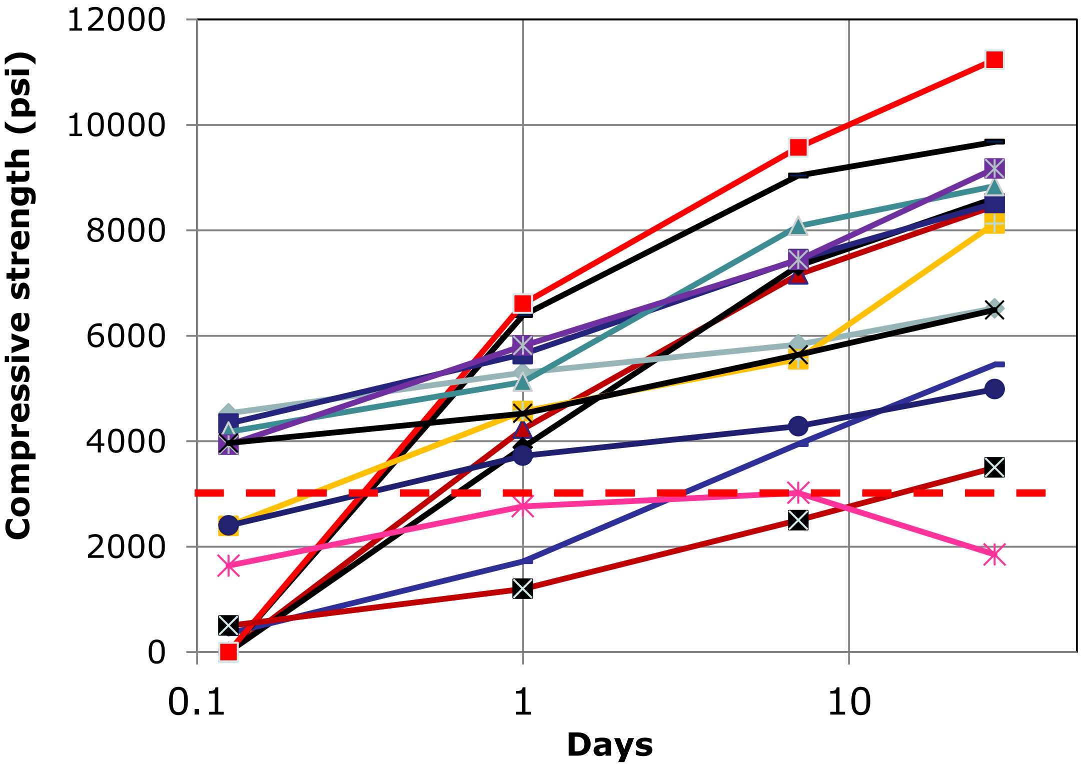
- This was achieved by:
  - Extending the current standards to include laboratory tests that represent colder climate conditions.
  - Eliminating those that do not provide additional information about the performance of patches.
  - Investigating what additional data can be retrieved from tests that are currently in practice.

Experimental Program

- Focus is on laboratory testing:
  - Basis was formed by ASTM C928 specification
- Testing scope:
  - Test 13 rapid set cementitious products and mixes using the current acceptance criteria (ASTM C928 specification)
  - Choose 4 products from the original list to undergo a more rigorous set of tests
    - *The tests in this phase are more tailored to climatic effects on the materials.*
- Tests that were developed to focus on bond
  - Pull-out bond test (adapted ASTM C900) and flexural bond test
- Gather additional data from existing tests
  - Record mass loss during freeze-thaw testing

Rapid Set Materials (13)

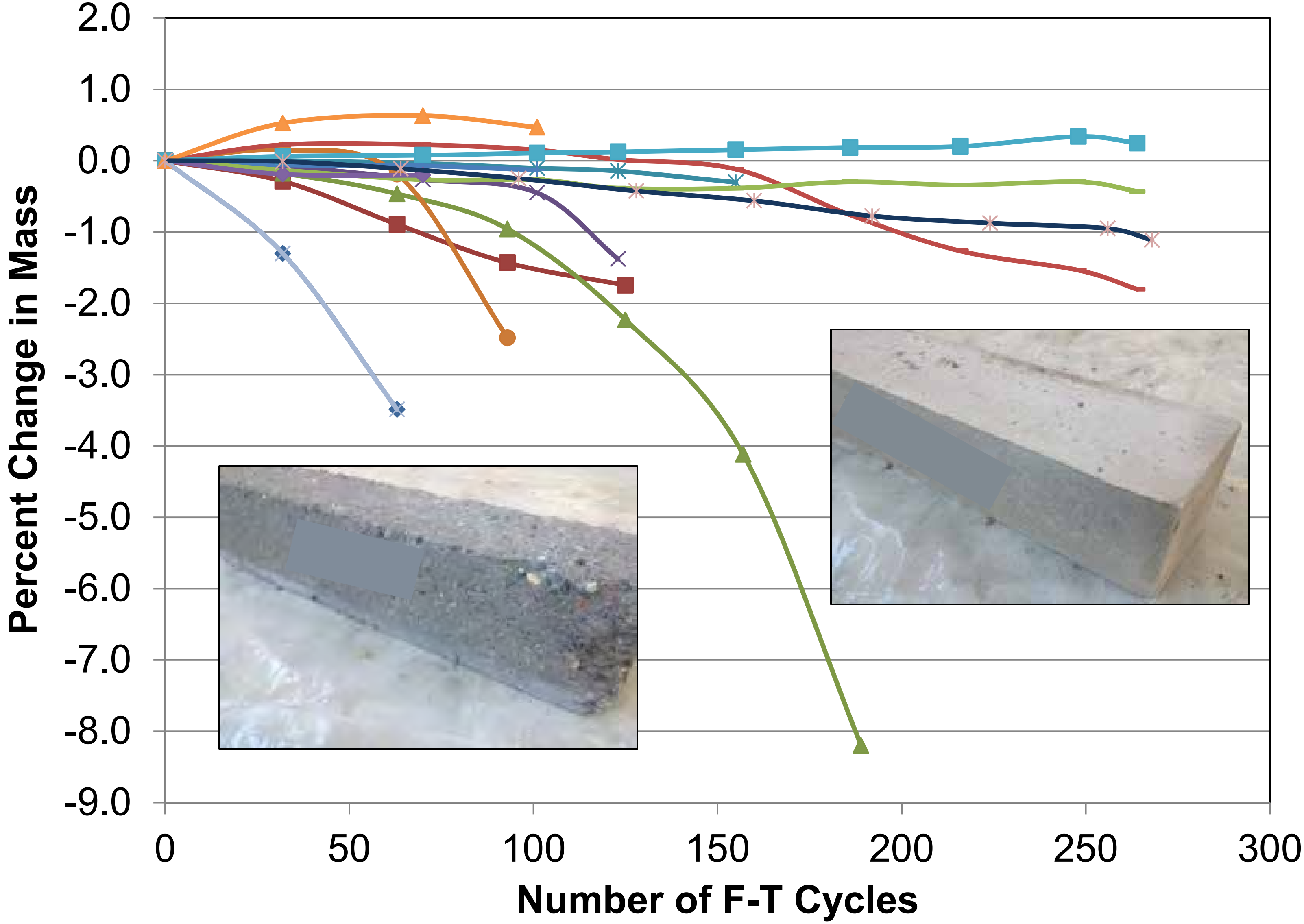
- Portland Cement Based – PCC# (4)
- Magnesium Phosphate Based – MP# (2)
- Polymer Modified Cement - PMod (1)
- Unknown – Pro# (6)



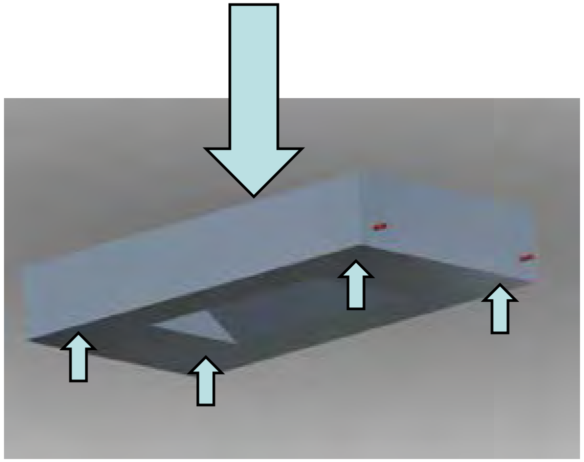
Freeze-Thaw Testing

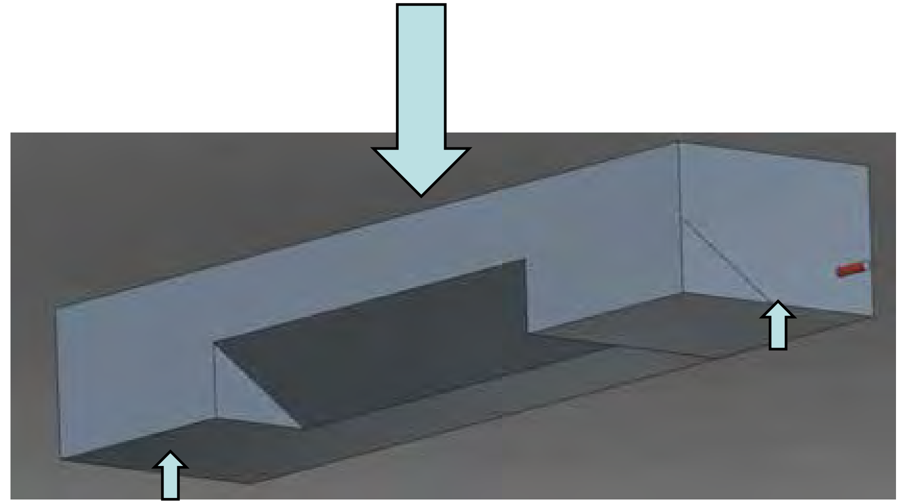
- Freezing and thawing is of concern in colder regions
  - Spring and Fall are critical periods
- Considerations:
  - Mass loss: an indicator of surface durability in cold weather
  - Relative dynamic modulus (stiffness): measure of material integrity

Freeze-Thaw Testing: Mass Loss



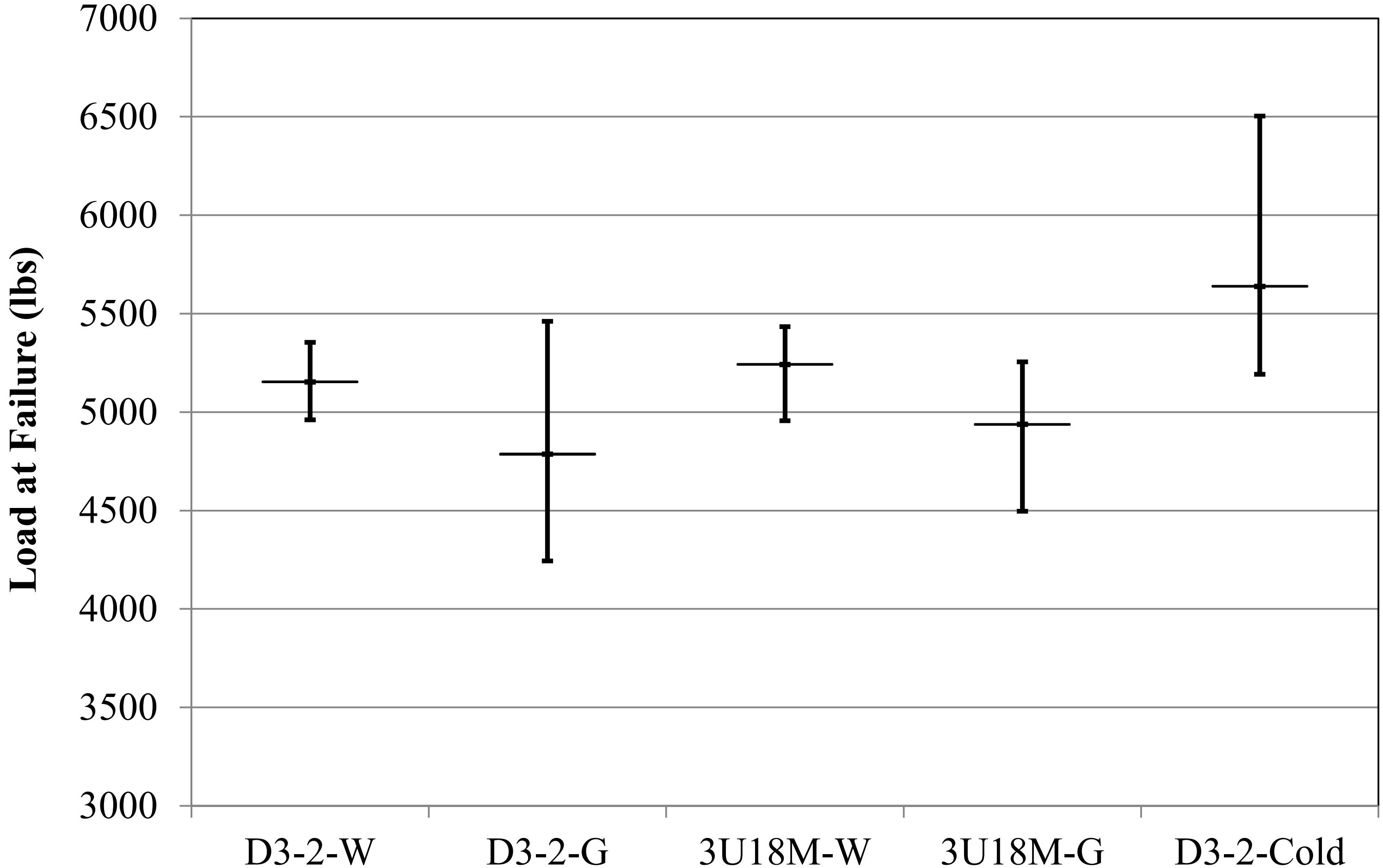
Pop out/Flexural Bond Test



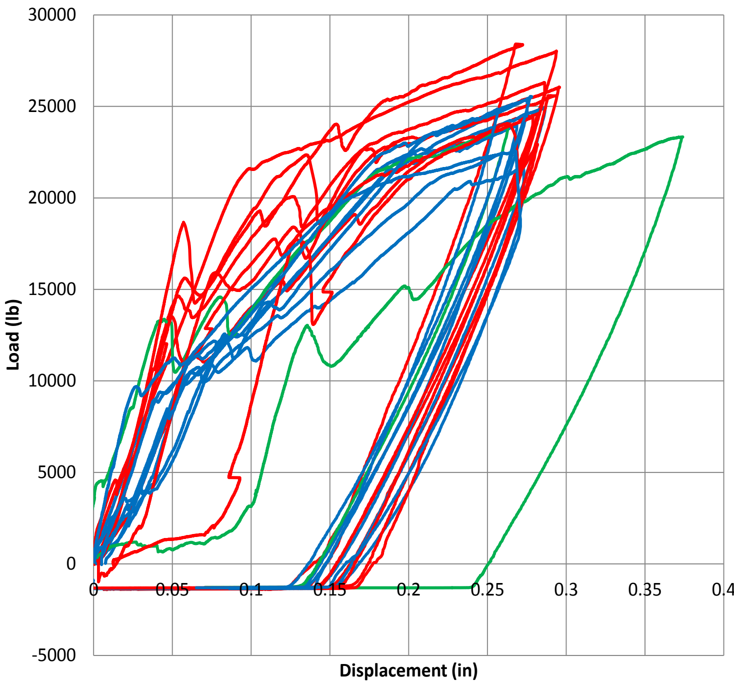


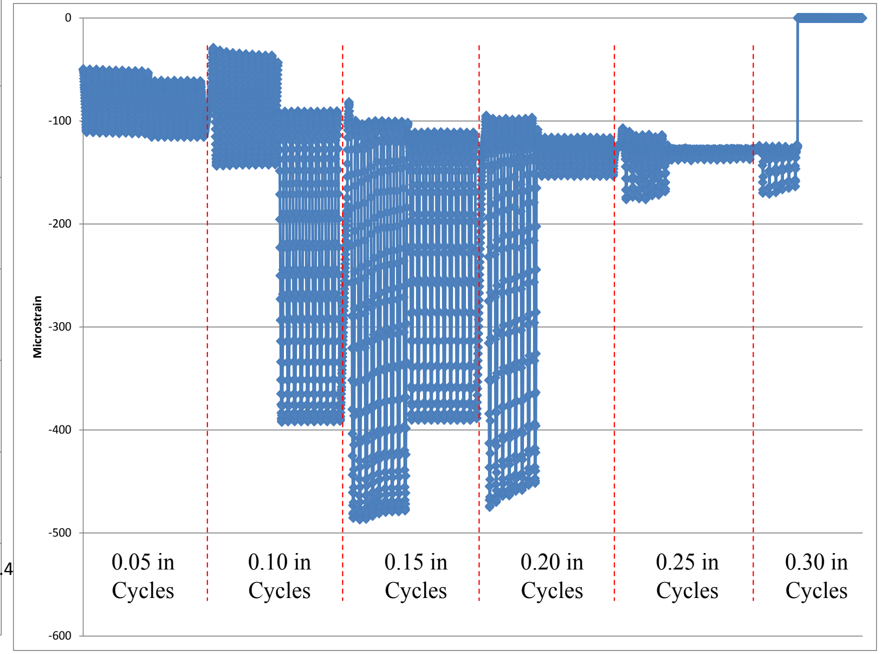
Flexural Bond, Static tests

- Peak load at failure for half slab specimens, 3 replicates



Flexural Bond, Cyclic Loading





Summary and Conclusions

- Laboratory testing based material acceptance process is recommended to be used as routine practice
  - ASTM C928 is very good starting point, some changes are strongly recommended through the present study
- Modulus of Elasticity
  - No specific target value, but should require it to be close to rest of the pavement
- Freeze-thaw testing
  - Current requirements primarily focus on durability factor (DF)
  - Both RDM and mass loss should be included in the requirements
- Bonding of patching materials
  - Chemical bond did not appear to be an issue of concern for materials studies herein
  - Modified bond test has potential to become a “pass/fail” requirement

Recommendations

- Tests that should be included in the acceptance procedure for rapid set materials
  - Consistency and workability of patching mixes
  - Compressive strength at 3 hours and 28 days
  - Shrinkage, length change
  - Freeze-thaw durability
    - *Including mass loss and initial dynamic modulus*
    - *Air entrainment strongly recommended for all patch materials*
  - Setting time
  - Modulus of elasticity, match closely to pavement concrete
    - *If the dynamic modulus matches closely (<15%) to the PCC dynamic modulus it may be considered a match*
  - Abrasion resistance
    - *Especially for patch materials containing aggregates that may be susceptible to polishing*
  - Water and grout did not show significantly different results

Comprehensive Field Evaluation of Asphalt Patching Techniques

Objectives of Study

- Main objective is to improve the current asphalt patching practices and to aid in-field operations
  - Selection of appropriate technique and materials (decision tree)
  - Best practices manual
  - Aid in developing/optimizing patching materials
- Research Tasks

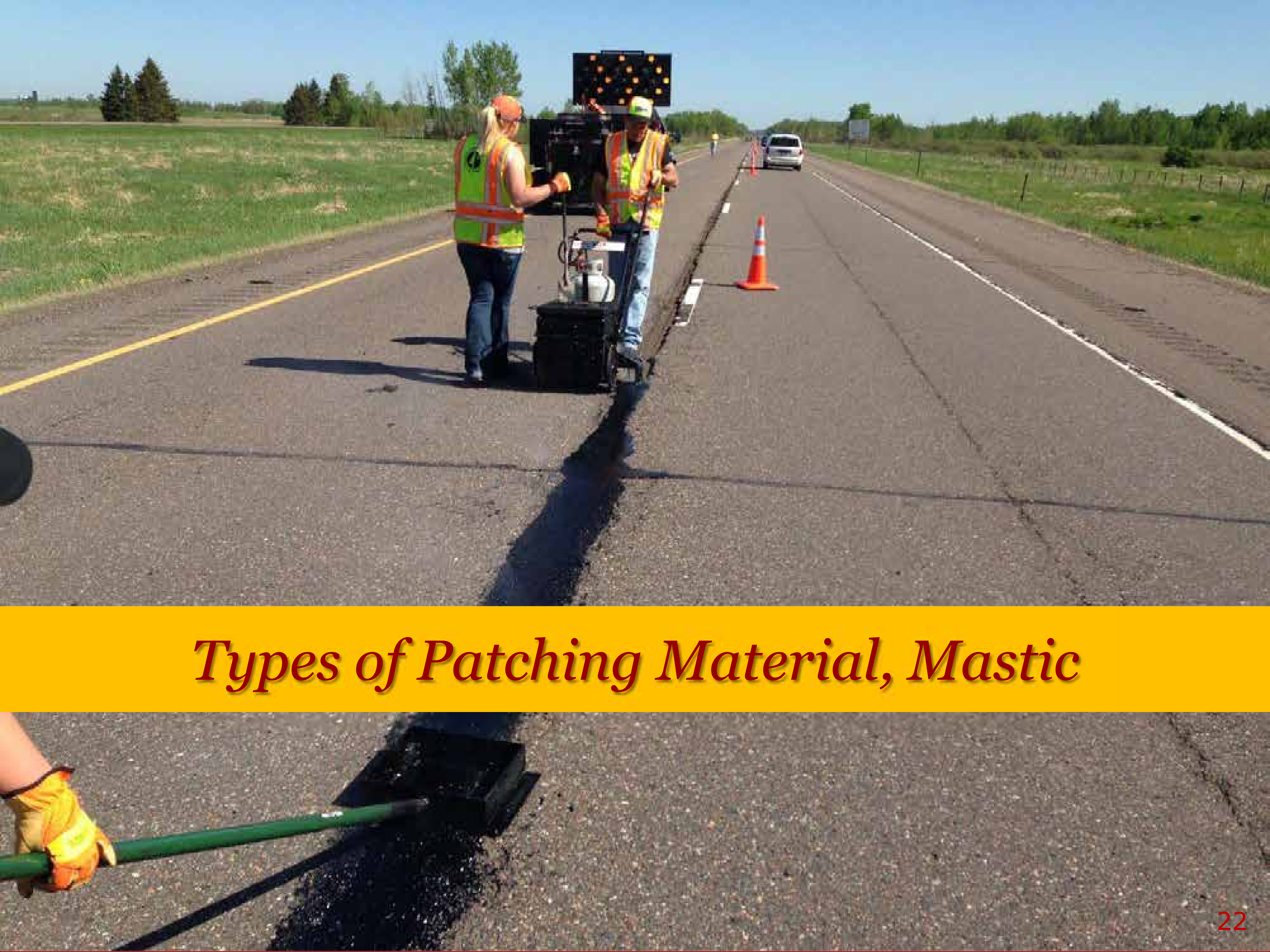
1) <u>Identify pothole locations for study</u>
2) <u>Field observation and evaluation (Year-1)</u>
3) Field observation and evaluation (Year-2)
4) <u>Laboratory testing to support mix design refinements</u>
5) Develop best practices guide and simple design tree

Underlined tasks are completed and will be briefly discussed in this presentation

Location Identification

Five Sites

- Site A (TH 61): Fine-Aggregate Cold Mix
- Site B (Grand Ave): Cold Mix and Hot Recycler
- Site C (I-35): Mastic
- Site D (Hwy 53-Trinity Rd): Mill and Fill
- Site E (Hwy 53): Mill and Fill



Types of Patching Material, Mastic

Fine Aggregate Cold Mix

Hot Recycler

Mill and Fill

Field Observations


A-4
Before Cleaning

Day 3

Day 149


CLOSED

Laboratory Testing for Slurry Mix Refinement

Trial Mixes Completed

Trial	Percentage Based on Weight of Aggregate (%)		
	Cement	Emulsion	Water
1	2.6	19.2	6.3
2	2.5	16.3	6.2
3	2.4	13.4	6.0
4	2.4	15.7	2.4
5	2.4	19.5	0
6	2.4	15.9	3.6
7	2.4	19.5	0
8	0	19.0	0
9	3	16	3.5
10	3	16	5
11	3	16	4.5

Future Research

- Observation on sites will continue for another year
  - Percent retention
  - Permeability

- Plans to place more patch materials for observations including:
  - Slurry mix design from laboratory testing
  - Virgin patch material using the recycling machine

- A Best Practice Guide and Simple Decision Tree for field use on basis of the findings of this study

Summary

- Year-1 of observations has been completed at 5 locations.
- Preliminary observations:
  - Fine-aggregate cold mix should be used in potholes with a depth less than 2 inches
  - Patches constructed with hot recycled mixes show rapid aging and ravelling
  - Mastic holds well
  - Mill and fill operations distress quickly and can sometimes create more damage than its benefits
- Laboratory and field testing has been conducted on mix designs with the intent to place and observe in the field during the upcoming year

Thank you for your attention

Questions?

Indirect Tensile Strength Results

Trial	Load (N)	Stress	
		(MPa)	(psi)
7	4,076.70	0.21	30.28
8	2,381.54	0.12	17.59
9	9,798.77	0.54	77.75
10	5,218.20	0.29	42.02
11	7,400.79	0.41	59.31