Evaluation of Rapid-Hardening Cementitious Mixes for Partial Depth Repair of Rigid Pavements

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Outline

- Introduction
- Need for Study
- Desirable Properties and Evaluated Products
- Testing Methodology
- Test Results
- Summary, Conclusions and Recommendations
Partial Depth Repair

- Removal and replacement of small shallow areas of deteriorated PCC pavements at spalled or distressed joints

  § Typically when damage is limited to top 1/3rd of slab and load-transfer devices are functional
Partial Depth Repair Areas

- Spalling that is isolated to the upper portion of the slab and caused by freeze-thaw damage (low air PCC)
- Spalling caused by intrusion of incompressible materials into the joint or crack
- Spalling caused by poor consolidation, inadequate curing or over-finishing
- Spalling caused by localized areas of scaling, weak concrete, clay balls or high steel
- Non-working cracks, either longitudinal or transverse
MnDOT Repair Methods

30° to 60° Angle Small Jack Hammer
2" Min.

Sawcut

30° to 60° Angle Small Jack Hammer or Milled
2" Min.

Sawcut

Dowel Bar

If Dowel Bar is exposed Coat the bar with duct tape for bond breaker

Install Preformed Compression Relief filler prior to Concrete Placement

10" Min.

2" 3" Min.
PDR Patching Related Issues

FHWA/SHRP

§ Thermal incompatibility between the repair material and the pavement

§ Extreme climatic conditions during the life of the repairs that are beyond the capabilities of the repair material.

§ Incompatibility between the joint bond breaker and the joint sealant

§ Inadequate cure time prior to opening repairs to traffic
**Big Picture**

**Expected Outcomes**
- Develop a comprehensive system to evaluate products prior to accepting them as viable options for cold climate PDR
- Establish optimal construction techniques for the placement of the patching materials

**Benefits**
- Longer lasting patches to extend the life of rigid pavements
- Reduce the overall cost of rigid pavement rehabilitation and maintenance
- Faster repair times leading to savings for the end users through reduced delays
Reasons for the Study

- Reduction in the failure rates of patches
- More focused acceptance criteria is needed in colder climates
  - The temperature differential from summer to winter is substantially larger in cold climate regions
  - Florida for instance sees a 70 degree temperature swing throughout the seasons
  - Minnesota’s temperature change averages 120 degrees throughout the seasons
  - Considering thermal deformation, the same slab in Florida expands and contracts only half as much as it would in Minnesota
Desirable Properties

- Fast setting times
  - Open lanes quicker

- Durability
  - Longevity of the patches
  - Cold climate durability

- Bond strength
  - Paramount for patch success
  - Matching thermal properties
Rapid Set Materials (13)

- Portland Cement Based
  - 3U18
  - 3U18M
  - MnDOT District 3 Mix 1
  - MnDOT District 3 Mix 2
  - Rapid Set Concrete Mix
- Magnesium Phosphate Based
  - Mono-Patch
  - Pavemend SLQ
- High Alumina
  - Pavemend SL
- Polymer Modified Cement
  - AKONA Rapid Patch
- Unknown
  - Futura 15
  - Futura 45
  - Five Star Highway Patch
  - TCC Taconite Mix
Research Approach

- Start with comprehensive testing as per ASTM C928
  - Including: Strength gain, shrinkage, adapted bond strength, and freeze-thaw durability
- 4 of the 13 products will be chosen to undergo further evaluation in the next phase of study
Phase I testing

- The compression/strength gain test
  - § ASTM C39
- Length change in air as well as in water
  - § ASTM C596
- Flexural strength presented as the modulus of rupture
  - § ASTM C78
- Freeze-thaw testing
  - § ASTM C666
- Initial and final setting times
  - § ASTM C191, Vicat needle method
- § Adapted bond strength test
  - § Version of the ASTM C900 pull out test
Results: Compressive Strength Gain

- 2U18
- 3U18M
- Akona
- D3-1
- D3-2
- Fivestar
- Futura 45
- Futura 15
- Monopatch
- PaveMend SL
- PaveMend SLQ
- Rapid set
- Normal Concrete
- TCC Taconite

Compressive strength (psi) vs. Days
Results: Shrinkage in air/Expansion in water

Length change

Air limit (-0.15 %)  Water limit (+0.15 %)

3U18
3U18M
Akona
District 3 mix 1
District 3 mix 2
Five star
Futura 15
Futura 45
Mono Patch
Pavemend SL
Pavemend SLQ
Rapid Set Concrete Mix
TCC Taconite Mix

Length Change (%) Water
Length Change (%) Air
Results: Flexural Strength at 4 Hours
Estimated vs. Measured Modulus of Rupture

Modulus of Rupture (psi)

- Estimated Min.
- Measured
- Estimated Max.

3U18, 3U18M, Akona, District 3 mix 1, District 3 mix 2, Five star, Futura 15, Futura 45, Mono Patch, Pavemend SL, Pavemend SLQ, Rapid Set Concrete Mix, TCC Taconite
Results: Mass Loss vs Number of F-T Cycles
Results: RDM vs. Number of F-T Cycles
Freeze-Thaw Durability

![Bar Chart]

- 3U18
- 3U18M
- Akona
- District 3 mix 2
- District 3 mix 1
- Five Star
- Futura 15
- Futura 45
- Mono Patch
- Pavemend SL
- Pavemend SLQ
- Rapid Set Concrete Mix
- Normal Concrete
- Air Entrained (5.5%)
Summary and Conclusions

The estimation method of getting the modulus of rupture may be considered sufficient
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Approximate correlations with compressive strength gave reasonable estimates for 10 out of 13 mixes

Compressive strength data is imperative for patching materials
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3 hour strength dictates the amount of time required to reopen the roadways
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28 day strength is less important but may be an indicator of patch longevity
Summary and Conclusions (cont.)

Setting time measurements are needed to indicate the working times for each product.

Length change is an important property to define a basic component of bonding.
  - For some of the non Portland cement based products unexpected results may be obtained.

Freeze-thaw testing may be the most important of all tests for determining the endurance of patching materials.
  - The cold climate of Minnesota imparts a series of freezing and thawing cycles on patches every year.
**Recommendations**

- Flexural strength can be removed from routine testing regimen
- Compressive strength measurements can be reduced to only recording the 3 hour and 28 day values
- Shrinkage testing should be required
- Freeze-thaw testing should be required
  - Mass loss should also be reported for the duration of the testing
  - Air entrainment strongly recommended for patching materials
- Setting times should be recorded and reported
Future Testing

- Scaling and sulfate resistance
  - ASTM C1012
  - This is an indication of resistance to de-icing agents

- Modulus of elasticity
  - ASTM C469
  - This should match the existing pavement

- Coefficient of thermal expansion
  - ASTM C531
  - This property is important for bond integrity
  - The material must expand and contract at the same rate as the existing pavement
Future Testing (cont.)

§ Abrasion resistance
  § Empirical test used for comparing the products against one another
  § An important property involving friction numbers
  △ These are recommended in the ASTM C-928 but not required for acceptance of the materials
  △ “Pop out” flexural test (proposed by Dr. Eric Musselman)
    § Empirical test simulating loading on patches while slabs are warped/curled
    § Measure of patch de-bonding resistance
“Pop out” Test
Thank you for your attention

Questions?