Retrofit Dowel Bars In Jointed Concrete Pavement - Long Term Performance and Best Practices

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NATIONAL CONFERENCE ON PRESERVATION, REPAIR, AND REHABILITATION OF CONCRETE PAVEMENTS
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Outline

• Background
• Long Term Performance Case Studies
• Minnesota Best Practices
• Construction Issues and Rehabilitation
Background

• One of the major distresses in jointed concrete pavement is joint and or crack faulting
  – Traffic load/volume change (previously undoweled)
  – Excessive panel length (mid-panel cracks)
  – Dowel deterioration (not common)

• Retrofit dowel bars are a proven technique
  – Most research focused on quantity and spacing of bars

• Need to understand longer term performance with respect to backfill material in extreme climates
Long Term Performance Case Studies

**TH 52, Zumbrota, Minnesota**

- First retrofit dowel bar project in state - 1994
- Original 9” thick JRCP pavement constructed in 1984
  - 27 foot long panels, mesh reinforcement across mid-panel cracks
  - Virtually no faulting of mid-panel cracks (10 years old)
  - Transverse doweled contraction joints in good condition
  - HCADT = Approx 2100

- Project objective: To determine if retrofit dowel bars could prevent or slow down faulting of mid-panel cracks
  - No surface grinding necessary (no faulting yet)
Long Term Performance Case Studies

TH 52, Zumbrota, Minnesota

• **Design variables**
  - Backfill mortar type
    - Polymer-modified quickset patch (PMQP) material
    - Mn/DOT 3U18 patch mix
  - Saw and chip slotting method
  - Two dowel bar sizes
    - 1.5 inch dia. x 15 inch long
    - 1.5 inch dia. x 18 inch long
  - Various retrofit dowel bar placement patterns
Long Term Performance Case Studies

TH 52, Zumbrota, Minnesota
Long Term Performance Case Studies

*TH 52, Zumbrota, Minnesota*

- **Observed Performance (14 years after retrofit)**
  - Faulting of mid-panel cracks minimal (avg = 1.7 mm)
  - Small number of distressed retrofit dowel bar slots caused by longitudinal cracking
  - Backfill material performance very good
    - PMQP had some loss of material near surface
    - Mn/DOT 3U18 patch mix good despite early shrinkage cracking around slots
  - LTE (2006)
    - 60 to 80 percent
Long Term Performance Case Studies

*TH 52, Zumbrota, Minnesota*

13 years old

Longitudinal panel crack
Long Term Performance Case Studies

*TH 52, Zumbrota, Minnesota*

13 years old

Mn/DOT 3U18

PMPQ
Long Term Performance Case Studies

*TH 52, Zumbrota, Minnesota*

13 years old

Faulted mid-panel crack
Long Term Performance Case Studies

TH 12, Willmar, Minnesota

- Retrofit in 1996
- Original 8” thick JPCP pavement constructed in 1981
  - 15 foot long panels, undoweled transverse joints
  - Substantial faulting in outside wheel tracks (15 years old)
  - Wide joint openings (up to 1.25 inch)
  - HCADT = Approx 600

- **Project objective:** To determine if retrofit dowel bars and surface grinding could extend service life
Long Term Performance Case Studies

TH 12, Willmar, Minnesota

• Design variables
  ▪ Backfill mortar type
    – Mn/DOT 3U18 patch mix
  ▪ Slots established using milling machine
  ▪ Dowel bar size
    – 1.5 inch dia. x 18 inch long
  ▪ Two retrofit dowel bar placement patterns
Long Term Performance Case Studies

TH 12, Willmar, Minnesota

![Diagram showing Taper Sections and Typical sections with traffic directions.]
Long Term Performance Case Studies

TH 12, Willmar, Minnesota

• Observed Performance (12 years after retrofit)
  ▪ Faulting of transverse joints minimal (avg = 1.5 mm)
  ▪ Backfill material performance good
    – Minor surface distress in slots near joint
    – May be linked to milling process
  ▪ LTE (2006)
    – 51 to 65 percent
Long Term Performance Case Studies

TH 12, Willmar, Minnesota

12 years old

Backfill mortar distress near joint
Long Term Performance Case Studies

TH 23, Mora, Minnesota

• Retrofit in 1998
• Original 9-7-9” thick JPCP pavement constructed in 1952
  ▪ 16 foot long panels, undoweled transverse joints
  ▪ Substantial faulting in outside wheel tracks (46 years old)
  ▪ Wide joint openings (no aggregate interlock)
  ▪ HCADT = Approx 500

• Project objective: To determine if retrofit dowel bars and surface grinding could extend service life of a very old pavement
Long Term Performance Case Studies

TH 23, Mora, Minnesota

- **Design variables**
  - Backfill mortar types
    - Rapid Set Mortar (RSM)
    - Mn/DOT 3U18 patch mix
  - Saw and chip slotting method
  - Two dowel bar size
    - 1.5 inch dia. x 15 inch long
    - 1.5 inch dia. x 13 inch long
  - Various retrofit dowel bar placement patterns
### Long Term Performance Case Studies

**TH 23, Mora, Minnesota**

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**Traffic Directions:**
- **Left Traffic:** Section 1a to Section 1c
- **Right Traffic:** Section 1b & d to Section 1c
Long Term Performance Case Studies

*TH 23, Mora, Minnesota*

- **Observed Performance (10 years after retrofit)**
  - Faulting of transverse joints minimal (avg = 0.5 mm)
  - Backfill material performance very good
  - LTE (2006)
    - 64 to 80 percent
Long Term Performance Case Studies

TH 23, Mora, Minnesota

8 years old

Mn/DOT 3U18 backfill mortar
Long Term Performance Case Studies

I-90, Beaver Creek, Minnesota

• Retrofit in 1999
• Original 9” thick JRCP pavement constructed in 1984
  ▪ 27 foot long panels, mesh reinforcement across mid-panel cracks
  ▪ Significant faulting of mid-panel cracks (15 years old)
  ▪ Transverse doweled contraction joints in good condition
  ▪ HCADT = Approx 1200

• Project objective: To determine if retrofit dowel bars and surface grinding could restore ride quality and slow down redevelopment of mid-panel crack faulting
Long Term Performance Case Studies

I-90, Beaver Creek, Minnesota

- **Design variables**
  - Backfill mortar type
    - PMPQ patch mix
  - Saw and chip slotting method
  - Dowel bar size
    - 1.5 inch dia. x 15 inch long
  - Two retrofit dowel bar placement patterns
Long Term Performance Case Studies

_I-90, Beaver Creek, Minnesota_

- **Observed Performance (9 years after retrofit)**
  - Faulting of mid-panel cracks minimal (avg = 0.3 mm)
  - Backfill material performance very good
  - Some slot distresses caused by transverse and longitudinal panel cracking after retrofit installation
  - LTE (2006)
    - 70 to 89 percent
Long Term Performance Case Studies

• Summary
  ▪ Retrofit dowel bar applications:
    – Prevention of faulted mid-panel cracks
    – Structural capacity improvement
    – Extension of service life (for very old pavement)
    – Restoration of ride quality
Conclusions

- Effective in preventing faulting of mid-panel cracks
- Effective in extending service life of previously undoweled joints
- Surface grinding critical to performance of retrofit dowel bars
- Fairly insensitive to various dowel patterns and bar length
- Good performance from most backfill materials
- Milling not recommended for slot formation
Minnesota Best Practices

• Development issues
  ▪ Economical construction
  ▪ Long-term durability in extreme climate

• Slot formation
  ▪ Saw and Chip recommended
  ▪ Milling quicker, but long-term performance not as good

• Dowel bar length
  ▪ 1.25 inch dia x 15 inch long recommended
  ▪ Minne-ALF testing demonstrated that bar lengths down to 13 inches perform satisfactorily (= shorter slots)
Minnesota Best Practices

- **Dowel bar placement**
  - Faulting near outer wheelpath
    - 3 dowels outer wheel track
  - Faulting across entire joint/crack
    - 3 dowels outer wheel track, 2 dowels inside wheel track
  - Adjust for traffic volume (example: passing lane)
    - 2 dowels outer wheel track, 2 dowels inside wheel track
  - Center groups of bars within wheel track (12 inches on center)
  - Install so embedment length is equal across joint or mid-panel crack

Note: Two dowels in a wheel track are as efficient as three, however joint deflections increase (Minne-ALF results)
Minnesota Best Practices

- Dowel bar design

Shallower cover has been found to work successfully (Minne-ALF)
Minnesota Best Practices
Minnesota Best Practices

• Construction Method

  ▪ Mn/DOT requires contractor to construct a small test section
    – 24 retrofit dowels in test area
    – 24 hours after retrofit installation, three 6 inch diameter cores taken and inspected
  • Continuity at dowel/concrete interface and consolidation beneath dowel
  • Check that dowel supports do not collapse
  • Check bond between backfill mortar and slab
    – Paid for at unit price
Construction Issues

Honeycombing of backfill mortar ➤ Switched mortar type
Rehabilitation of Retrofit

Age = Approximately 5 years
Rehabilitation of Retrofit

Lakeland Rest Area

Age = Approximately 5 years
Thank you

QUESTIONS?