The National Academies of
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TRANSPORTATION RESEARCH BOARD

Rigid Pavement Rehabilitation: Looking Back, Looking Forward

Tuesday, September 5, 2017
1:00-3:00 PM ET

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.

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REGISTERED CONTINUING EDUCATION PROGRAM

Purpose

Examine how rigid pavement rehabilitation has evolved over the last several decades, and also looks towards the future with highlights of some new and innovative rehabilitation solutions.

Learning Objectives

At the end of this webinar, you will be able to:

- Discuss early experiences with rigid pavement rehabilitation
- Describe common rigid pavement rehabilitation treatments
- Identify critical elements of design and construction of various rigid pavement treatments
- List new and evolving methods of rehabilitating rigid pavements

Past, Present, and Future of Rigid Pavement Rehabilitation

Michael I. Darter

Applied Research Associates, Inc.

Emeritus Prof. Civil Engineering, UIUC

5 September 2017

In the beginning…..

- Concrete pavement design, materials, construction, and truck traffic estimation in 60's through 80's+ had many major flaws that led to many types of early deterioration.
  - **All pavement types:** PCC durability, underestimation of truck loads and volume, erodible bases, construction issues.
  - **JPCP:** Lack of dowels, too long joint spacings, no tied shoulders, no subdrainage
  - **JRCP:** Inadequate reinforcement, long joint spacing & joint deterioration
  - **CRCP:** Inadequate reinforcement, lots of reinforcement construction issues.
- **These flaws led to lots of pavement deterioration that** began in the 1970's and increased over time, which sparked a **great need for rehabilitation to this day**.

My Introduction to Rehab….

- Visit to Illinois DOT in early 1970s to identify pavement problems that needed solutions. Everyone said “repair of CRCP!”
- IDOT provided funding for several years which supported numerous bright students to address rehab of CRCP.
- This proved to be a very challenging problem, but we made progress & advanced the SOA and practice with standards that are still used today.

3R and 4R Programs

- Beginning in the mid-1970s, a major Federal initiative was undertaken to fund the rehabilitation of Interstate pavements.
- Initially termed the “3R” (restoration, resurfacing, and rehabilitation) program.
- Expanded later to include reconstruction, and called the 4R program.
- Generated lots of R&D and training resulting in a major impact to help highway agencies maintain their pavements.

NCHRP 1-21 Rehabilitation of Concrete Pavement, early 1980s

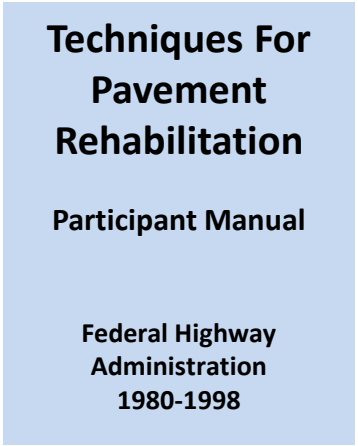
- **NCHRP 1-21: Academic (University of Illinois) and contractors/industry (ACPA)** teamed up and developed first comprehensive procedures for seven rehabilitation treatments (NCHRP #281):
  - Full-Depth Repair
  - Partial-Depth Repair
  - Subsealing
  - Diamond Grinding
  - Joint sealing
  - Dowel Bar Retrofit
  - Edge support Retrofit

FHWA Sponsored R&D Studies 1985-1990+

- **FHWA sponsored R&D** 1985-1990s to improve rehabilitation techniques
  - Field surveys of many rehab projects, analysis of results, improvements to techniques
  - Topics:
    - Restoration techniques
    - Thin bonded and unbonded PCC Overlays of PCC pavements.
    - AC and PCC Overlays of fractured slabs.
    - Saw and seal of AC Overlays of PCC pavements.

NHI/FHWA Techniques for Pavement Rehabilitation Training Course

- **Training Course** developed & presented several times in every States (200+).
- **Comprehensive Manual p**repared & revised over and over: 1980, 1982, 1984, 1987, 1993, 1998
  - ✓ **Pavement Evaluation** of JPCP, JRCP, CRCP, HMA pavements
    - Condition survey
    - NDT and interpretation
    - Coring and lab testing
    - Drainage
    - Traffic
    - Overall evaluation



NHI/FHWA Techniques for Pavement Rehabilitation Training Course

- ✓ **Rehabilitation** of JPCP & CRCP & JRCP
  - Full-depth repair
  - Partial-depth repair
  - Joint resealing
  - Slab stabilization and jacking
  - Joint/crack load transfer restoration
  - Grinding
  - Grooving
  - Pressure relief joints
  - Subdrainage
  - Recycling Concrete pavement
  - Shoulder rehabilitation with PCC
  - PCC unbonded overlay
  - PCC bonded overlay
  - AC overlay intact PCC, fractured PCC
  - Selection of preferred rehabilitation

Techniques For Pavement Rehabilitation

Participant Manual

Federal Highway Administration
1980-1998

Other State, NCHRP, FHWA, & Industry Rehabilitation Studies & Guidelines (90s-Today)

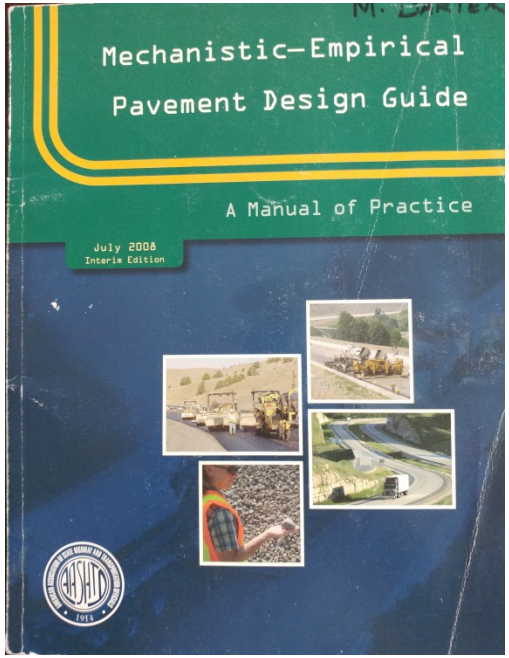
- **States** (Wisconsin FDR JPCP, Illinois FDR CRCP, KS Cross-stitching, Colorado BCOA, current Missouri: 6 repair types, etc.)
- **SHRP** (H-106 Spall Repair, Early Opening PCC repairs, PDR, etc.)
- **FHWA/LTPP** (CPR Techniques, Precast Concrete Repairs, PCC OLs, Strategy Selection Guide, etc.)
- **ACPA/IGGA/Nat'l Center:** Cross stitching, diamond grinding, DBR, many other restoration treatments; PCC overlays on PCC and AC pavements, etc.

AASHTO 1986/93 Part III Rehabilitation Design

- Evaluation existing pavement
- Restoration for JPCP
- Unbonded PCC overlay of existing PCC
- Bonded PCC overlay of existing PCC
- AC overlay of PCC and fractured PCC

AASHTO Pavement ME Design 2008+

- Evaluation existing pavement
- Restoration for JPCP
- JPCP & CRCP Unbonded overlays of PCC
- PCC bonded overlay of JPCP & CRCP
- AC overlay of JPCP & CRCP and fractured PCC
- Conventional joint space (12x15) JPCP bonded overlay of AC pavement
- Short Joint Spacing (6x6) Bonded SJPCP overlay of AC pavement (portion of BCOA University of Pittsburgh)

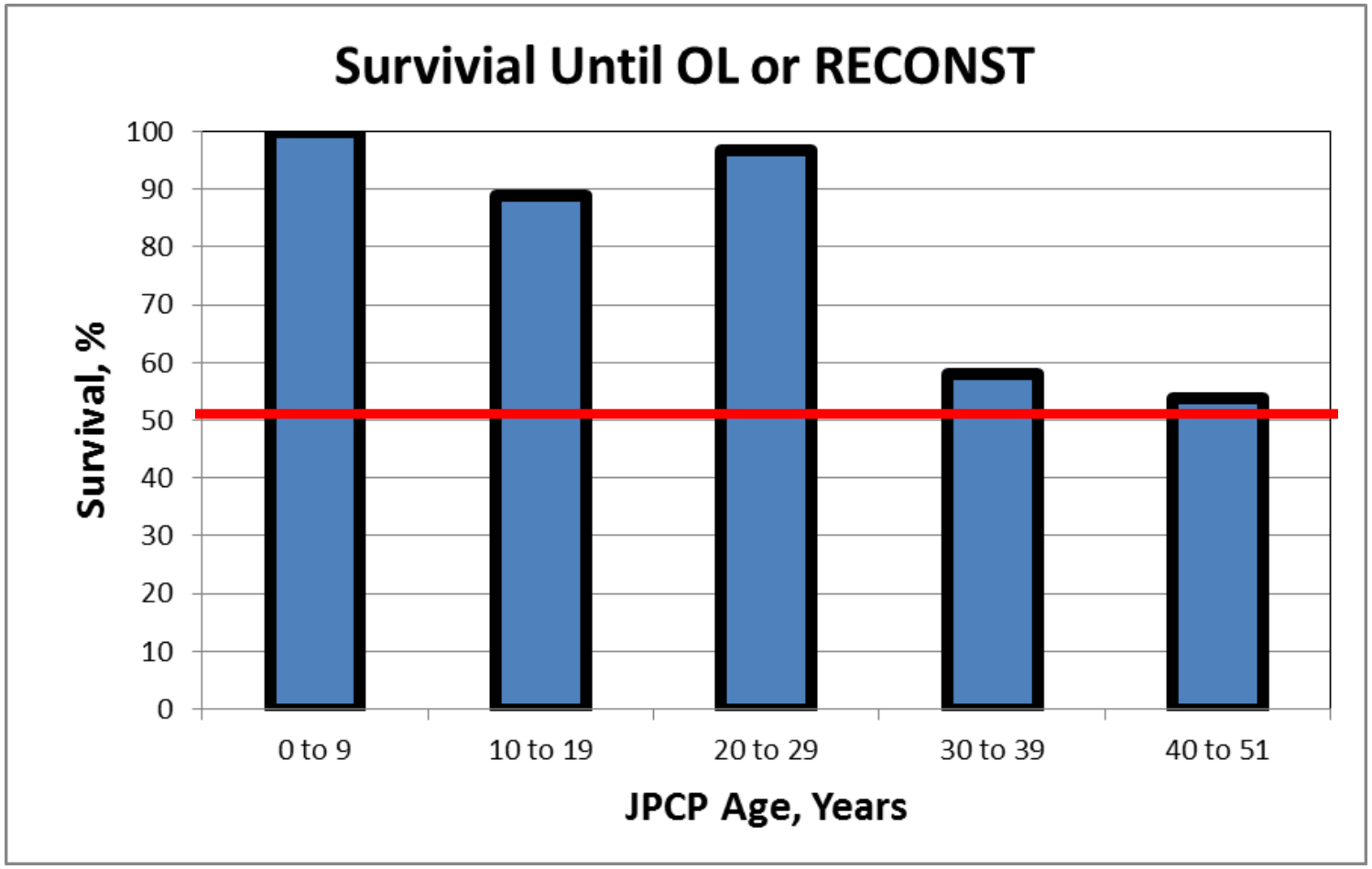


In the future ……

- **Good news:** Many design, construction, and materials problems have been reduced, thus, reduced need for rehabilitation of better designed and constructed PCC pavement.
  - Utah survival study illustration

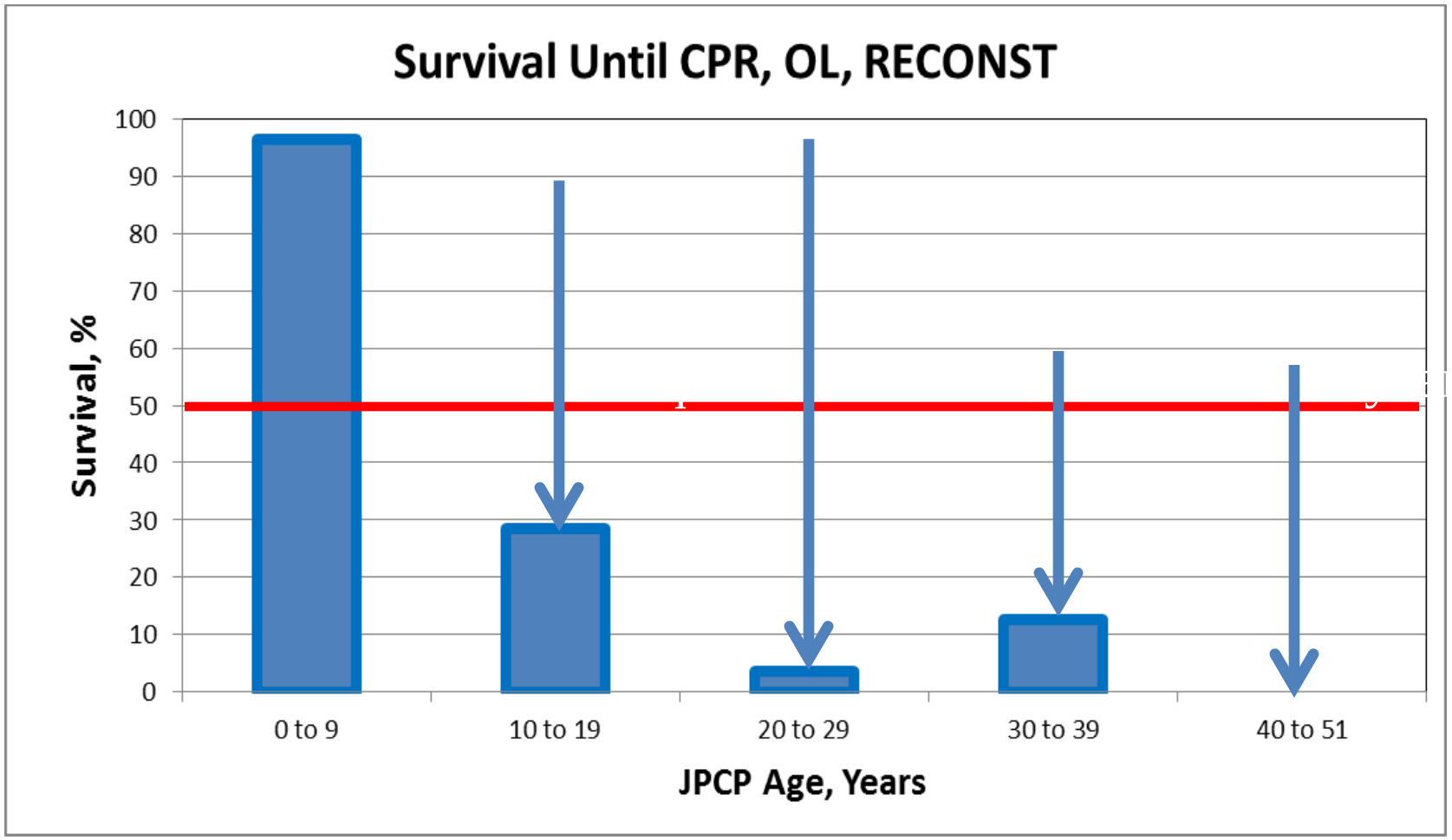
Utah JPCP Survival

(108 Projects 1964-2015)



Utah JPCP Survival

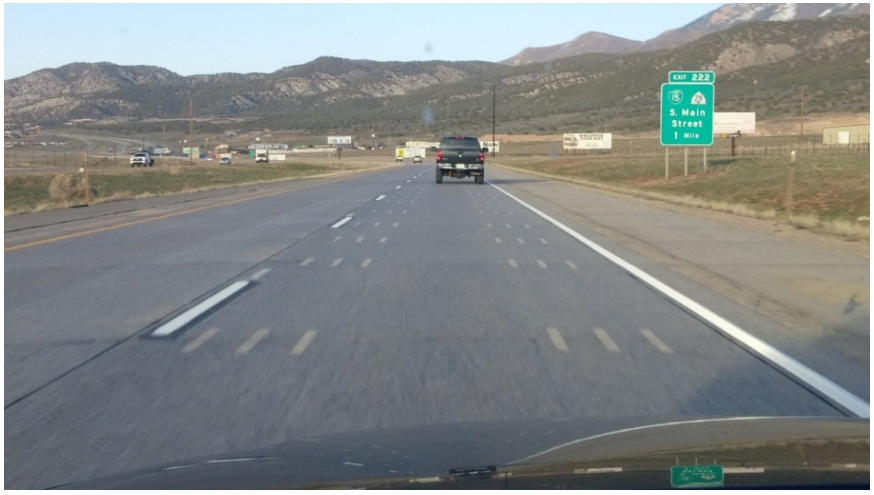
(108 Projects 1964-2015)



Utah JPCP Survival

(108 Projects 1964-2015)

- 50 percent of JPCP required CPR at **10 to 19 years.**
- Without CPR preservation, 50 percent of JPCP would not survive **41 to 51 years** w/o Overlay/Reconstruction
- **CPR techniques** played a major role in more than doubling JPCP 20-year service life!



Utah JPCP Survival

(108 Projects 1964-2015)

- **Primary reason for rehab** need was lack of dowel bars & tied shoulders resulting in **joint faulting**.
- **Dowels & shoulders required since late 1990s. Survival will increase. Rehab needs will decrease over time!**

Recent State/Contractor Survey on CPR

[GA, CA, WA, UT, MO, MN, KS]

- **State Specs** have greatly improved!
- **Inspection** has improved, still deficient!
- **Experience** of State and Contractors have greatly improved. More training needed!
- **Survival** has increased for diamond grinding, full depth repair, partial depth repair, dowel bar retrofit, cross stitching, and slab stabilization.

Recent State/Contractor Survey on CPR

[GA, CA, WA, UT, MO, MN, KS]

- **Diamond grinding:**
  - 10-15 years (non-doweled) (I-10 CA project: 4 CPRs)
  - 15-30 years (doweled)
- **Full depth repair:** 10-20+ years
- **Partial depth repair:** 5-15 years
- **Dowel bar retrofit:** 10-22+ years
- **Cross stitching:** 10–20+ years
- **Slab stabilization:** 5-15 years

In the future ……

- **Needs: More RAPID & LONG LASTING concrete pavement rehabilitation.**
- **How to accomplish this goal? Today's speakers!**
  - **Provide more training** on rehabilitation to Agencies (engineers, inspectors), Contractors, etc.
  - Improved **acceptance procedures (incentives based)**.
  - Improved tools for **pavement evaluation** (correctly identify problems, specify required repair)
  - Improved **repair materials** (**rapid opening to traffic AND long life**)
  - Improved **repair techniques (performance feedback)**

TRB Webinar: Rigid Pavement Rehabilitation – Looking Back, Looking Forward

DOT Perspective on Rigid Pavement Rehabilitation

September 5, 2017

John Donahue, P.E.
Missouri DOT

Mechanisms for Performing Rehabilitation

- Construction contract
  - Defined quantities and scope (traditional)
  - Regional on-call
- Maintenance

CPR Project Development

- Initial scoping 1-3 years before letting
- Project put on State Transportation Improvement Program (STIP)
- Commitment to estimated budget

Project Designer Responsibilities

- Field measure quantities
- Locate repair locations by logmiles, geospatial coordinates, stations, etc.
- Build in tolerable overrun quantities
- Develop project-specific special provisions

Specification Guidance

- Design standards s*hould* apply to DOT maintenance and contracting industry equally

- Construction specifications, standard drawings and contract special provisions should not conflict

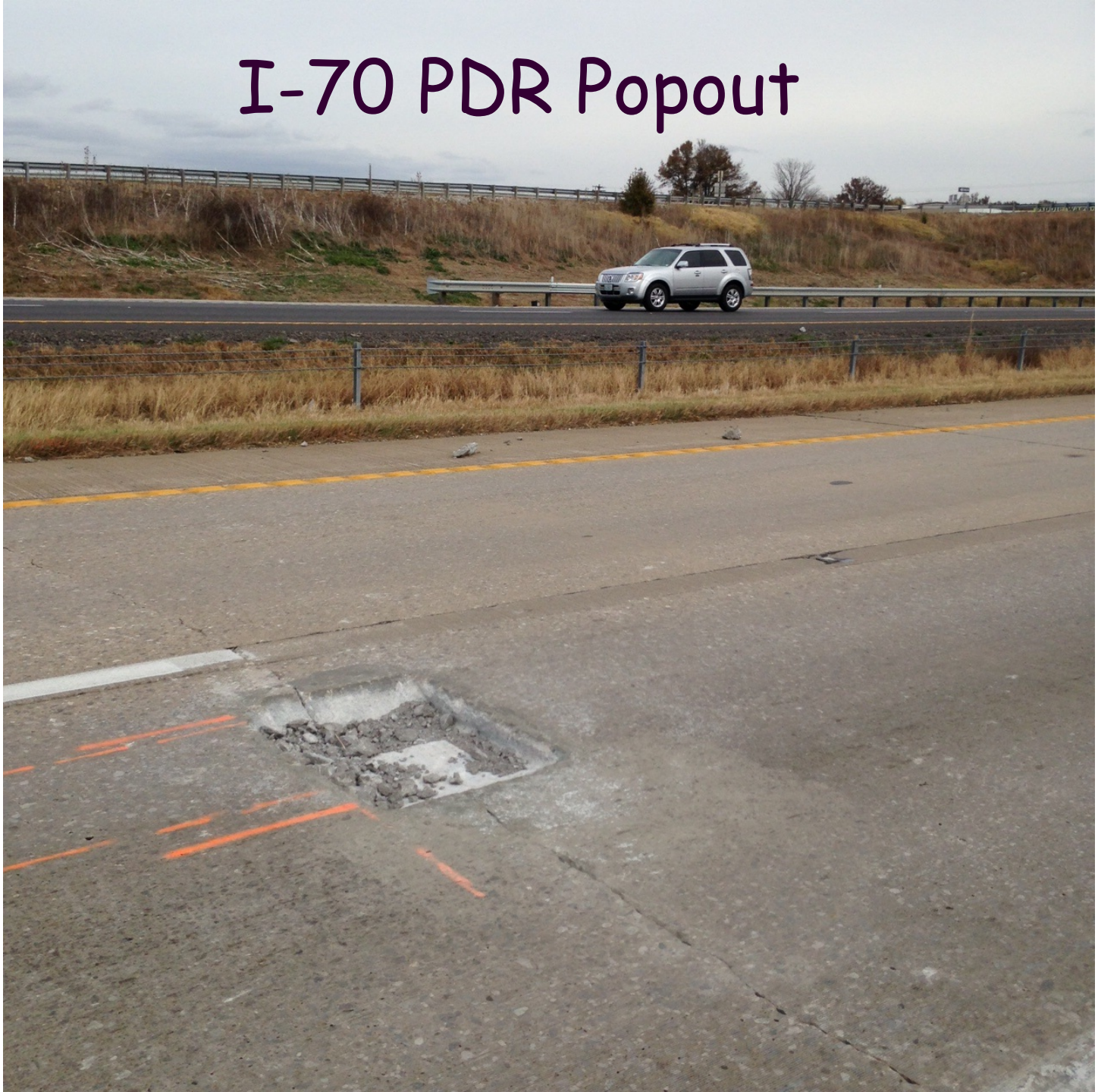
Specification Guidance

- Use performance-based language to degree possible
- Require performance evaluation period for critical repairs
- Consider declaring CPR failures ‘unacceptable’ and let contractor propose mitigation methods

Communication During Construction

- Don’t assume contractor has read the specs - clearly explain repair expectations at pre-activity meeting
- Request schedule updates
- Define critical hold points

I-70 PDR Popout




Ten-year old DBRs
in St. Louis

Inspector Responsibilities

- Re-measuring field quantities
- Marking repair locations
- Changing repair types and quantities
- Watching…


RAISERITE

On-Call Contracting

- Allows flexibility in timing and geographical limits
- Fixed prices with unit multipliers
- Can significantly underrun with no price renegotiation

Maintenance Repairs

- Utilizing existing resources
- Cost-effective in certain situations
- Most maintenance workers have limited experience with concrete pavement repair techniques, but…
- …they are innovative

Typical Maintenance Experience

- Full depth repairs – likely
- Partial depth repairs – less likely
- Undersealing – dying art
- Cross-stitching – unlikely
- Dowel bar retrofit – unlikely
- Diamond grinding - none

Maintenance FDR

Maintenance DBR

Maintenance
Cross-stitching

Non-Traditional CPR Applications

- Rehabbing smaller panel concrete overlays
- Converting larger panel pavements to smaller panels.

FDRs in Kansas City intersection 4′ x 4′ BCOA

Converting I-35 JPCP unbonded overlay to 'big block'.

Thank you!

john.donahue@modot.mo.gov

Transportation Research Board Webinar
September 5, 2017

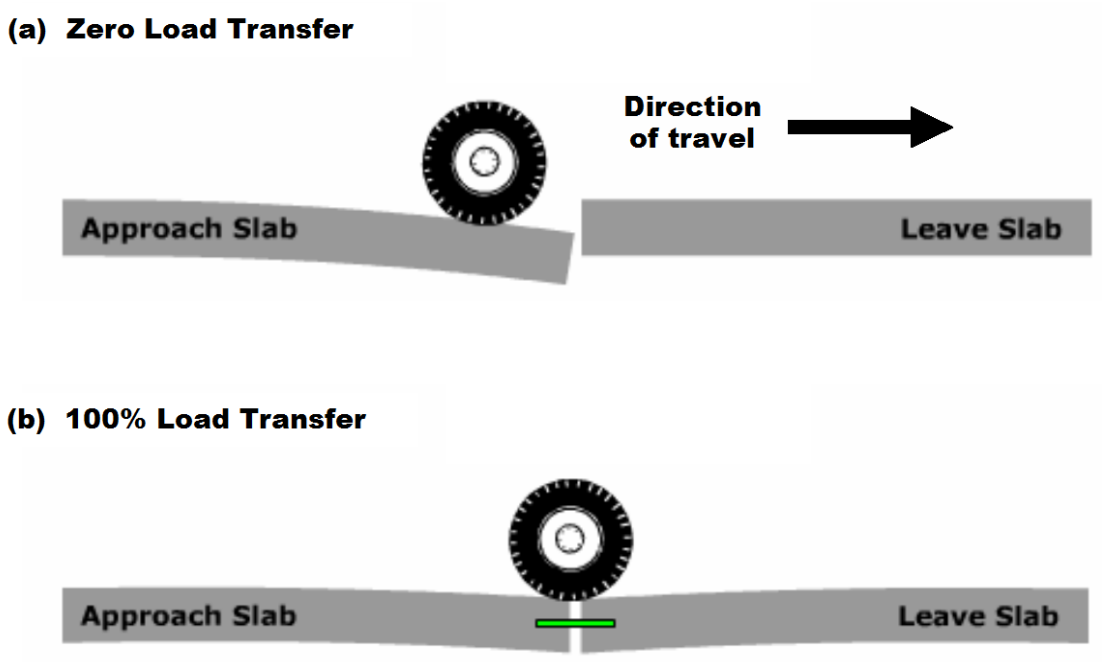
Rigid Pavement Rehabilitation: Looking Back, Looking Forward
Sponsored by Committee* AFD50, Design and Rehabilitation of *Concrete Pavements

Load Transfer Restoration

Linda Pierce
NCE
Spokane, Washington

Load Transfer Restoration

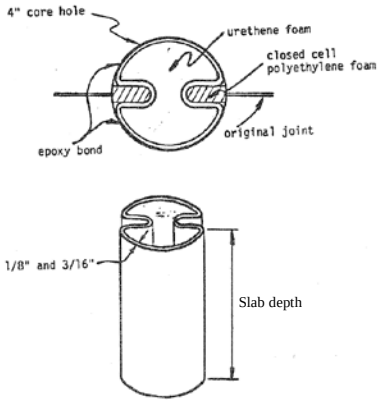
- Restore load transfer at transverse joints and cracks
- Insert mechanical device



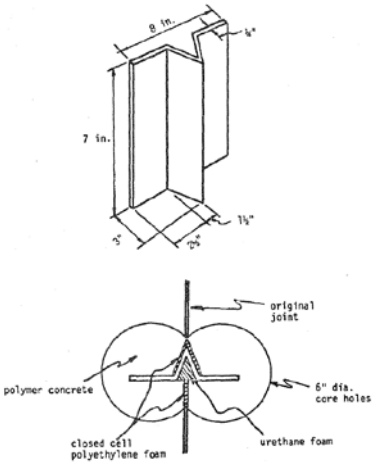
Muench, et al. (2005)

LTE Devices

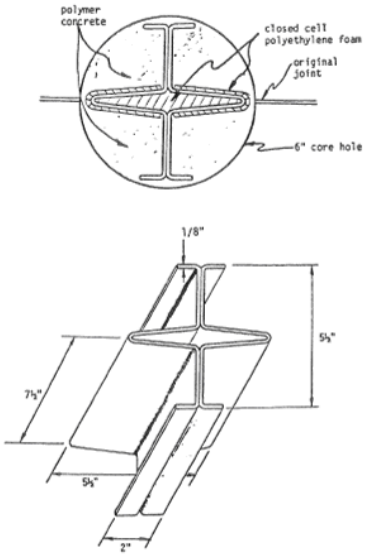
Figure Eight



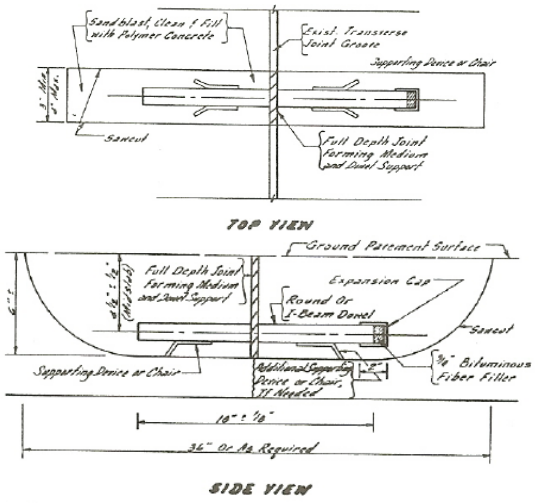
Vee



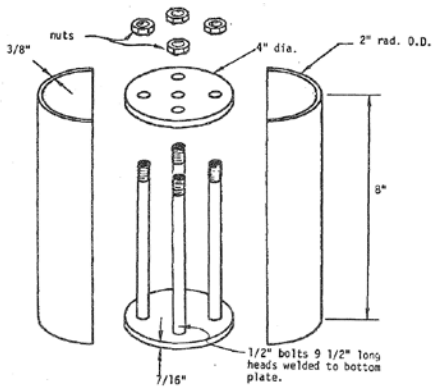
Double Vee



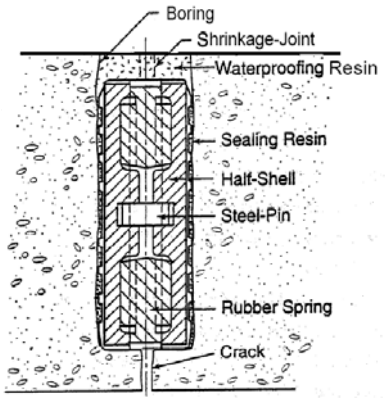
Miniature I-Beam



Georgia Split Pipe

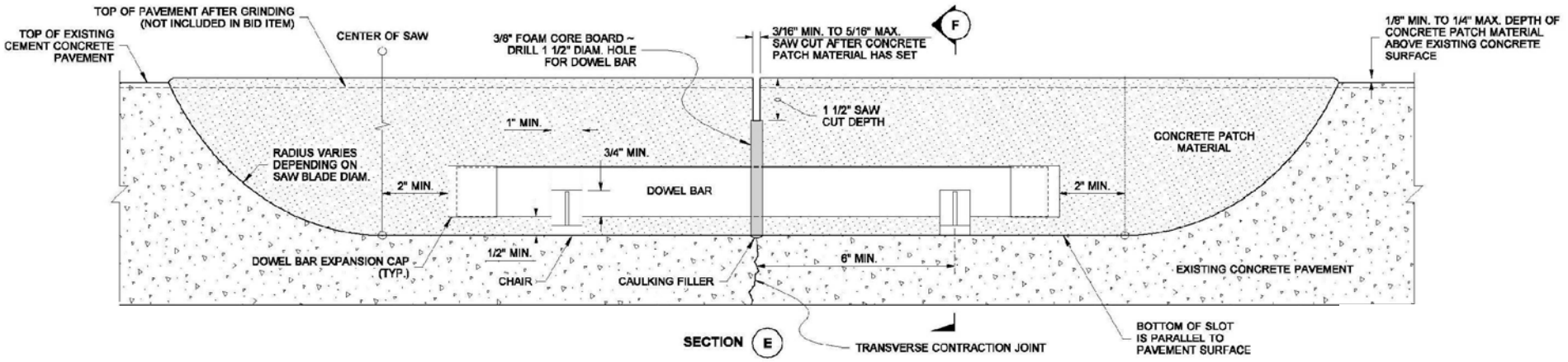


Freyssinet Connector



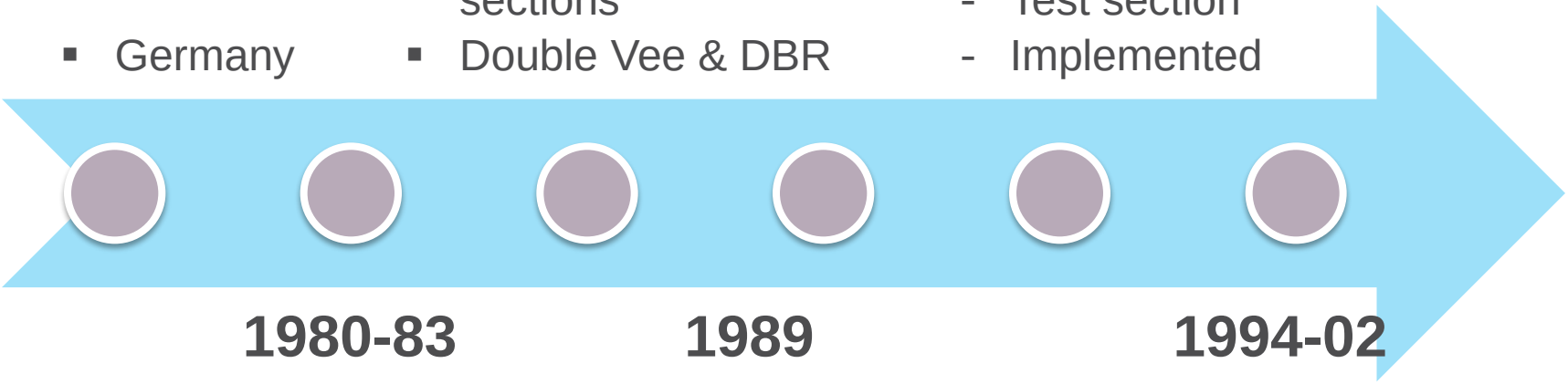
LTE Devices *(continued)*

Dowel bar retrofit (DBR)



DOWEL BAR PLACEMENT DETAIL

Where We've Been



1975

- Germany

1980-83

- Puerto Rico
  - Test section
  - Implemented

1981-86

- CO, FL, GA, IL, KS, LA, OH, NY, and PA test sections
- Double Vee & DBR

1989

- Snyder et al. identified DBR provided best results

1992-93

- WA
  - Test section
  - Implemented

1994-02

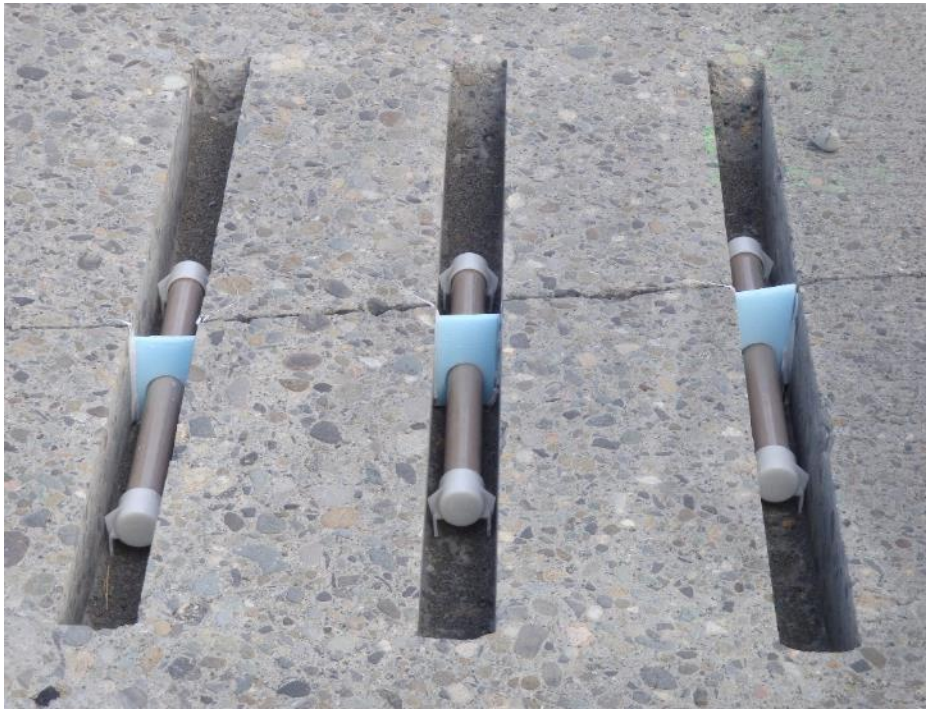
- CA, MI, MN, ND, and WI
  - Materials
  - No. Bars
  - Length

Project Selection

- No ASR, ACR, or D-cracking
- Structural integrity
- Successful & cost effective when:
  - LTE < 60 percent
  - Faulting < 0.5 inch
  - < 10% slabs with multiple cracks

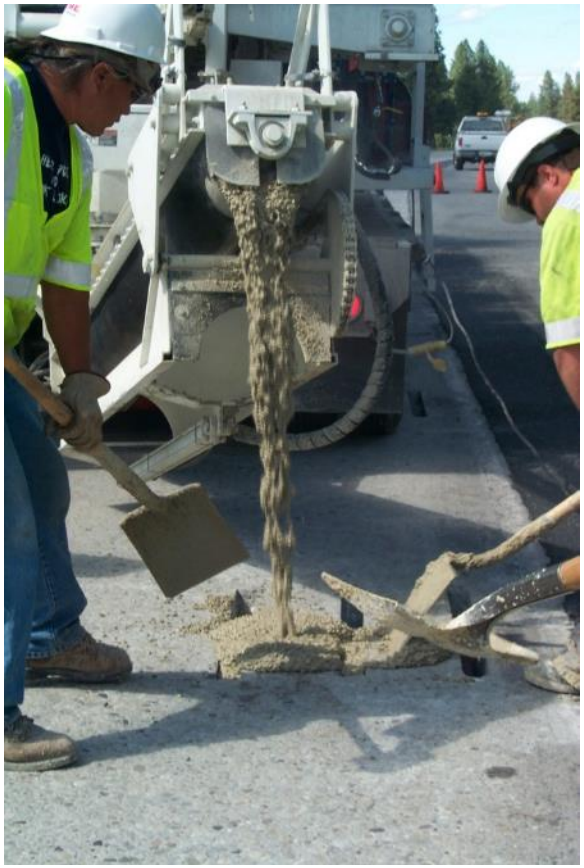
Material Selection

- Dowel Assembly
  - Dowel bars
  - Bond breaker
  - Expansion caps
  - Support chairs
  - Foam core insert
  - Caulking filler



Material Selection *(continued)*

- Backfill Material
  - Compressive strength
    - 3000 psi (min. 3-hour)
    - 5000 psi (min. 24-hour)
  - Scaling: 2 or less (visual)
  - Shrinkage: < 0.13% (4-day)
  - Durability Factor: > 90% (300 FT cycles)
  - Bond strength: > 1000 psi (24-hour)



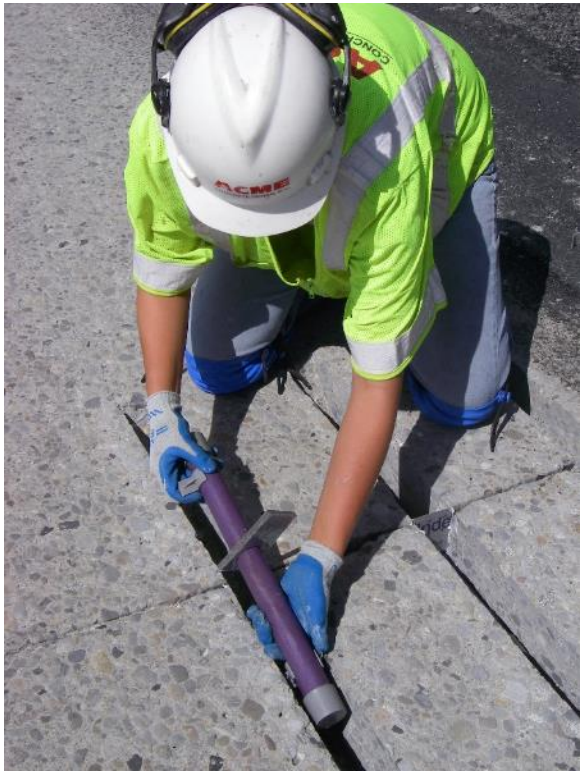
Construction

Construction *(continued)*

Construction *(continued)*

Construction *(continued)*

Construction *(continued)*



Construction *(continued)*

Watch for…

Epoxy coating quality

Backfill material consolidation

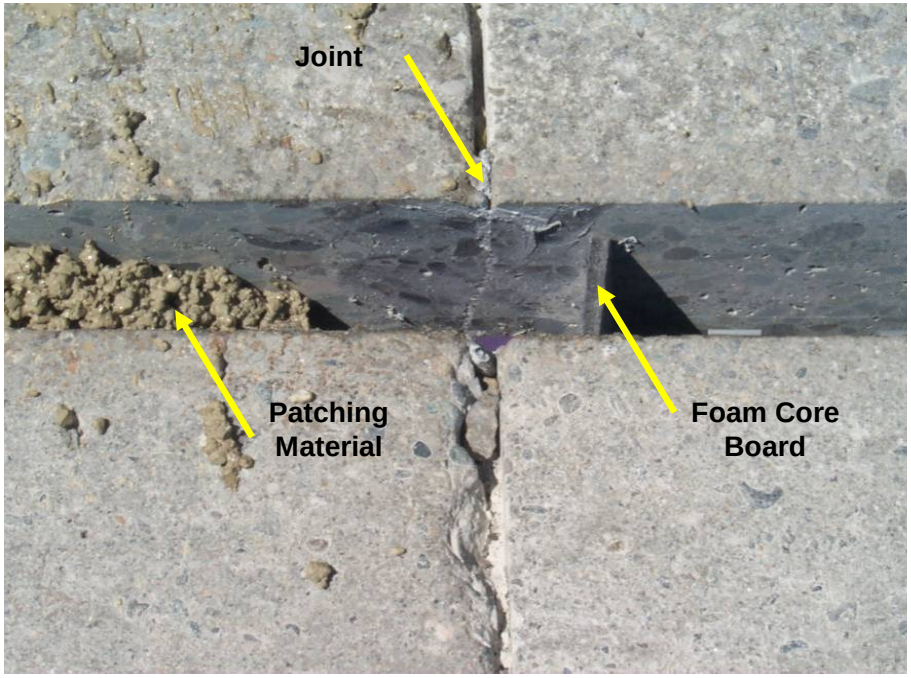
Depth of sawcut / jackhammer weight

Watch for... *(continued)*

Remove water prior to placing backfill material

Cut slots parallel to centerline

Watch for... *(continued)*



Align foam core board with joint or crack

Foam core board misalignment

Watch for... *(continued)*

Longitudinal crack intersects dowel bar slot

Avoid longitudinal cracks

Watch for... *(continued)*

Prior to cleaning

After cleaning

Performance

- Viable treatment
- 10+ years
  - Fault < 1/8” 15+ years
- Key activities:
  - Slot cleanliness
  - Foam core board alignment
  - Patching material consolidation

Future Efforts

- Improved patching materials
  - More robust and forgiving
- Automated installation equipment
  - More effectively cut, install, and backfill
  - Smaller, shallower, and shorter dowels
- Thin section DBR for low volume roads
  - Configurations and applications

Courtesy: John Roberts
Executive Director
International Grooving and Grinding Association

Concrete Overlays – Looking Back, Looking Forward

Tom Burnham, P.E. | Senior Road Research Engineer, Minnesota Department of Transportation

TRB Webinar: Rigid Pavement Rehabilitation: Looking Back, Looking Forward

9/5/2017

Topics

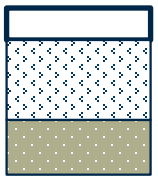
- **Concrete Overlay Types**
- **Typical Applications**
- **Design Features**
- **Failure mechanisms**
- **Design procedures**
- **Future trends**

Acknowledgements

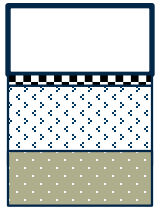
- **ISU-CPtech Center - Guide to Concrete Overlays: Sustainable Solutions for Resurfacing and Rehabilitating Existing Pavements (3rd edition)**
- **MnROAD Staff**

Concrete Overlay Types

- **Bonded Concrete Overlays on Concrete Pavement (BCOCP)**
  - New concrete layer placed directly on existing concrete pavement
  - Relies on bond for structural integrity
  - Not common

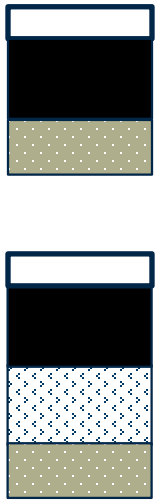


- **Unbonded Concrete Overlays on Concrete Pavement (UCOCP or UBOL)**
  - New concrete layer placed on interlayer placed on existing concrete or composite pavement
  - Interlayer can be new asphalt, fabric, or existing asphalt overlay on concrete (composite)
  - Have typically been same thickness as concrete pavement on gravel base materials



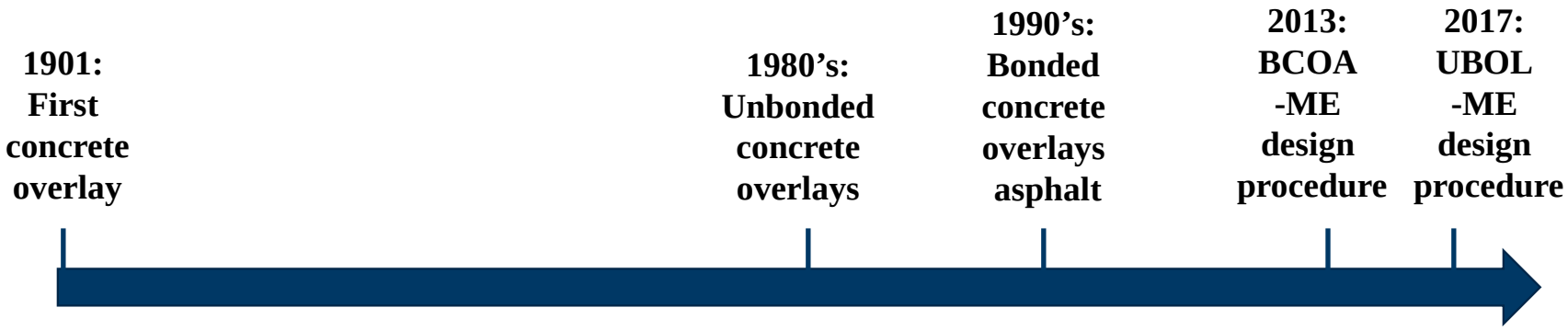
Concrete Overlay Types

- **Bonded Concrete Overlays on Asphalt Pavement (BCOA or "Whitetopping")**
  - **New concrete layer placed on existing asphalt pavement or thick asphalt overlay on concrete (composite pavement)**
  - **Existing asphalt often milled to enhance bond**
  - **Tend to be thinner to keep costs competitive**



COMPOSITE

Concrete Overlay Timeline



- **Application of concrete overlays coincides with needs on roadway networks**
- **Improvements in design procedures coincide with increased experience and significant advancements in computing power**

Unbonded Concrete Overlays on Concrete

- **Typical Applications**
  - **Medium to high volume highways**

Urban highway (9” thick) UBOL

State highway (6” thick) UBOL

Unbonded Concrete Overlays on Concrete

- **Design Features**
  - Most are jointed plain concrete, also CRCP
  - Common design thickness range: 6” – 10” (150-250 mm)
  - Current trend toward thinner sections (5” in service, 3” research sections)
  - Typical panel sizes: similar to standard concrete pavement (smaller panels for thinner slabs)
  - Transverse joints of thicker UBOLs are often doweled
  - Common interlayer materials:
    - Dense graded hot-mix asphalt
    - Permeable asphalt
    - Existing milled asphalt
    - Non-woven geotextile fabric (recent trend)

Unbonded Concrete Overlays on Concrete

- **Failure Mechanisms**
  - Longitudinal and corner cracking (no reflective cracking)

Unbonded Concrete Overlays on Concrete

- **Failure Mechanisms**
  - **Joint Faulting: Undoweled on dense graded HMA interlayer**

Unbonded Concrete Overlays on Concrete

- **Design Procedures**
  - **AASHTO (older and current Pavement-ME)**
  - **Army Corps of Engineers (COE) Rigid Overlays for Airfields**
  - **Portland Cement Association (PCA) Method**
  - **Minnesota Department of Transportation Method: Average of COE and PCA**
  - **FAA Rigid Overlays for Airfields**
  - **Ohio Department of Transportation Method**
  - **MEPDG**
  - **Pooled Fund TPF 5(269) "UBOL-ME" (not official name, available in 2018)**

Bonded Concrete Overlays on Asphalt

- **Typical Applications**
  - **Low to medium volume city streets, county roads and state highways**

Low volume rural (4” thick) BCOA

Lower volume interstate (6” thick) BCOA

Bonded Concrete Overlays on Asphalt

- **Design Features**
  - **Most are jointed plain concrete (some fiber reinforced)**
  - **Common design thickness range: 3” – 7” (75-180 mm)**
  - **Typical panels sizes: 6’ x6’, 12’ x 12’**
    - **Other panels sizes: 2’x2’, 3’x3’, 4’x4’, 7’x7’, 10’Lx12’W, 15’Lx12’W**
  - **Often placed on milled asphalt surface**

Bonded Concrete Overlays on Asphalt

- **Failure Mechanisms**
  - **Longitudinal cracking**
  - **Corner cracking (if wheel loads close to longitudinal joints)**

Bonded Concrete Overlays on Asphalt

- **Failure Mechanisms**
  - **Joint faulting: large and small panels**

Bonded Concrete Overlays on Asphalt

- **Failure Mechanisms**
  - **Panel Migration (also observed in Illinois)**

Bonded Concrete Overlays on Asphalt

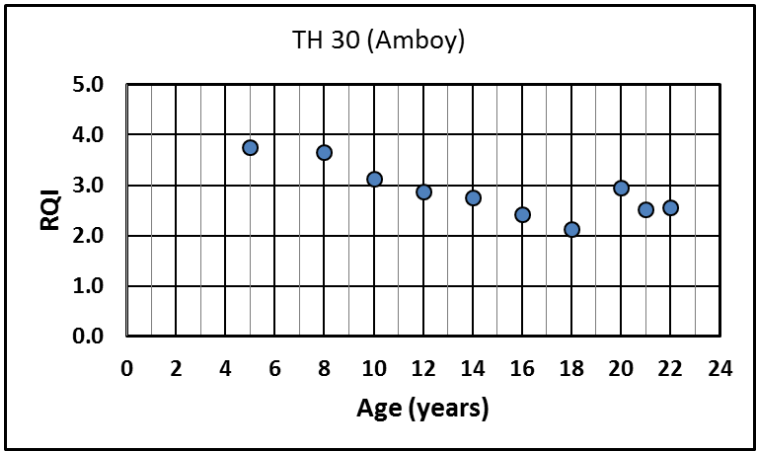
- **Design Procedures**
  - **"Rule of thumb" or trial sections**
  - **Portland Cement Association (PCA) Method**
  - **DOT methods: Colorado, New Jersey, Illinois, Minnesota**
  - **AASHTO (not applicable to thinner slabs)**
  - **BCOA-ME (2013)**

Future Trends

- **Developing effective maintenance and rehabilitation techniques**
  - **Most common concrete repair techniques valid for overlays**
  - **Some challenges with tying into thin slabs**

Future Trends

- **Developing performance curves to improve project selection and manage networks**
  - **MnDOT research project to develop performance curves for BCOA**
  - **BCOA project selection study recently completed for MnDOT**
  - **Iowa DOT has similar effort for all types of concrete overlays**
  - **NCHRP 01-61 (Starting soon)**



Future Trends

- **Continued research toward the use of fiber-reinforced concrete (FRC) to enhance thin concrete overlay performance**
  - **MnDOT research project to identify improved laboratory procedures for selecting fiber type and dosage**
  - **MnDOT currently evaluating several FRC overlay test sections at the MnROAD facility**
    - **4" and 5" BCOA**
    - **3" UBOL (on 2 different thicknesses of fabric interlayer)**
  - **MnROAD recently constructed two new thin UBOL test sections with FRC**
    - **5" UBOL on geotextile fabric (12'Lx14'W panels; 12'L x 6'W panels)**
    - **Evaluate improvement in LTE across transverse joints**
    - **Potential for longer panels?**

Future Trends

- **Other ideas:**
  - **Precast concrete panel overlays (Canada)**
  - **CRCP overlays over jointed PCC (Texas)**
  - **Ultra-thin unbonded concrete overlays (MnROAD)**
  - **Overlays using Roller Compacted Concrete?**

Questions?

Tom Burnham

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Today's Participants

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Panelists Presentations

http://onlinepubs.trb.org/onlinepubs/webinars/170905.pdf

After the webinar, you will receive a follow-up email containing a link to the recording

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- Getting involved is free!
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  - Search for AFD50 (Standing Committee on Design and Rehabilitation of Concrete Pavements)
- Become a Friend of a Committee (http://bit.ly/TRBcommittees)
  - Networking opportunities
  - May provide a path to become a Standing Committee member
- For more information: www.mytrb.org
  - Create your account
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97th TRB Annual Meeting: January 7-11, 2018

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