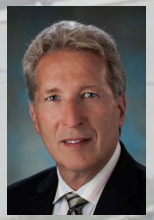
Current U.S. Practices for Successful Design and Construction of Concrete Overlays



EUPAVE Webinar Presentation By:

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and

American Concrete Pavement Association

May 19, 2020

WHY CONCRETE OVERLAYS?

BENEFITS OF CONCRETE OVERLAYS

- Can be applied to a wide variety of existing pavements exhibiting a range of performance issues
- Can be constructed rapidly and with effective construction traffic management
- Most importantly: cost-effective long service life

Can be designed to achieve a service life of 40 years (or more)!

CONCRETE OVERLAYS

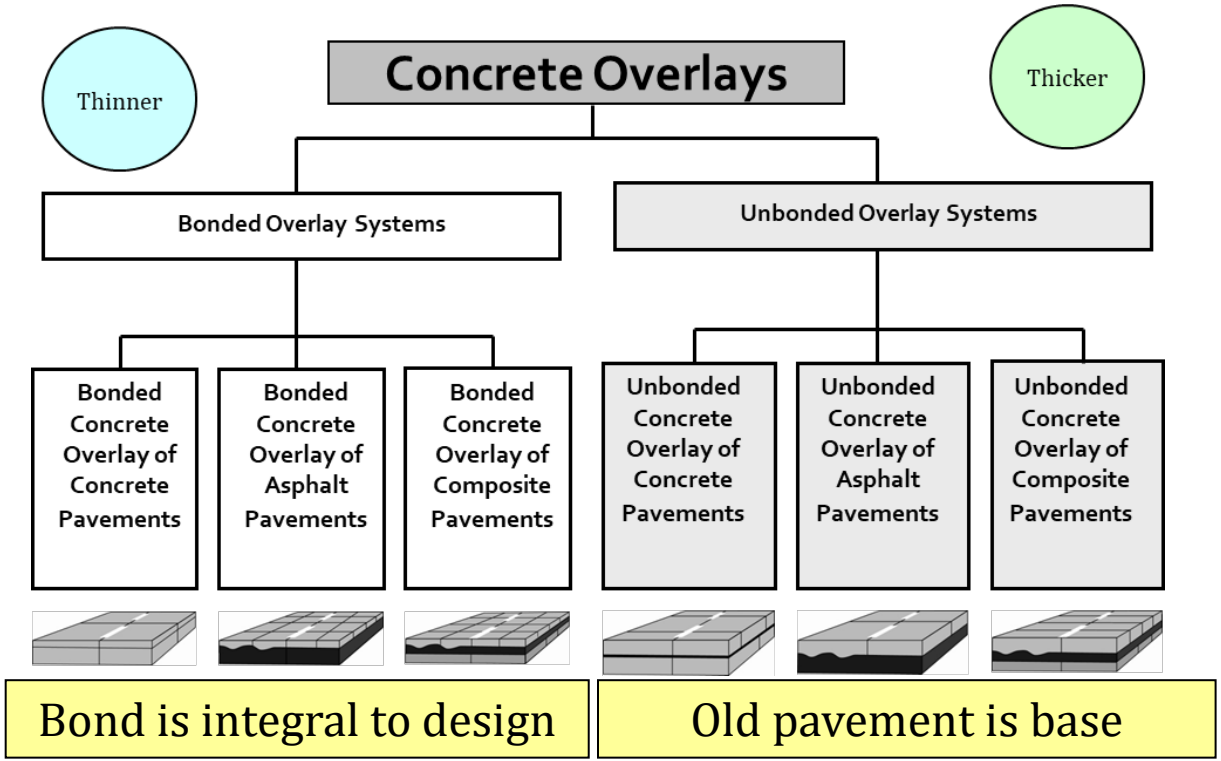
INTRODUCTION

- >1,263 concrete overlays in the U.S., dating from **1901** through present (including >410 since year 2000)

- Concrete overlays have been successfully constructed in at least 49 different states and Canadian provinces

Source: ACPA's National Concrete Overlay Explorer)

CONCRETE OVERLAY SYSTEMS



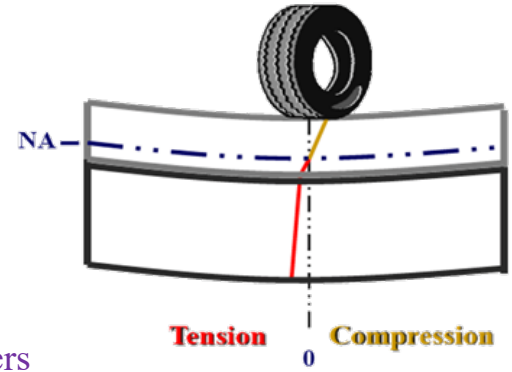
Source: U.S. National Concrete Pavement Technology Center

BONDED OVERLAYS VS. UNBONDED OVERLAYS

DESIGN *ASSUMPTIONS* AND CONSTRUCTION REQUIREMENTS

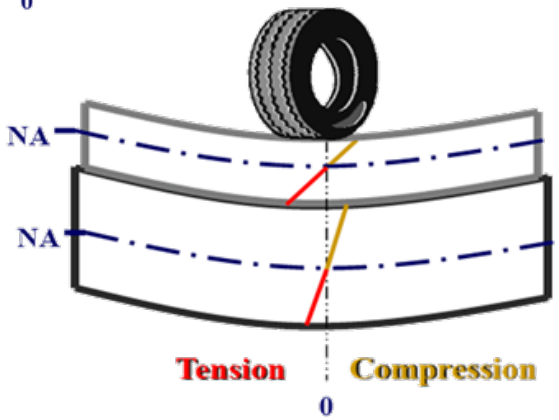
Bonded:

- Bond between layers is assumed in design
- Bond *must* be achieved during construction
- Designed as a monolithic structure



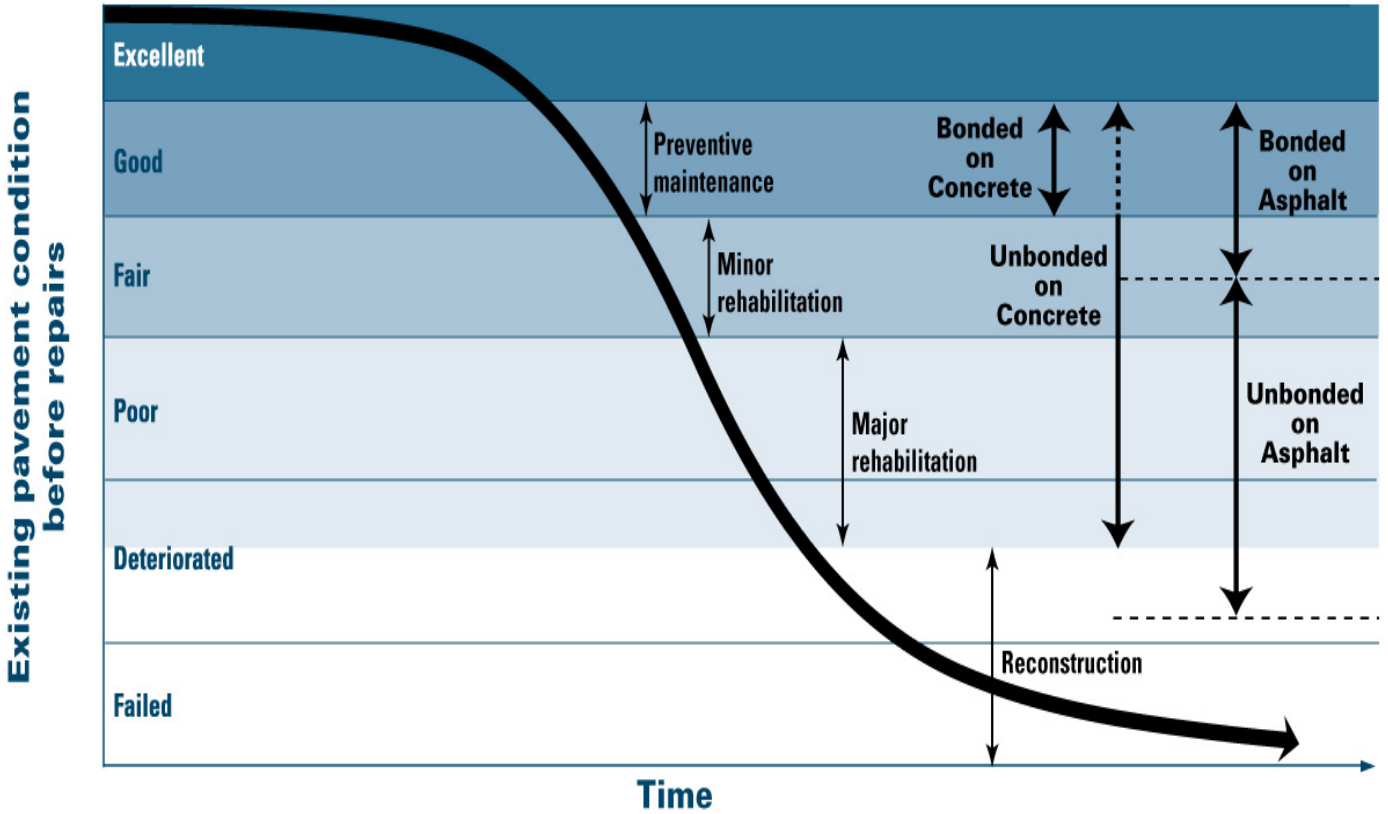
Unbonded:

- In design, *assume* there is no bond between layers
  - Bond can cause pavement distress to reflect through overlay
- Usually place separation/isolation layer on concrete pavement during construction
- No effort to debond from asphalt pavement during construction
  - Any bond with asphalt makes the design conservative
- Designed like a new pavement on stiff foundation



Source: U.S. National Concrete Pavement Technology Center

APPLICABILITY OF CONCRETE OVERLAY SOLUTIONS



Source: U.S. National Concrete Pavement Technology Center

TYPICAL CONCRETE OVERLAY SERVICE LIVES

Concrete Overlay Type	Typical Life
Bonded on Concrete	15-25 years
Unbonded on Concrete	20-30 years
Bonded on Asphalt/Composite	5-15 years
Unbonded on Asphalt/Composite	20-30 years

Based on FHWA's "Portland Cement Concrete Overlays – State of the Technology Synthesis" (FHWA-IF-02-045)

Overlay service life is dependent upon :

- Sound overlay structural design - compatible with expected traffic and site conditions
- Good construction practices

THE PRINCIPAL FACTORS OF CONCRETE (OVERLAY) PAVEMENT DESIGN

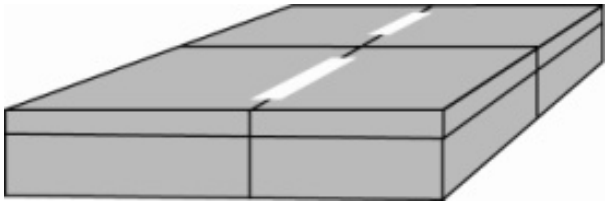
- Geometrics
- Thickness
- Joint Systems
- Materials

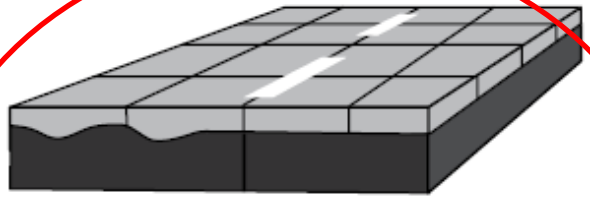
Most Often Influence Cost & Selection of Projects

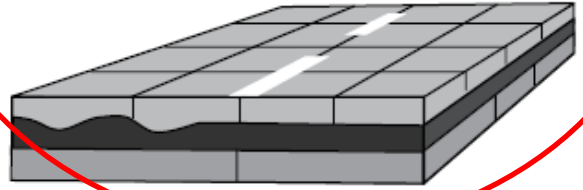
THE PRINCIPAL FACTORS OF CONCRETE (OVERLAY) PAVEMENT DESIGN

- Geometrics
- Thickness
- Joint Systems
- Materials

BONDED CONCRETE OVERLAYS







- Concrete resurfacing of existing asphalt, concrete or composite pavement
- *Designed and constructed with bond* between concrete overlay and layer below
- Typically relatively thin overlays (50 – 150 mm)
- Panel size:
  - Match joints over concrete
  - Typically small panels over asphalt (1–2m square)

BONDED CONCRETE OVERLAY OF ASPHALT-SURFACED PAVEMENT

Existing pavement condition:

- Fair or better structure
  - No asphalt stripping
  - ≥ 75mm asphalt after milling
- Surface distress can be present
  - Rutting is OK
  - Non-load cracking is OK

Typical applications:

- Eliminate surface defects
- Improve friction, ride quality
- Increase structural capacity

Typical thickness: 50 – 150mm

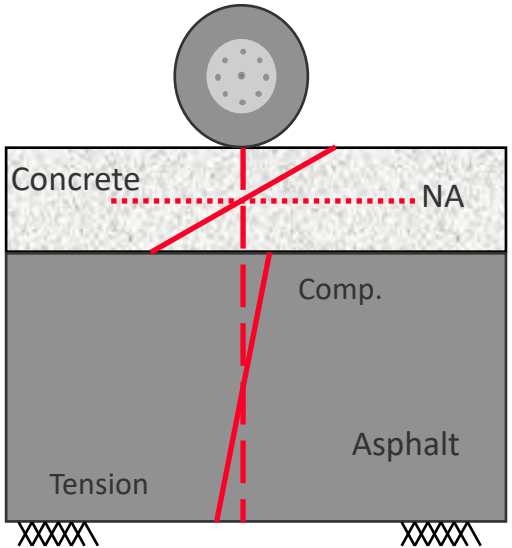
Major highway

Intersection approach

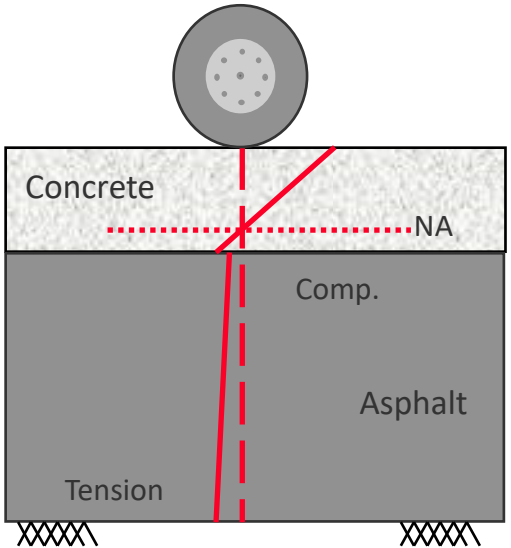
HOW DO BONDED CONCRETE OVERLAYS OF ASPHALT WORK?

1. Concrete bonds to asphalt
   - Lowers neutral bending axis
   - Decreases tensile stress in PCC
2. Small panels
   - Reduces shrinkage, curl/warp and load-related stresses
3. Fiber reinforcing can be used to improve concrete toughness

EFFECT OF OVERLAY BOND ON EDGE STRESS

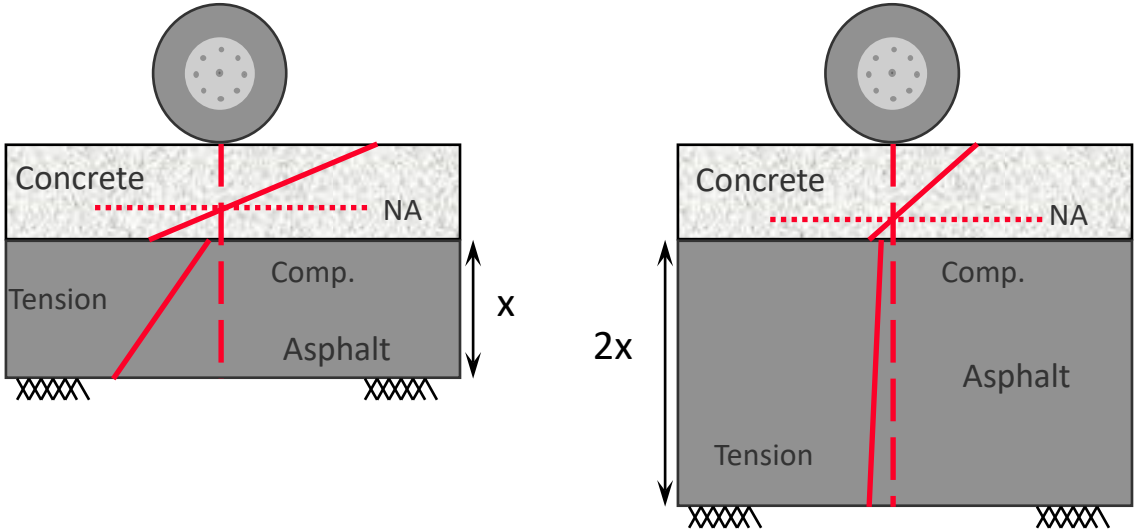


Unbonded

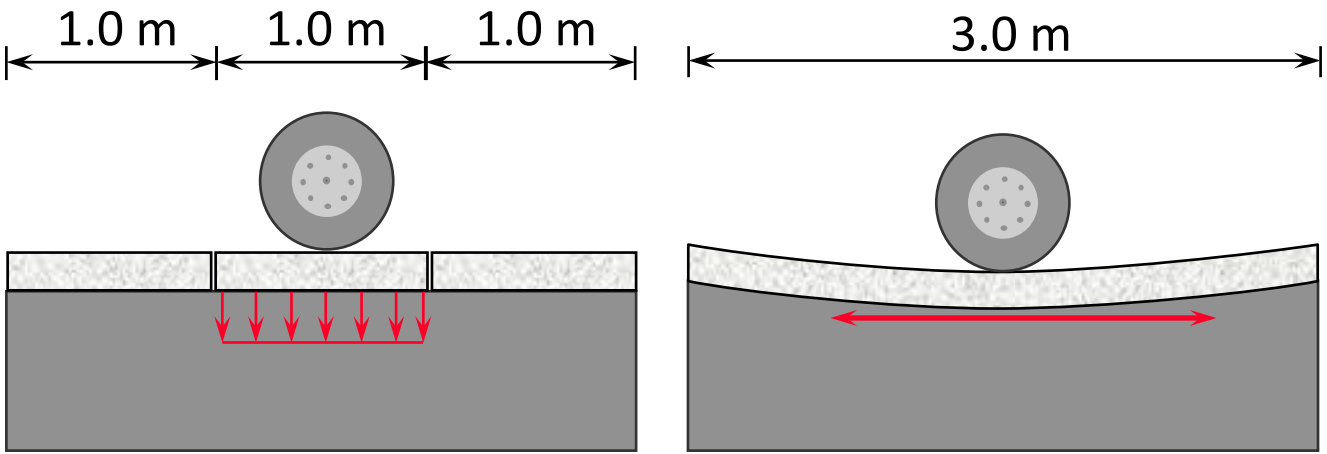


Bonded

EFFECT OF ASPHALT THICKNESS ON EDGE STRESS



EFFECTS OF PANEL SIZE ON LOAD-RELATED STRESS



Short Slabs Deflect

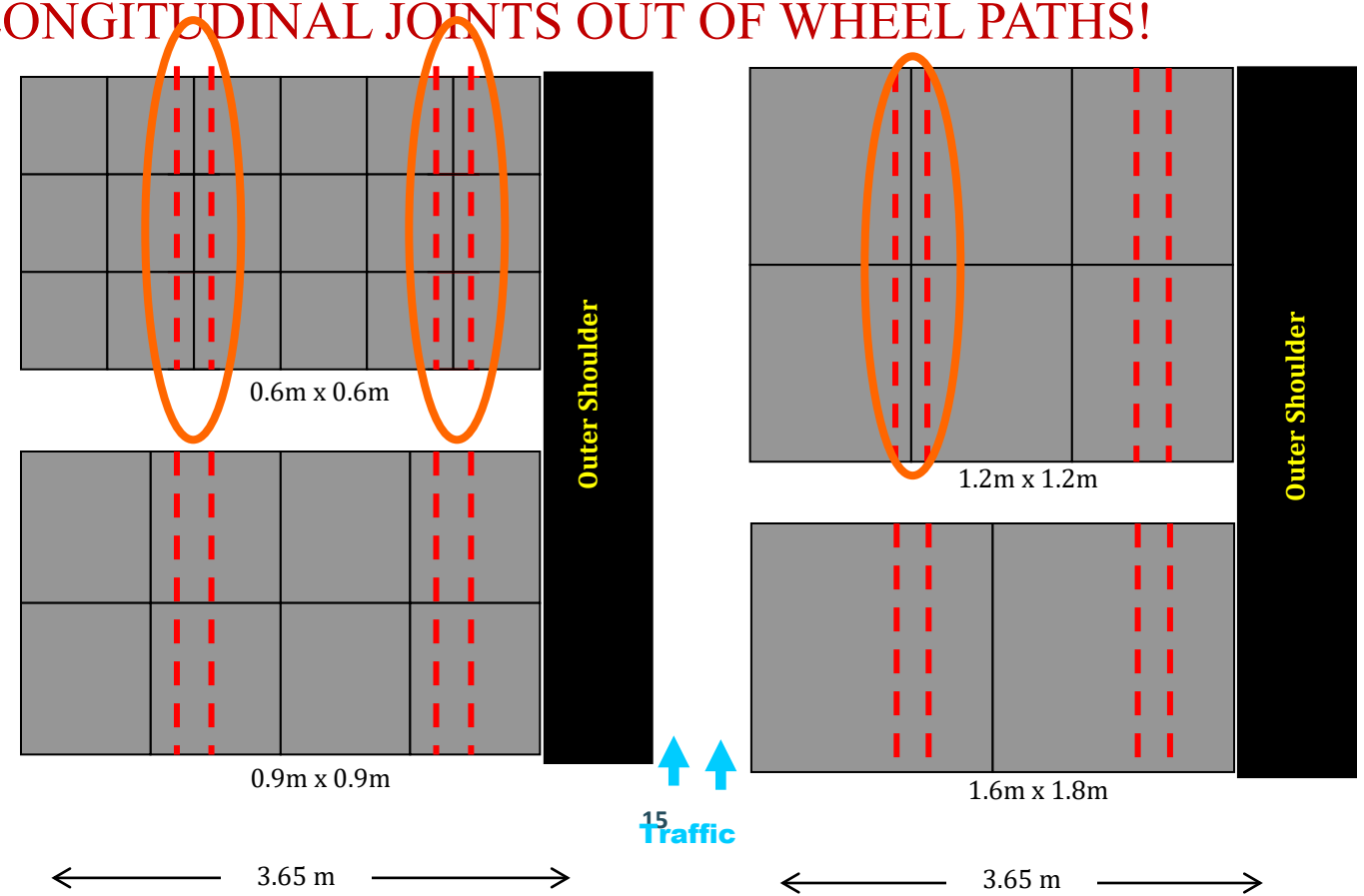
Very little flexural stress

Standard Slabs Bend

Higher flexural stress

BCOA JOINT LAYOUT

KEEP LONGITUDINAL JOINTS OUT OF WHEEL PATHS!



MnROAD BCOA PERFORMANCE

(After 5 yrs service, ~5M 80-kN ESALs)

Design (Thickness – Length x Width)	Panels Cracked (%)	Corner Cracks
100mm – 1.2m x 1.2m	5	6
75mm – 1.2m x 1.2m	40	165
75mm – 1.5m x 1.8m	8	17
150mm – 1.5m x 1.8m	0	0
150mm – 3m x 3.7m – No dowels	13	0
150mm – 3m x 3.7m – Dowels	3	0

1.2m x 1.2m Panels:
Corner Breaks due to Wheel Loadings

BCOA JOINT LAYOUT

KEEP LONGITUDINAL JOINTS OUT OF WHEEL PATHS!

75mm PCC over 250mm AC,
1.2m x 1.2m panels, 6 yrs (~6M ESALs)

75mm PCC over 250mm AC,
1.8m x 1.8m panels, 6 yrs (~6M ESALs)

BEST BCOA JOINTING PRACTICES

Maximum Panel Size = 18-24 x Slab Thickness

- For overlay thickness <75mm, typically use 1m sq.
- For overlay thickness = 75 – 150mm, typically use 2m sq.

Usually No Dowels

- Small panel size increases effectiveness of aggregate interlock
- Thickness (dowel cover) concerns
  - 25mm diameter dowels have been used in 150mm thick concrete overlays with *mixed results*
  - Longitudinal joint ties have been used successfully when thickness > 4 in.
  - Structural fibers may be effective “ties” between lanes

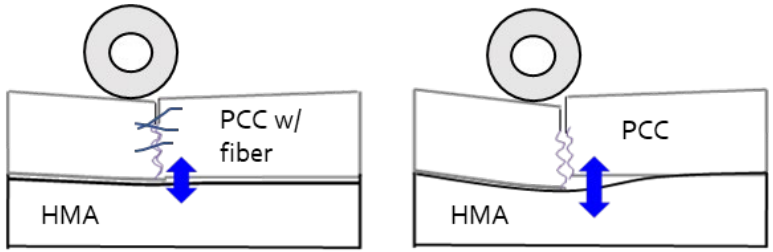
Longitudinal Joints Should be “Tied” if Possible

  - Small tie bars have been used successfully when overlay thickness > 100mm
  - Structural fibers may effectively “tie” lanes and prevent excessive joint opening

BCOA STRUCTURAL FIBER CONSIDERATIONS

Does not increase concrete strength

Increases toughness, post-crack integrity



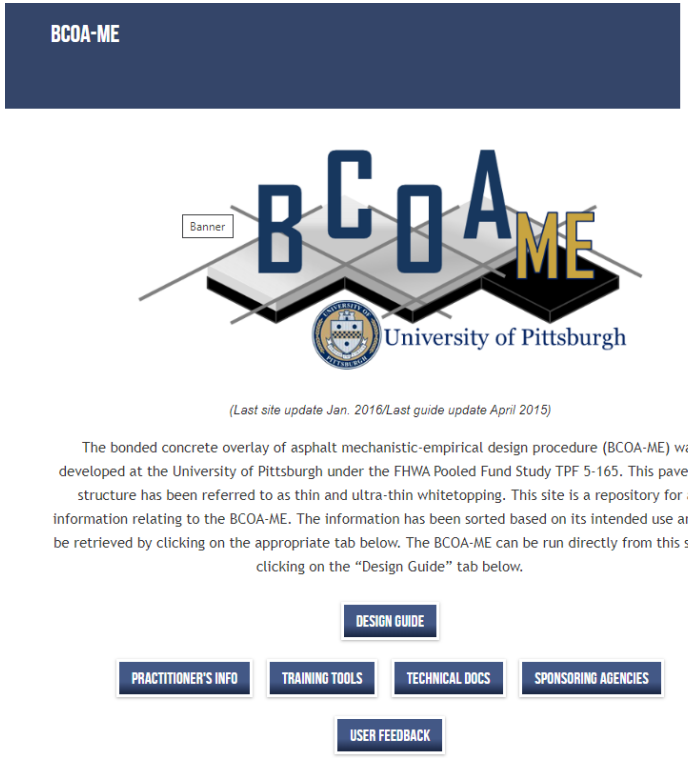
Straight synthetic: Strux 90/40

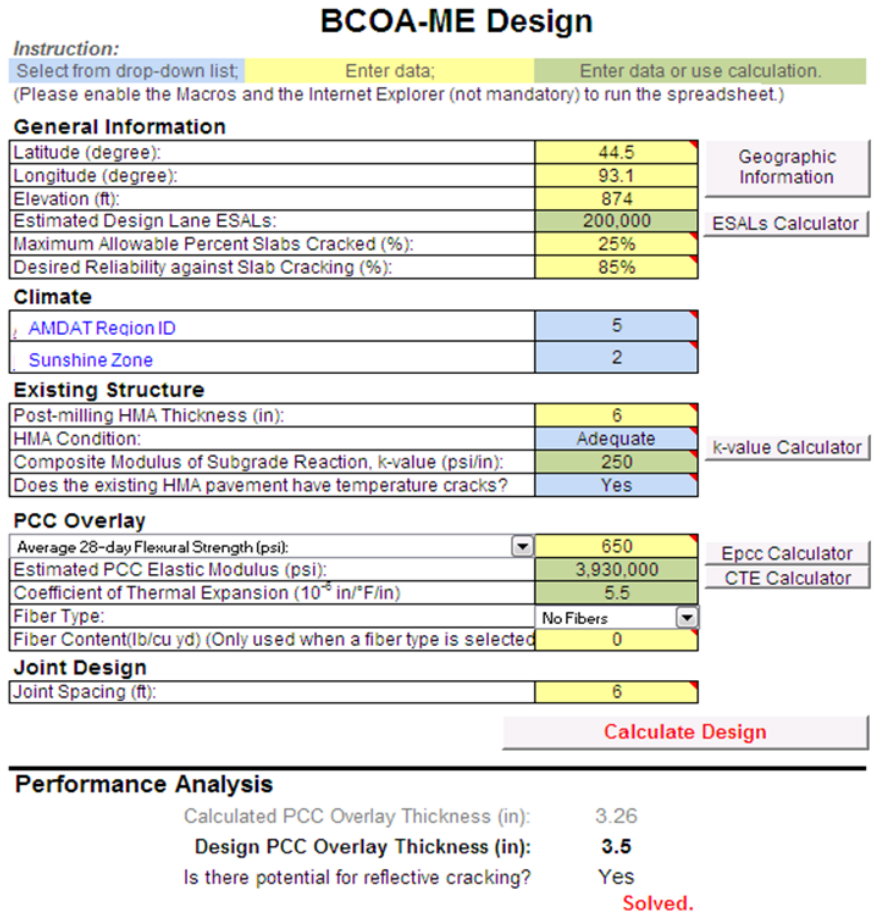
Residual strength ratio = 24%

Crimped synthetic: Enduro 600

BCOA DESIGN PROCEDURES:

- BCOA-ME
- AASHTO PavementME - SJPCP Module





https://www.engineering.pitt.edu/Vandenbossche/BCOA-ME/

CONSTRUCTION STEPS FOR BCOA

- Mill and clean surface.
- Pre-overlay repairs, if required.
- Set forms for roller screed.
- Prepare surface.
- Place concrete.
- Texture pavement.
- Apply curing compound.
- Saw cut joints.
- Monitor strength gain (maturity).

BCOA SURFACE PREPARATION

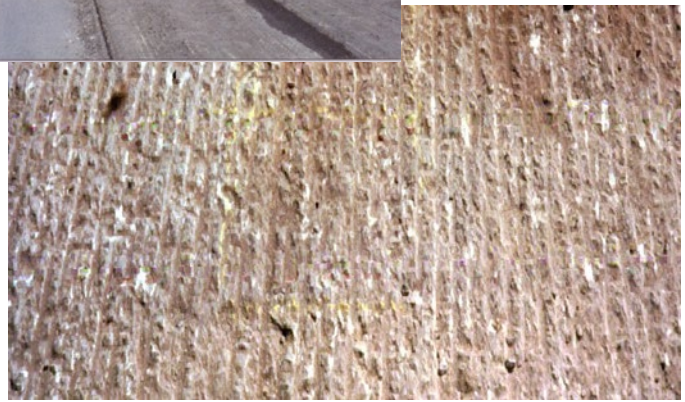
MILLING

Mill AC Surface (optional)

- Remove rutting
- Restore profile (remove high spots)
- Enhance bond
- Minimum 75mm AC remaining after milling

Can place without milling if rutting <50mm

- Results in variable overlay thickness



BCOA SURFACE PREPARATION

MILLING

Cautions!

- Minimize milling to retain structural support of overlay
- Make major grade corrections by varying overlay thickness

Excessive milling of existing asphalt

BCOA SURFACE PREPARATION

CLEANING THE SURFACE

Power-broom

- Remove loose material
- Allow inspection to determine need for pre-overlay repairs

BCOA

PRE-OVERLAY REPAIRS

Primary purpose: restore uniform support

- Repair potholes, localized areas of severe fatigue cracking
- Preferred material: concrete (improved bond) vs. asphalt
- Can fill cracks, but usually not

BCOA

PRE-PAVING (FINAL SURFACE CLEANING)

Power Brooming

Air Blasting

Water Blasting

BCOA

CONCRETE PLACEMENT AND STRIKE-OFF

BCOA - FINISHING

5-m float for smoothness

Need for finishing is minimized by:

- Selecting a workable mix
- Operating the paving equipment properly

BCOA – SURFACE TEXTURING

Tines – 19mm spacing

Longitudinal Tining

Longitudinal Brushing

Artificial Turf Drag

BCOA CURING

Keys for success:

- Apply when surface sheen is gone
- High application rate (0.27 – 0.36 liters/m^2)
- Cover all exposed surfaces (including sides)
  - Automated equipment provides most reliable coverage
  - Check spray nozzles frequently
- Minimum cure time 72 – 96 hrs

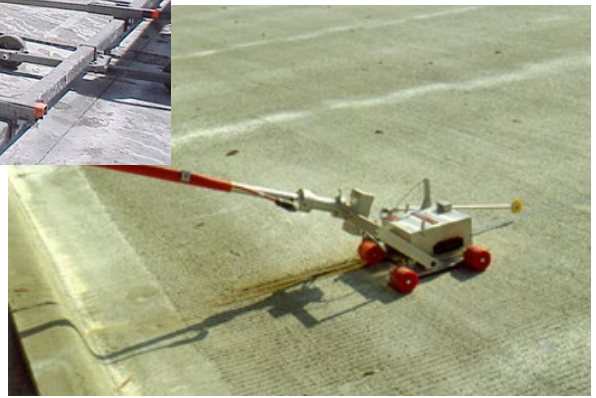
BCOA JOINT SAWING

Saw cut depth = D/3 (typical)

- Less for early-entry saws
- Adjust cut depth for slab thickness (especially for variable thickness overlays)

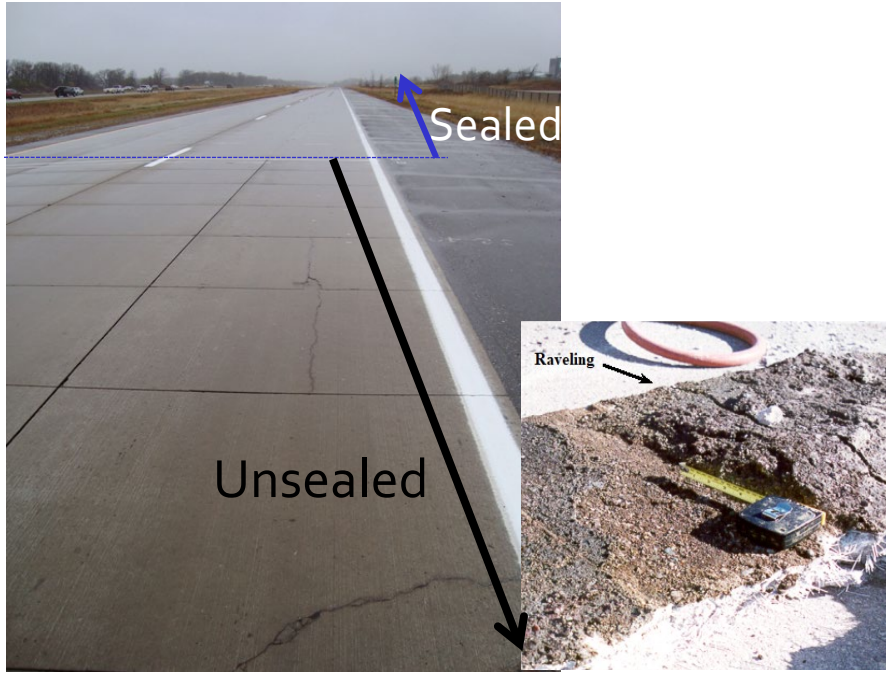
Timely sawing is critical!

- More joints = need for more equipment, operators and spare parts!



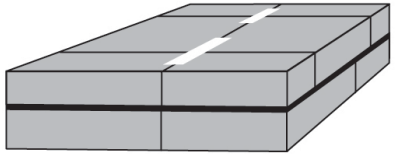
BCOA JOINT SEALING

- Recommended for BCOA to prevent loss of bond!
- Minimize infiltration of water and incompressible material

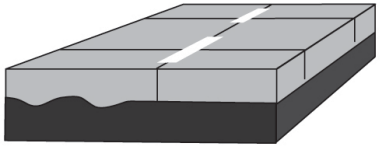


UNBONDED CONCRETE OVERLAYS

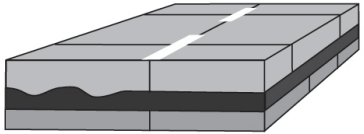
Unbonded Concrete Overlays of Concrete Pavements
–previously called unbonded overlays–



Unbonded Concrete Overlays of Asphalt Pavements
–previously called conventional whitetopping–



Unbonded Concrete Overlays of Composite Pavements



UNBONDED CONCRETE OVERLAYS OF CONCRETE

- Concrete resurfacing of existing concrete or composite pavement
- Designed and constructed with separation interlayer between two concrete layers and assuming no bond
- Thicker overlays (≥125 mm)
- Panel size:
  - 1.8m x 1.8m for D≤150mm
  - Full-lane width for D>150mm

UNBONDED CONCRETE OVERLAY OF CONCRETE PAVEMENT

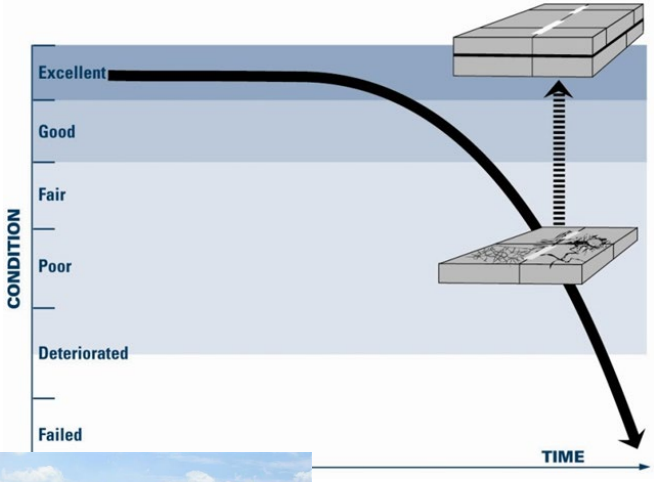
Existing pavement condition:

- Poor or better structure
  - Repairs required only where structural integrity is lost at isolated spots

Typical applications:

- Use to restore structural capacity and increase pavement life equal to new full-depth pavement
- Improve friction, ride quality, noise

Typical thickness: >125mm



Missouri county road, pre-overlay condition, no repairs prior to 125mm unbonded overlay (2008)

UBOL DESIGN PROCEDURES:

- AASHTO (1993)
- AASHTO PavementME
- UBOL Design version 1.0

1993 AASHTO Unbonded Concrete on Concrete / Composite

- Slab Thickness Design

Unbonded overlay design equation:

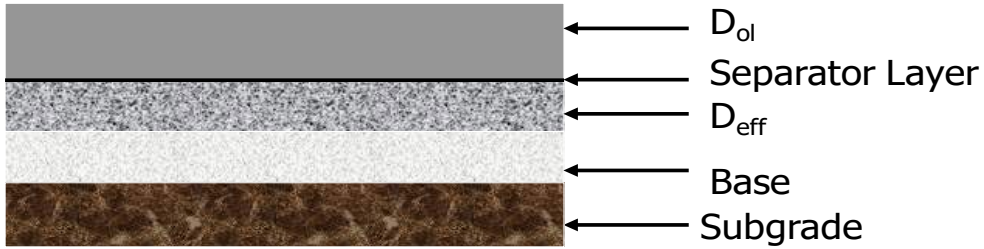
$$D_{ol} = \sqrt{D_f^2 - D_{eff}^2}$$

where:

D_{ol} = *Required PCC overlay thickness*

D_f = *Thickness of new PCC pavement for design conditions*

D_{eff} = *Effective thickness of existing PCC*

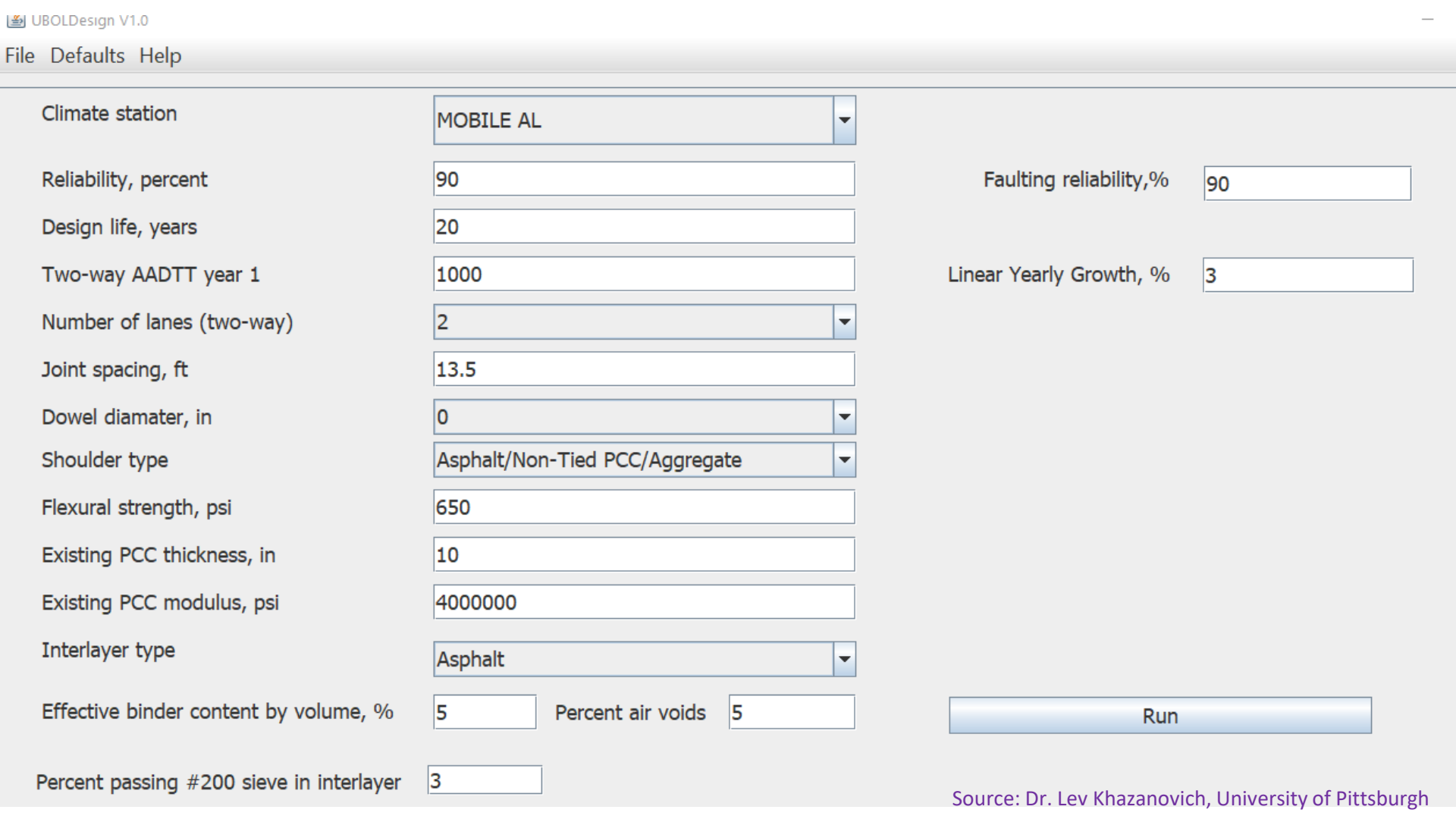


AASHTOWare PavementME-Design for Unbonded Concrete Overlays

- Essentially same design process and performance models as for new pavement design.
- Determine basic design input parameters (traffic, soil conditions, material properties, etc.).
- Develop preliminary designs (thickness, base designs, joint spacing, and other design features).
- Use software to evaluate predicted performance over the analysis period (e.g., 50 years).
- Determine life-cycle activity profiles ("what" rehabilitation activities to perform and "when").
- Calculate the Initial and Life Cycle Costs for each pavement design over the analysis period.
- Evaluate designs and modify as needed to develop a pavement section that meets or exceeds the required initial performance period and has the lowest life cycle cost.

UBOL Design Version 1.0

- New mechanistic-empirical unbonded overlay design procedure.
- Developed at University of Pittsburgh under pooled-fund study by several state highway agencies.
- Structural analysis simulates FEM models using neural network for quick, inexpensive results.
- Performance models are based on data obtained from unbonded concrete overlays throughout the U.S.
- Can be used to evaluate trial designs or to develop designs based on input performance parameters.
- Public domain (“free”) software.



Source: Dr. Lev Khazanovich, University of Pittsburgh

UBOLDesign V1.0

File Defaults Help

PCC coefficient of thermal expansion: 5.5E-6

Percent of trucks in design direction (%): 50

Lane distribution factor:
=1.0 if number of lanes = 2
=0.9 if number of lanes = 4
=0.8 if number of lanes =6
=0.7 if number of lanes >7

Target percentage of cracked slabs, %: 15

Cracking model coefficients: C_1 = 1.375 C_2 = -2

$$CK = \frac{100\%}{1 + C_1 FD^{C2}}$$

FD: fatigue damage

Coefficients of Variation, %

Overlay thickness: 3

PCC flexural strength: 8.7

Erosion factors: C_{E1} = 0.0000002 C_{E1} = 140

$$ER = C_{E1} L\, e^{C_{E2} EROSION}$$

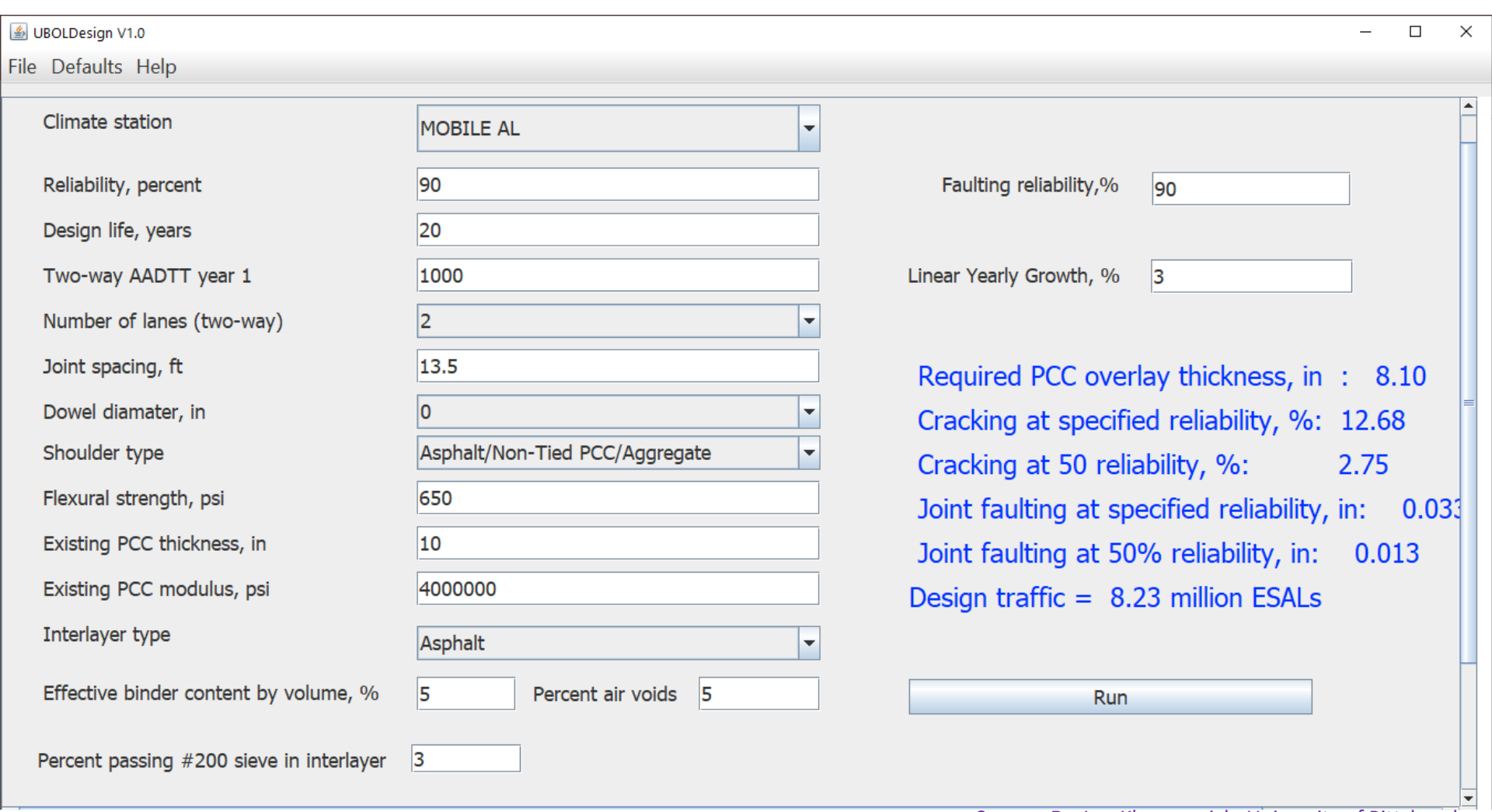
a = 0.14

b = 0.15

$$EROSION = \begin{cases} (1.8483 * \alpha^2 - 0.8179 * \alpha + 0.1123) & Asphalt\ Interlayer \\ 0.02 & Non\ woven\ geotextile\ fabric\ \text{Interlayer} \end{cases}$$

where α is the erodibility index:

Source: Dr. Lev Khazanovich, University of Pittsburgh



Source: Dr. Lev Khazanovich, University of Pittsburgh

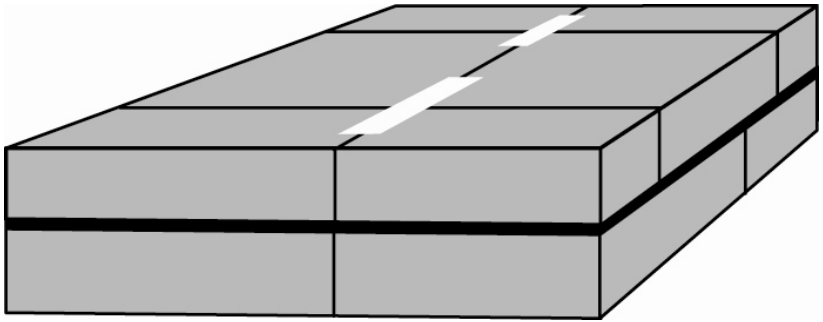
UNBONDED OVERLAYS OF CONCRETE PAVEMENT

PRE-OVERLAY REPAIRS

UNBONDED OVERLAYS OF CONCRETE PAVEMENT

KEYS TO SUCCESS

- Full-depth repairs are required only where structural integrity is lost at isolated spots.
- Separator layer to isolate overlay from underlying pavement - minimize reflective cracking.
  - 25-50 mm dense- or open-graded asphalt
    - Drainage or anti-strip for heavy traffic
  - Geotextile fabric



- Shorter joint spacing helps minimize curling and warping stresses.
  - Transverse joints at 18-24 times thickness to maximum of ~5m
  - No need to match joints with those of the underlying concrete pavement.

UNBONDED CONCRETE OVERLAYS OF CONCRETE

SEPARATION LAYER OPTIONS

UNBONDED CONCRETE OVERLAY

GEOTEXTILE INTERLAYER PROPERTIES

Property	Requirement (95% PWL)
Fabric Type (EN 13249 Annex F)	• **Non-woven, needle-punched** geotextile • Uniform color
Mass per unit area (ISO 9864)	≥ 450 g/m^2 ≥ 500 g/m^2 ≤550 g/m^2
Thickness under pressure (ISO 9863-1)	At 2 kPa: ≥ 3.0mm At 20 kPa: ≥ 2.5mm At 200 kPa: ≥ 0.1mm
Tensile strength (ISO 10319)	≥ 10 kN/m
Maximum elongation (IS0 10319)	≤ 130% (≤ 60% recommended as best practice)
Water permeability in normal direction under pressure (ISO 12958)	≥ 1.0×10^{-4} m/s) [under pressure of 20 kPa]
Alkali resistance (EN 13249)	≥ 96% Polypropylene/Polyethylene

GEOTEXTILE INTERLAYER COLOR

- **Black – absorbs UV energy**
- **Requires sprinkling to reduce heat in warm weather conditions**

White - reflects UV energy
Lower surface temperature in warm weather conditions

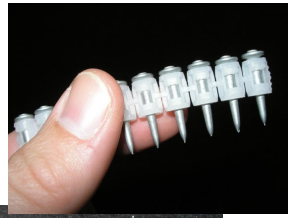
GEOTEXTILE FABRIC INTERLAYER

INSTALLATION

- Sweep surface prior to placement
- Avoid wrinkles
- Overlap 100-200mm (similar to roofing shingles)
  - Avoid 3 layer thickness
- Free edge extend beyond edge of new concrete and into drainage layer by 100mm or more.

GEOTEXTILE FABRIC INTERLAYER

INSTALLATION



Secure to underlying layer

- Nails and washers (~2m centers)
- Adhesive

GEOTEXTILE FABRIC INTERLAYER

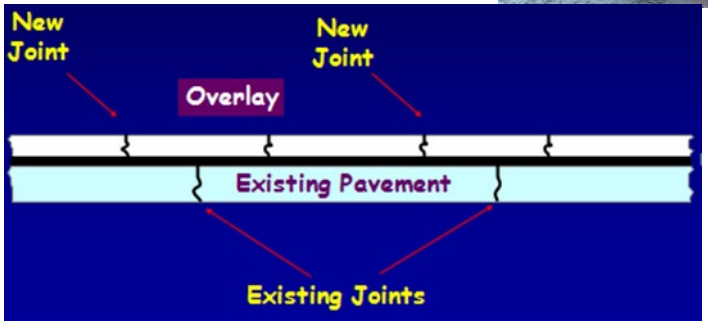
PRE-PAVING/PAVING

- Dampen fabric before paving.
- Minimize trafficking on geotextile – avoid turning movements

UNBONDED CONCRETE OVERLAYS

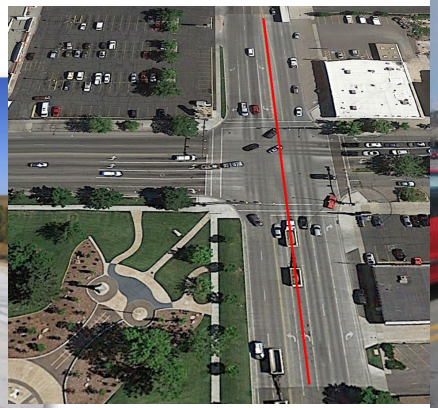
PAVING MIXTURES, FINISHING, CURING AND JOINTING

- Conventional vs. Rapid Early Strength
- Fiber-reinforcement?
- Conventional Finishing
- Conventional Texturing
- Conventional Curing
- Jointing
  - Conventional panel sizes (sometimes smaller)
  - Sometimes offset transverse joints, but not necessary



SUMMARY/CLOSURE

- Concrete overlays offer a broad range of treatments for existing concrete, asphalt and composite pavements.
- Well-designed, well-constructed concrete overlays can provide 40 or more years of low-maintenance service life.



RESOURCE

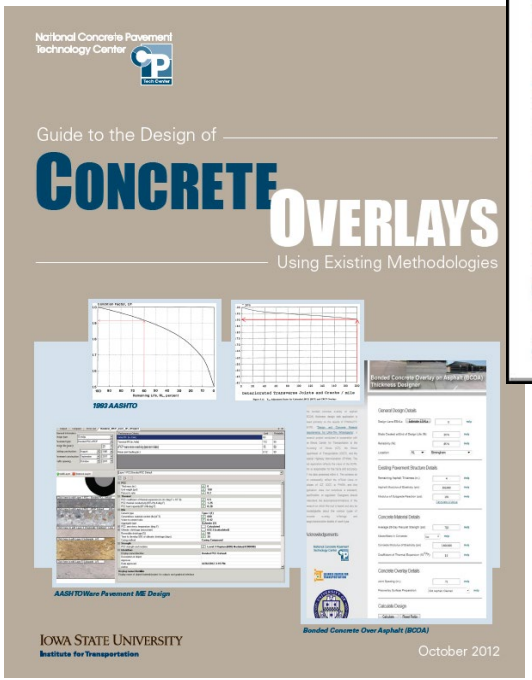
GUIDE FOR DESIGN OF CONCRETE OVERLAYS

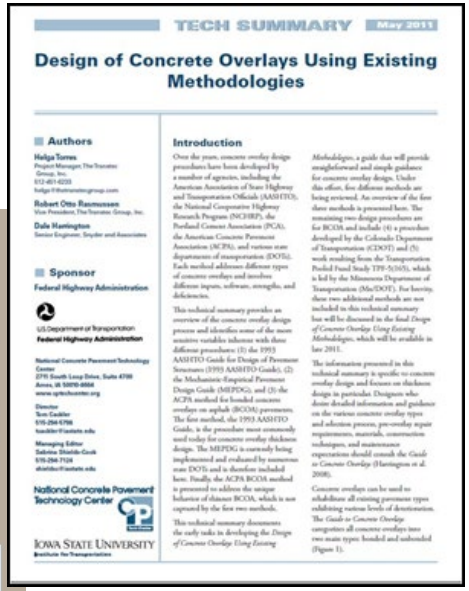
Background of recommended overlay design techniques

- 1992 AASHTO Overlay procedure
- Pavement-ME/MEPDG
- ACPA Bonded Concrete Overlay of Asphalt pavements
- (BCOA-ME background on host website)

Detailed examples of how to use the existing design methodology

Learn by example – then apply for your situation!




TECH SUMMARY May 2011

Design of Concrete Overlays Using Existing Methodologies

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Introduction

Over the years, concrete overlay design procedures have been developed by a number of agencies, including the American Association of State Highway and Transportation Officials (AASHTO), the National Cooperative Highway Research Program (NCHRP), the Portland Cement Association (PCA), the American Concrete Pavement Association (ACPA), and various state departments of transportation (DOTs). Each method addresses different types of concrete overlays and involves different inputs, software, strengths, and deficiencies.

This technical summary provides an overview of the concrete overlay design process and identifies some of the more sensitive variables inherent with three different procedures: (1) the 1993 AASHTO Guide for Design of Pavement Structures (1993 AASHTO Guide), (2) the Mechanistic-Empirical Pavement Design Guide (MEPDG), and (3) the ACPA method for bonded concrete overlays on asphalt (BCOA) pavements. The first method, the 1993 AASHTO Guide, is the procedure most commonly used today for concrete overlay thickness design. The MEPDG is currently being implemented and evaluated by numerous state DOTs and is therefore included here. Finally, the ACPA BCOA method is presented to address the unique behavior of thinner BCOA, which is not captured by the first two methods.

This technical summary documents the early tasks in developing the *Design of Concrete Overlays Using Existing Methodologies*, a guide that will provide straightforward and simple guidance for concrete overlay design. Under this effort, five different methods are being reviewed. An overview of the first three methods is presented here. The remaining two design procedures are for BCOA and include (4) a procedure developed by the Colorado Department of Transportation (CDOT) and (5) work resulting from the Transportation Pooled Fund Study TPF-5(305), which is led by the Minnesota Department of Transportation (MnDOT). For brevity, these two additional methods are not included in this technical summary but will be discussed in the final *Design of Concrete Overlays Using Existing Methodologies*, which will be available in late 2011.

The information presented in this technical summary is specific to concrete overlay design and focuses on thickness design in particular. Designers who desire detailed information and guidance on the various concrete overlay types and selection process, pre-overlay repair requirements, materials, construction techniques, and maintenance expectations should consult the *Guide to Concrete Overlays* (Harrington et al. 2008).

Concrete overlays can be used to rehabilitate all existing pavement types exhibiting various levels of deterioration. The *Guide to Concrete Overlays* categorizes all concrete overlays into two main types: bonded and unbonded (Figure 1).

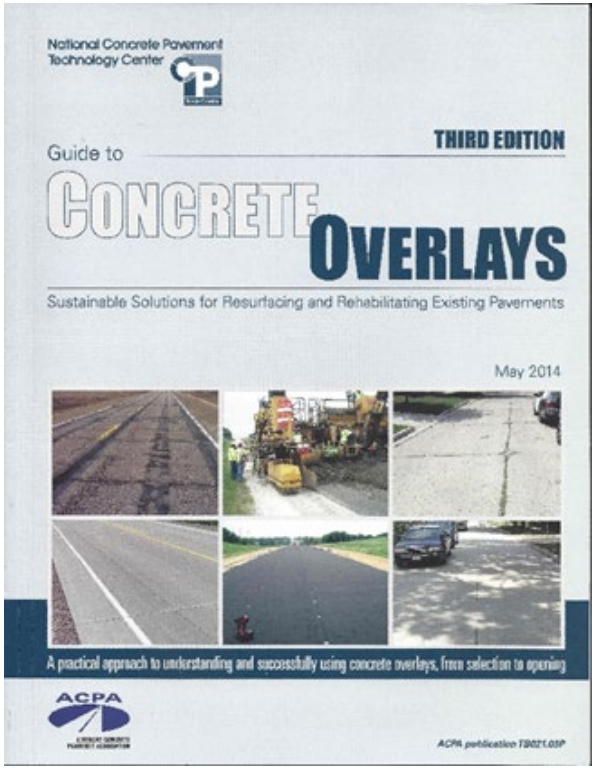
Available online:
http://www.cptechcenter.org/

RESOURCE:

CONCRETE OVERLAY GUIDE, 3RD EDITION

145 pages, including:

- Overview of Overlay Families
- Overlay types and uses
- Six Overlay Summaries
- Evaluations & Selections
- Design Section
- Miscellaneous Design Details
- Overlay Materials Section
- Work Zones under Traffic
- Key Points for Overlay Construction
- Accelerated Construction
- Project & Specifications Considerations



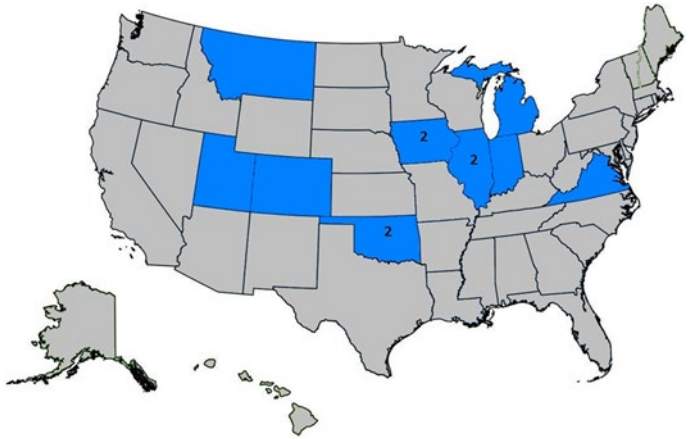
https://intrans.iastate.edu/app/uploads/sites/7/2018/08/Overlays_3rd_edition.pdf

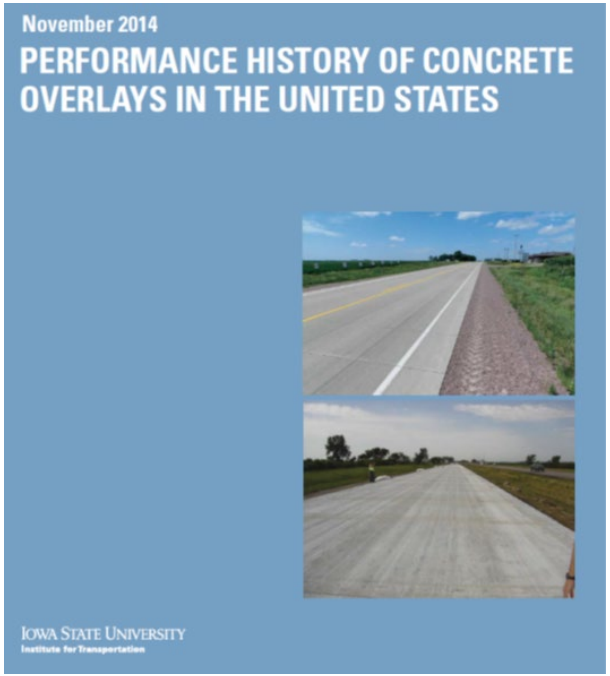
Updated 4th Edition is expected out in late 2020!

RESOURCE:

PERFORMANCE HISTORY OF CONCRETE OVERLAYS IN U.S.

Highlights twelve concrete overlay projects across the U.S.

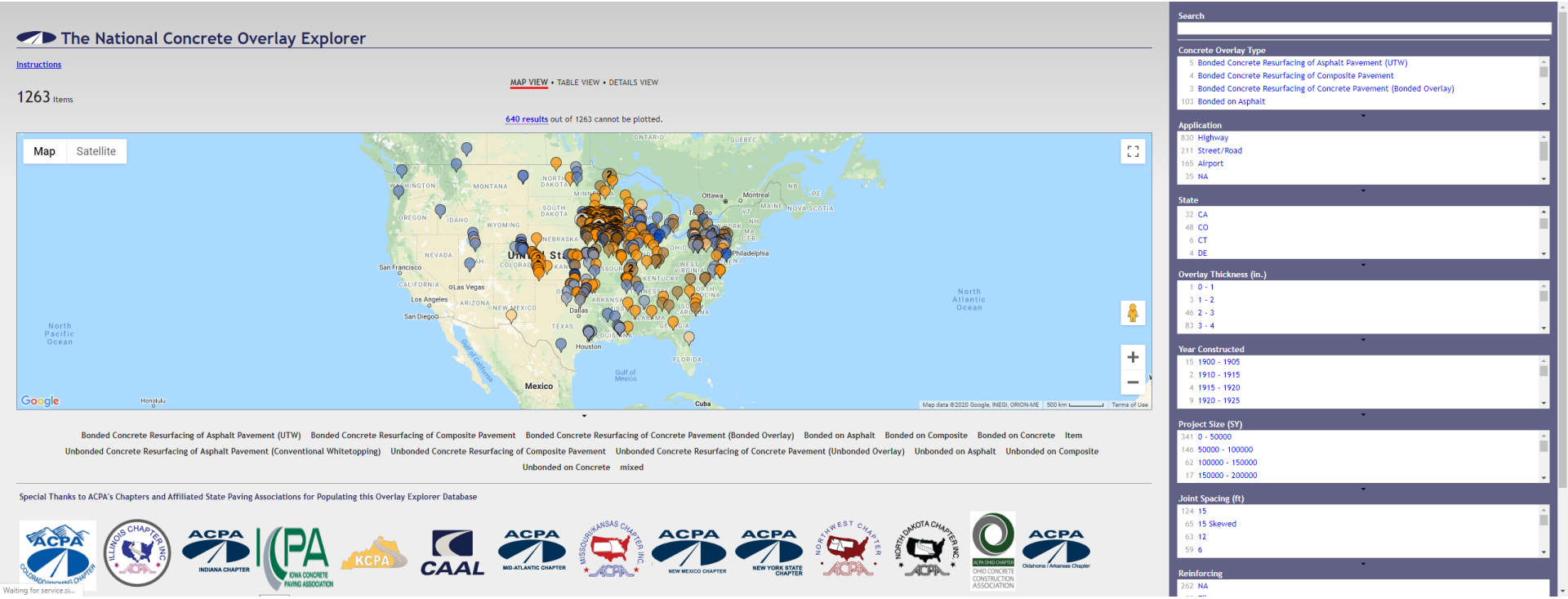




https://intrans.iastate.edu/app/uploads/2018/10/Performance-History_FHWA-acknowledgment_tagged-1.pdf

RESOURCE:

NATIONAL CONCRETE OVERLAY EXPLORER DATABASE



http://overlays.acpa.org/webapps/overlayexplorer/index.html

RESOURCE:

NATIONAL CONCRETE OVERLAY EXPLORER DATABASE – EXAMPLE DATASET

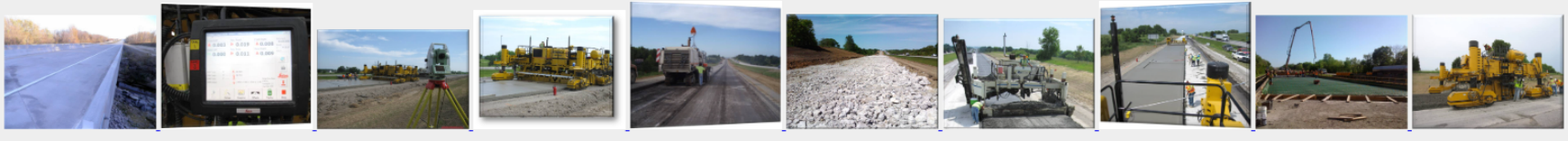
The National Concrete Overlay Explorer

Rt. I-35 Clay County Missouri
Type of Overlay: Unbonded on Concrete
Application: Highway
Constructed in 2010 in Kearney, MO (Clay County)
Contractor: Ideker, Inc.
Engineer: MoDOT
Owner: MoDOT

New Construction Details
Thickness: 8 in.
Project Size: 386415 square yards
Joint Spacing: 15 ft
Doweled Joints: Yes
Interlayer Matieral: Geotextile *and Thickness:* .25
Traffic: 34000
Integral Widening Constructed with Overlay: No
Truck Traffic: 34%
Reinforcing: NA
Existing Pavement Type: Composite

Current Conditions
Still in Service: Yes
Current Condition: Excellent Condition
Last Condition Rating: Novemeber 2010

Photos



Local ACPA Chapter or State Paving Associations: Missouri/Kansas Chapter Inc. - ACPA

Disclaimer: Every effort has been made to ensure that all information presented in this National Concrete Overlays Explorer is as accurate as possible as of the last posting date: 7/28/2014. If you have any questions or concerns about the data on a particular project, please contact the local ACPA Chapter or State Concrete Paving Association for the sta

MANY OTHER RESOURCES:

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- Dr. Shiraz Tayabji (Fugro Consultants, Inc.)
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- Dr. Julie Vandenbossche (University of Pittsburgh)
- Mr. Tom Burnham (Minnesota DOT)
- Dr. Lev Khazanovich (University of Pittsburgh)
- American Concrete Pavement Association

Thank You For Your Time and Attention!

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