Concrete Overlay Design (Design Functions and Thickness)

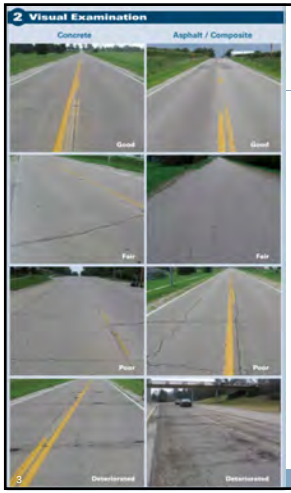
IOWA STATE UNIVERSITY
Institute for Transportation

National Concrete Pavement Technology Center
Tech Center

Overlay Design Process

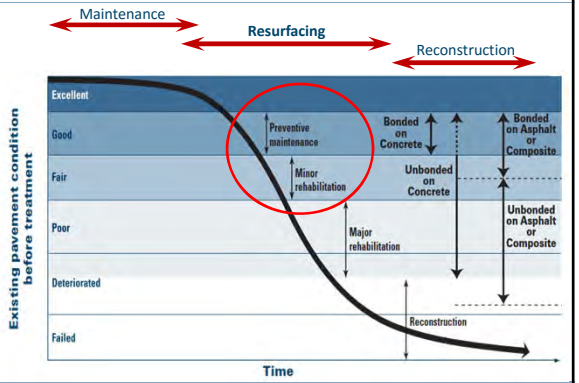
- Pavement Evaluation
- Determine Overlay Type
- Determine Design Life and Traffic
- Use Pavement Design Software
- Consider Additional Design Features
- Consider Construction Process
- Create Construction Documents

2



3

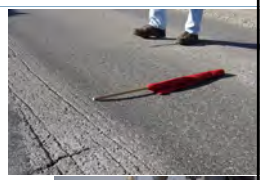
Evaluation Informs Design

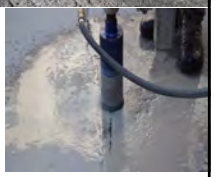


Evaluation and Survey Information

- Existing Pavement History Evaluation
  - Layer materials, properties, depths, & age
  - Widening material type, depths, widths, & age
  - History of full depth patching by location, type & age
- "As Built" Plan Information
  - Vertical & horizontal alignment
  - Previous test sections in project limits
  - Previous drainage structure remains

Where are the problem areas?
What maintenance has been done?
Are any pre-overlay repairs required?





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Overlay Type Selection

Concrete Overlays

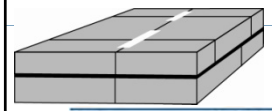
Asphalt / Composite

- **Unbonded Concrete Overlay of Asphalt / Composite**
  - Applicable for poor to deteriorated asphalt pavements
  - Up to ~100 M ESALs
  - 4 – 11 in.
- **Bonded Concrete Overlay of Asphalt / Composite**
  - Applicable for good to fair asphalt pavements
  - Up to ~15 M ESALs
  - 3 – 6 in.

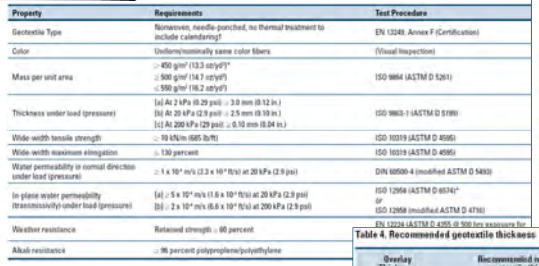
Concrete

- **Unbonded Concrete Overlay of Concrete (UCOC)**
  - Applicable for fair to deteriorated concrete pavements
  - Up to ~100 M ESALs
  - 4 – 11 in.
- **Bonded Concrete Overlay of Concrete (BCOC)**
  - Applicable for excellent to good concrete pavements
  - Up to ~15 M ESALs
  - 3 – 6 in.

Bond Breaker Selection



- Nonwoven Geotextile or Asphalt Interlayer



Property	Requirements	Test Procedure
Geotextile Type	Nonwoven, needle-punched, no thermal treatment to include calendaring†	EN 13249, Annex F (Certification)
Color	Uniform/nominally same color fibers	(Visual Inspection)
Mass per unit area	≥ 450 g/m² (13.3 oz/yd²)* ≥ 500 g/m² (14.7 oz/yd²) ≤ 550 g/m² (16.2 oz/yd²)	ISO 9864 (ASTM D 5261)
Thickness under load (pressure)	(a) At 2 kPa (0.29 psi): ≥ 3.0 mm (0.12 in.) (b) At 20 kPa (2.9 psi): ≥ 2.5 mm (0.10 in.) (c) At 200 kPa (29 psi): ≥ 0.10 mm (0.04 in.)	ISO 9863-1 (ASTM D 5199)
Wide-width tensile strength	≥ 10 kN/m (685 lb/ft)	ISO 10319 (ASTM D 4595)
Wide-width maximum elongation	≤ 130 percent	ISO 10319 (ASTM D 4595)
Water permeability in normal direction under load (pressure)	≥ 1 x 10⁻³ m/s (3.3 x 10⁻³ ft/s) at 20 kPa (2.9 psi)	DIN 60500-4 (modified ASTM D 5493)
In-plane water permeability (transmissivity) under load (pressure)	(a) ≥ 5 x 10⁻⁴ m/s (1.6 x 10⁻³ ft/s) at 20 kPa (2.9 psi) (b) ≥ 2 x 10⁻⁴ m/s (6.6 x 10⁻⁴ ft/s) at 200 kPa (2.9 psi)	ISO 12958 (ASTM D 6574)* or ISO 12958 (modified ASTM D 4716)
Weather resistance	Retained strength ≥ 80 percent	EN 12224 (ASTM D 4355 @ 500 hrs exposure for
Alkali resistance	≥ 96 percent polypropylene/polyethylene	

"Moving Advancements into Practice"
MAP Brief December 2017

Performance Assessment of Nonwoven Geotextile Materials Used as Separation Layer for Unbonded Concrete Overlay of Existing Concrete Pavement Applications in the U.S.

Introduction

Background

Table 4. Recommended geotextile thickness

Overlay Thickness	Recommended non-woven geotextile thickness
< 5 in	13.3 oz./yd²
≥ 5 in	14.7 oz./yd²

- https://cptechcenter.org/geotextiles/
- http://www.acpa.org/wp-content/uploads/2018/10/ACPAGeotextileGuideSpec-v1-5.pdf

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Design Life and Traffic

Planning Information

- Determine **Design Life**
  - Usually between 20 – 40 years
- Current & Projected **Traffic** – ADT & ADTT
  - Directional & lane distribution
  - Current & Expected Adjacent Land Use

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Selecting a Pavement Design Tool

AASHTO 93
(software as ACPA WinPAS)

WinPAS 12

FREE Industry Developed Method

PavementDesigner.org

DARWin ME

PvD AASHTOWare Pavement ME Design

AASHTOWare Pavement ME
(previously known as DARWin-ME and MEPDG)

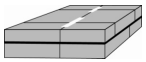
BCOA ME
University of Pittsburgh

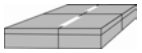
FREE – FHWA Pooled Fund TPF-5(165)
Google "BCOA ME"

AASHTO 93

Can Design:


Unbonded on Asphalt


Unbonded on Concrete


Bonded on Concrete

- Utilizes AASHTO 93/86 design equations with modifications

Change in Serviceability

Standard Normal Deviate — Overall Standard Deviation — ***Thickness***

$$Log(ESAL) = Z_R * s_o + 7.35 * Log(D+1) - 0.06 + \frac{Log\left[\frac{\Delta PSI}{4.5-1.5}\right]}{1+\frac{1.624*10^7}{(D+1)^{8.46}}}$$

"Traffic"

Modulus of Rupture — Drainage Coefficient

Terminal Serviceability

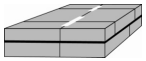
$$+(4.22-0.32*p_t)*Log\left[\frac{S_c'*C_d*(D^{0.75}-1.132)}{215.63*J*\left[D^{0.75}-\frac{18.42}{(E_c/k)^{0.25}}\right]}\right]$$

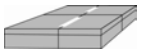
Load Transfer — Modulus of Elasticity — Modulus of Subgrade Reaction

AASHTO 93

Can Design:


Unbonded on Asphalt

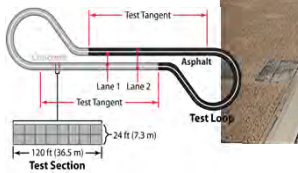

Unbonded on Concrete

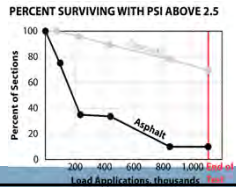

Bonded on Concrete

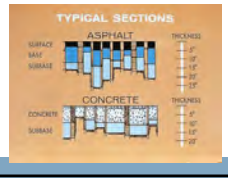
- Unbonded Concrete on Asphalt (UCOA)
  - Treats existing asphalt as a subbase layer
- Unbonded Concrete on Concrete (UCOC)
  - $T_{UCOC} = \sqrt{T_{required}{}^2 - T_{effective}{}^2}$
- Bonded Concrete on Concrete (BCOC)
  - $T_{BCOC} = T_{required} - T_{effective}$

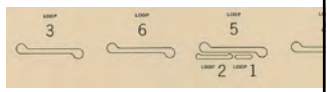
AASHTO 93

- Wholly empirical – AASHO Road Test
- Limited inference space:
  - Materials
  - Structural sections
  - Soils
  - Traffic
  - Climate
- Failure is "Serviceability"







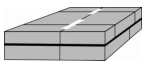


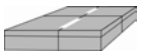
PavementDesigner

PavementDesigner.org

Can Design:


Unbonded on Asphalt


Unbonded on Concrete


Bonded on Concrete

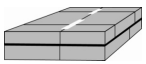
- Utilizes PavementDesigner Method (formerly StreetPave/PCA method) developed for JPCP with modifications
- FREE, industry-developed, mechanistic-empirical design method
  - Primarily for cities, counties, streets, and roads
- Allows for the use of synthetic macrofibers
- Joint spacing provided as an output
- Failure mechanisms of Cracking and Erosion

PavementDesigner

PavementDesigner.org

Can Design:


Unbonded on Asphalt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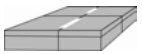
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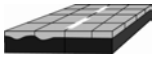
PavementDesigner.org

BCOA – ME

Can Design:



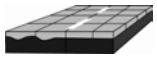
Bonded on Asphalt

- FREE Mechanistic – Empirical design tool specifically for Concrete Overlays of Asphalt
  - Assumes a partially bonded condition
- Developed at University of Pittsburgh under FHWA Pooled Fund TPF-5(165)
- Incorporates climatic distresses
- Joint spacing is featured as an input
- Allows for design with synthetic macrofibers directly

https://www.engineering.pitt.edu/Sub-Sites/Faculty-Subsites/J_Vandenbossche/BCOA-ME/BCOA-ME/
Or google "BCOA ME"

BCOA – ME

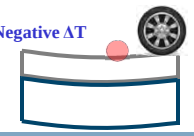
Can Design:



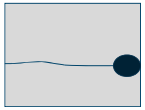
Bonded on Asphalt

≤ 4.5 ft
Corner Break

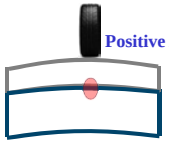
Negative ΔT



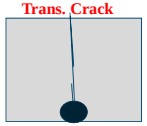
5 to 7 ft
Long. & Diag Crack



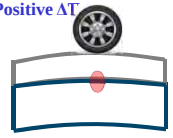
Positive ΔT



10 x 12 ft
12 x 12 ft
12 x 15 ft
Trans. Crack



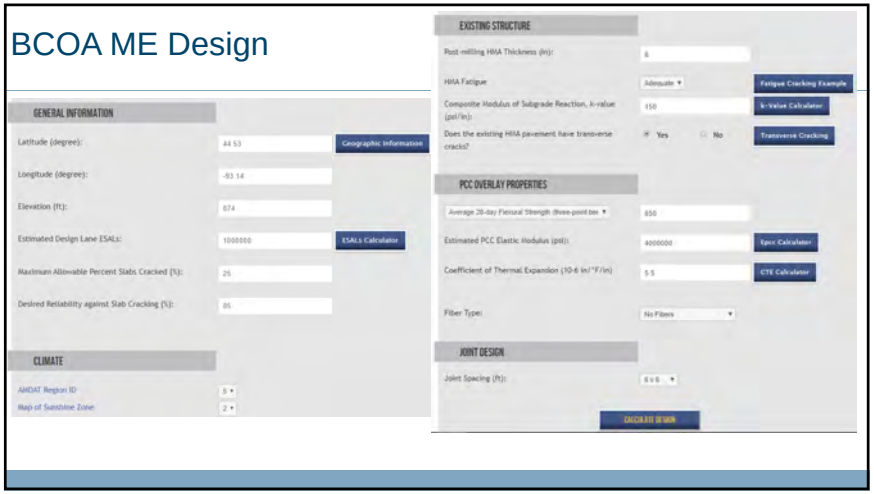
Positive ΔT



BCOA ME Design

Google: BCOA ME

BCOA ME Design



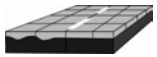
BCOA ME Design

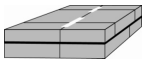
Pavement ME

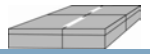
A.K.A. MEPDG

Can Design:


Unbonded on Asphalt


Bonded on Asphalt "SJPCP"

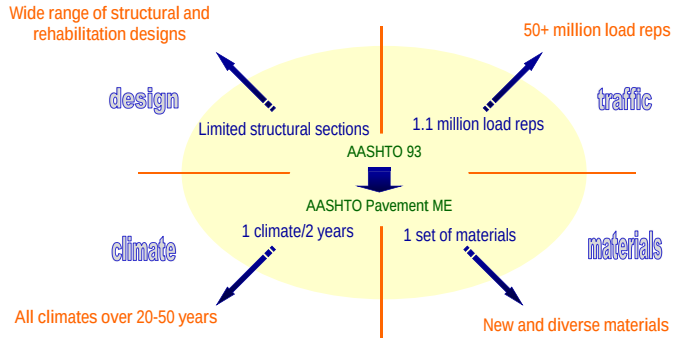

Unbonded on Concrete


Bonded on Concrete

- AASHTO's current design/analysis tool
  - Current version is 2.5.5
- License is yearly-based subscription
- Incorporates climate data
- Allows most control of all design tools
- Features joint spacing as an input
- Failure mechanisms include IRI, Faulting, and Cracking
  - SJPCP only includes longitudinal cracking

- https://me-design.com/MEDesign/

AASHTO 93 vs. ME



Design Tool Summary

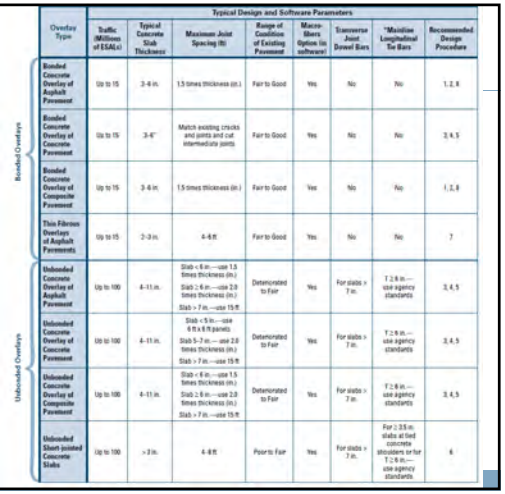
	AASHTO 93	PavementDesigner	BCOA – ME	Pavement ME
Designs for:				
Unbonded on Asphalt	Yes[1]	Yes[1]		Yes
Bonded on Asphalt		Links to BCOA-ME	Yes	Yes (SJPCP)
Unbonded on Concrete	Yes[1]	Yes[1]		Yes
Bonded on Concrete	Yes[1]	Yes[1]		Yes
Failure Criteria:				
Cracking		Yes	Yes	Yes
Faulting		Yes		Yes[2]
IRI				Yes[2]
Additional Design Information:				
Mechanistic – Empirical		Yes	Yes	Yes
Climatic Loading			Yes	Yes
Joint Spacing		Output	Input	Input
Design with Fibers in Tool		Yes	Yes	

[1] Via modifications to conventional JPCP design
[2] Not in SJPCP Module

Typical Design & Software Parameters

Recommended Design Procedures (see previous page for links)
1. *Bonded Concrete Overlay on Asphalt (BCOA) Thickness Designer* (ACPA 2012)
2. *BCOA ME* (Vandenbossche 2013)
3. *Guide for Design of Pavement Structures*. 4th ed. (AASHTO 1993)
4. *Mechanistic-Empirical Design Guide—A Manual of Practice* (AASHTO 1993)
5. *StreetPave* (ACPA 2012)
6. *Optipave V2.0* (TCPavements 2010)
7. *Flowable Fibrous Concrete for Thin Pavement Inlays* (Bordelon and Roesler 2011) (see Appen
8. Illinois DOT's spreadsheet for bonded concrete inlay/overlay of asphalt design (Roesler et al

Table 10 – Summary of Current Overlay Design Software (page 54)



Overlay Jointing Practices

Joint Spacing

- Thinner overlays tend to have shorter joint spacings
- See Guide to Overlays for detailed information

Dowel & tie bar use

- Dowels normally not necessary for overlay thicknesses < 7 in.
- For unbonded overlays ≥ 5 in., use tie bars at longitudinal joints

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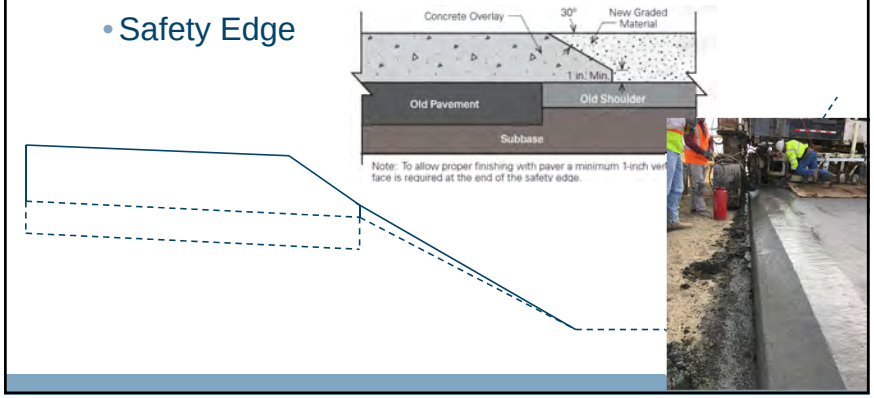
Additional Considerations in Overlay Design

- Shoulders / Widening
- Vertical Grade Changes
  - Overhead Clearance
  - Barriers and Rails
  - Safety Edge
  - Drainage Structures
- Transitions

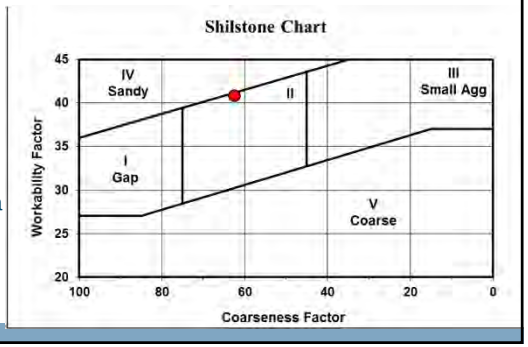
Foreslope Adjustment Options

- Safety Edge



Materials – Mixture Design

- Performance Engineered Mixtures - https://cptechcenter.org/performance-engineered-mixtures-pem/
- Standard concrete mixtures whenever possible
- Minimize the use of accelerated mixtures
- Focus on project sequencing to accommodate maintenance of traffic
- Optimized gradation – Tarantula Curve / Shilstone Chart
- Reduced paste content – durability and shrinkage



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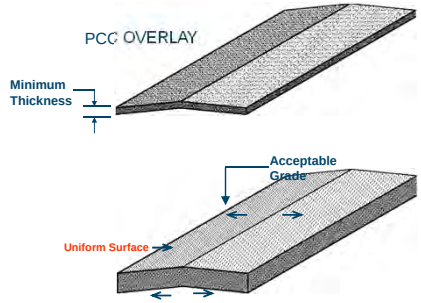
Concrete Overlay Quantity Control

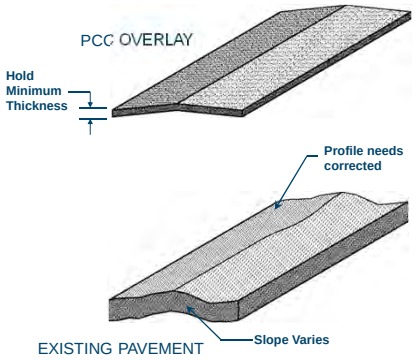
Concrete Overlay Quantities IDEAL SITUATION

- Quality of PCC is Uniform (set milling depth to remove exactly overlay depth and not worry about profile or smoothness)
- Profile is Perfect (never is)
- Concrete is bid in sq. yards; (Should be cu. yds for material & sy.yds. for placement)



Concrete Overlay Quantities -REALITY SITUATION-

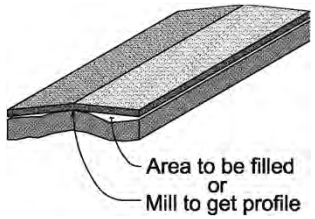
- Concrete is bid in sq. yards for placement, cubic yards for material
- Profile is not perfect and needs corrected
- Cross slope needs correction



Concrete Overlay Approach

If existing surface needs some improvement in cross slope or profile grade and want minimum survey:

- Must maintain minimum pavement thickness
- Contractor sets recommended grade
- Allow to mill to get cross slope and profile



Quantity Estimates

- Estimating plan quantity
  - Overlay cubic yard pay item is to adjust the theoretical volume by an appropriate factor that accounts for the non-uniformity of the existing surface

Concrete Overlay Thickness	½" Placement Tolerance as a % of Design Thickness	Additional % Adjustment for Gross Surface Irregularities in the Existing Surface	Total Adjustment Factor to be Applied to Theoretical Volume
4"	12.5%	5%	17.5%
6"	8.3%	5%	13.3%
8"	6.3%	5%	11.3%
10"	5.0%	5%	10.0%
12"	4.2%	5%	9.2%

Overlay Design Process

- Pavement Evaluation
- Determine Overlay Type
- Determine Design Life and Traffic
- Use Pavement Design Software
- Consider Additional Design Features
- Consider Construction Process
- Create Construction Documents

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Specifications and Construction Documents

- Guide specifications and standard drawings and design details available in CP Tech Center Resources
- Plans can be simple
  - Typical Section

- https://cptechcenter.org/concrete-overlays/
- https://intrans.iastate.edu/app/uploads/2018/09/overlay_construction_doc_dev_guide_w_cvr.pdf

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Next Up: The Colorado Experience

Concrete Overlays in Colorado & Wyoming

Angela Folkestad, PE
CO/WY Chapter - ACPA

Harmony Road near Fort Collins, CO - 1990
1st Thin Whitetopping Test Section in CO

- 3.5" & 5" thick sections
- Paved Saturday & open Monday
- 3,750 psi compressive strength

- 18,200 AADT
- 4% Truck Traffic
- 105,000 ESALs per year

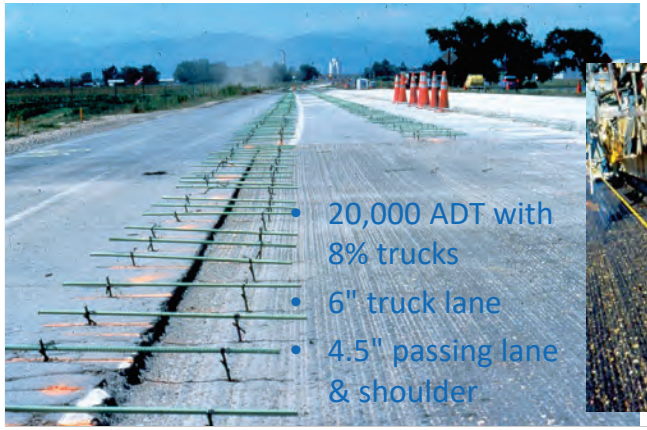
Harmony Road near Fort Collins, CO
Donated by Industry for 2 Year Test

Parker Road in SE Denver - 1994
4 – 200' Test Sections (5" thick)

- Joint Spacing: 6' x 6' and 10' x 12'
- 1,500 ADT with 25% Trucks

- Milled & Non-milled
- Tied Longitudinal Joints

SH 119 near Longmont, CO - 1996



- 20,000 ADT with 8% trucks
- 6" truck lane
- 4.5" passing lane & shoulder

SH 119 near Longmont, CO

Condition in 2009

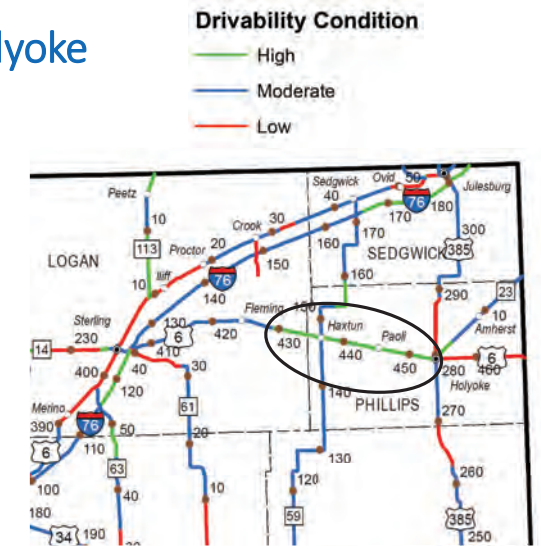
US 287 Near Campo, CO in SE CO – 1997 "The Lone Mile"

- 6" Concrete Overlay
- 6' x 6' Joint spacing
- 2,300 AADT with 60% trucks
- Test section removed (not due to distress)

US 6 – Fleming to Holyoke NE Colorado

1997: E. of Fleming to Haxtun
- MP 429 – 441
- 5.5" Concrete Overlay
- 12 years RDL – High (in 2019)
- IRI: 78.5 in./mile (in 2017)

2001: Haxtun to Holyoke
- MP 441 – 454
- 8" Concrete Overlay
- 11-17 years RDL – High (in 2019)
- IRI: 97.5 in./mile (in 2017)



SH 121 (Wadsworth Blvd.) in SW Denver - 2001

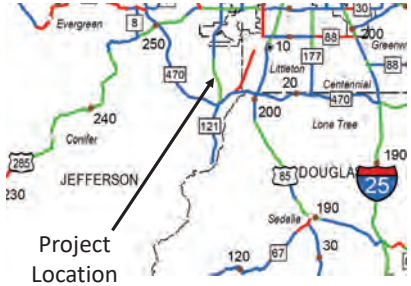
- 6” Overlay
- 3.5 miles long
- 45,000 AADT with 3% trucks

SH 121 (Wadsworth Blvd.) in SW Denver - 2001

- 4” test section with 4’ x 4’ joint spacing
- 4.5” test section with 6’ x 6’ joint spacing

SH 121 (Wadsworth Blvd.) in SW Denver

- 12 years RDL – High (in 2019)
- 47,000 AADT

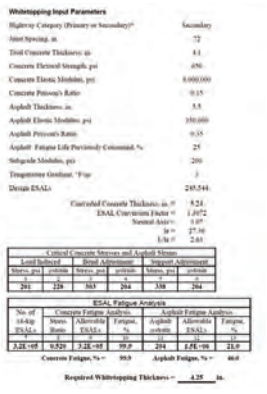


Research Contributes to Improving CDOT’s Thin Whitetopping Procedure


INSTRUMENTATION AND FIELD TESTING OF THIN WHITETOPPING PAVEMENT IN COLORADO: AND REVISION OF THE EXISTING COLORADO THIN WHITETOPPING PROCEDURE

DOT RESEARCH

AUGUST 2004


Whitetopping Input Parameters

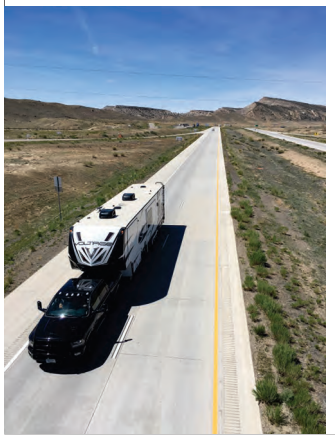
Count on CONCRETE

I-70 West of Grand Junction, CO (near UT)

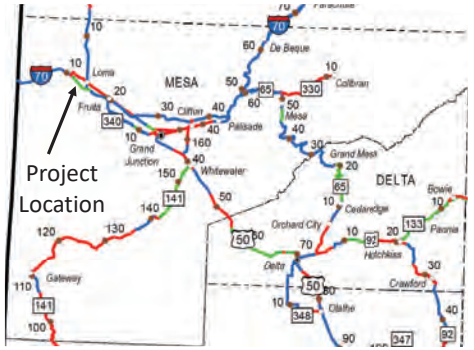
- 4.4 miles long
- 20-year design life
- Mill existing asphalt 0.5” – 4”

- Built in 2012
- 6” Concrete overlay
- 6’ x 6’ Joint spacing

I-70 West of Grand Junction, CO (near UT)



- 12 years RDL – High (in 2019)
- 11,000 ADT



US 30 near Cokeville, WY

- 6” thickness
- 6’ x 6’ joint spacing

US 30 near Cokeville, WY

SH 13 N. of Craig, CO - 2015

SH 13 N. of Craig, CO

- Alternate bid project – concrete pavement 1st cost low
- Smoothness: IRI < 50 in./mile
- 6” concrete overlay
- 6’ x 6’ joint spacing
- 6 miles long
- 20-year design

Pikes Peak Parking Lot
at Denver International Airport

- 4.5” - 5” overlay
- 6’ x 6’ joint spacing
- 146,000 SY
- Constructed in 2019

Parker Road Corridor
SE Denver

- 5” – 6” thickness
- 6’ x 6’ joint spacing

US 287 Corridor SE Colorado

- Full depth overlays 9” – 12”
- 12’ x 15’ joint spacing
- More than 150 miles of OLs

US 287 Corridor – SE Colorado

Where can Concrete Overlays be Built?

- Divided highways
- Urban arterials
- Rural 2-lane highways
- Interstates
- Parking lots
- Farm to market routes
- Heavy truck routes
- Commuter routes
- Industrial areas

Anywhere you need a durable surface to make your infrastructure investment go further!

Count on CONCRETE

What Have We Learned?

- Tie longitudinal joints
- Milling is beneficial
- Material selection is important
- Lower annual maintenance costs
- Performance typically exceeds design life
- Concrete overlays save time during construction

Count on CONCRETE

Thank you!

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