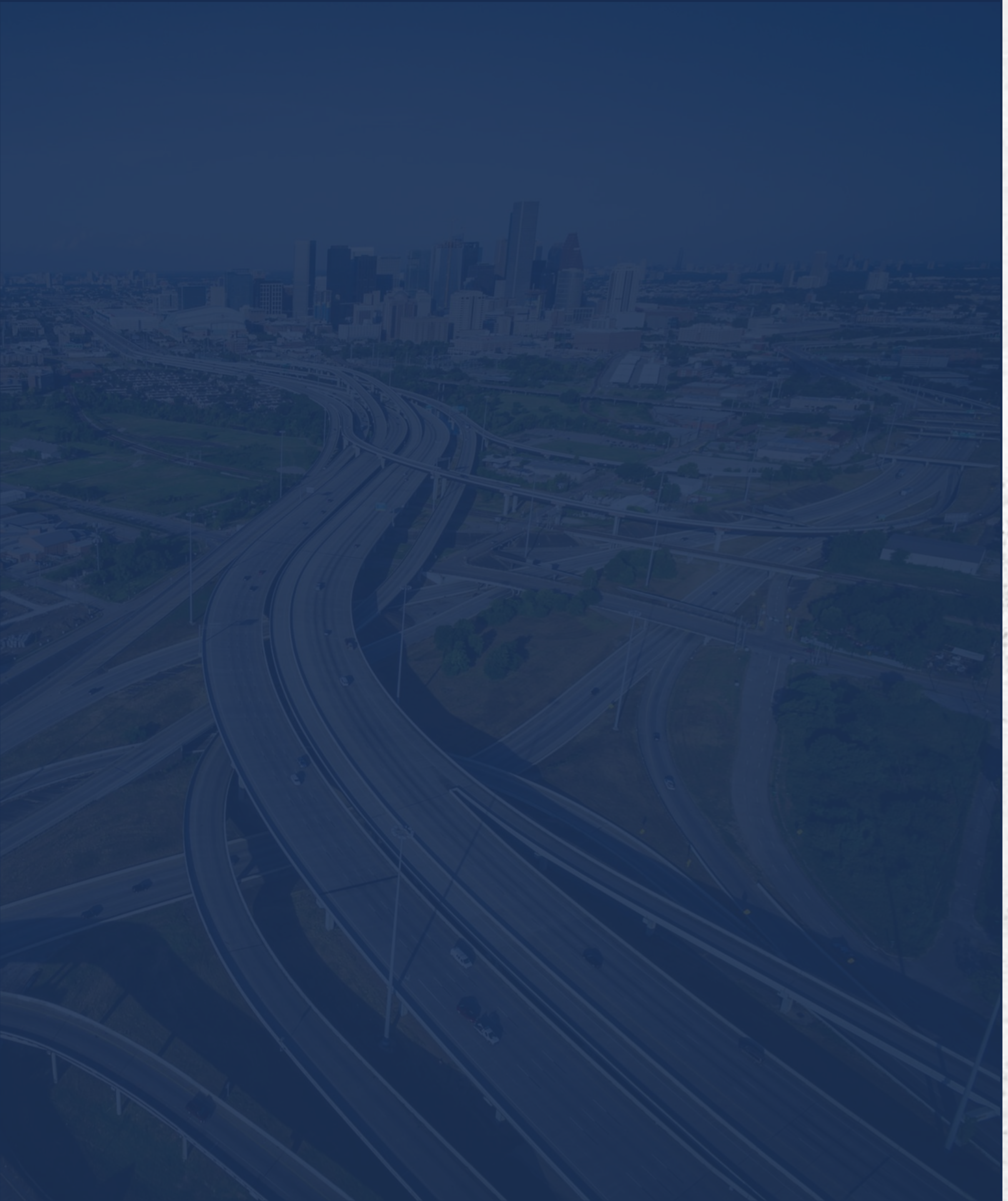

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Cement-Treated Bases: Design, Construction, and Performance

Randy Bowers, P.E.

Outline

- Materials
- Testing and Mix Design
- Lime plus Cement
- Construction
- Thickness Design Procedure
- Projects
- Summary

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CEMENT TREATED BASE

(by any other name)

- Cement Modified Soil (CMS)
- Cement Stabilized Subgrade (CSS) Soil
- **Cement Treated Base (CTB)**
- **Full-Depth Reclamation (FDR) with Cement**

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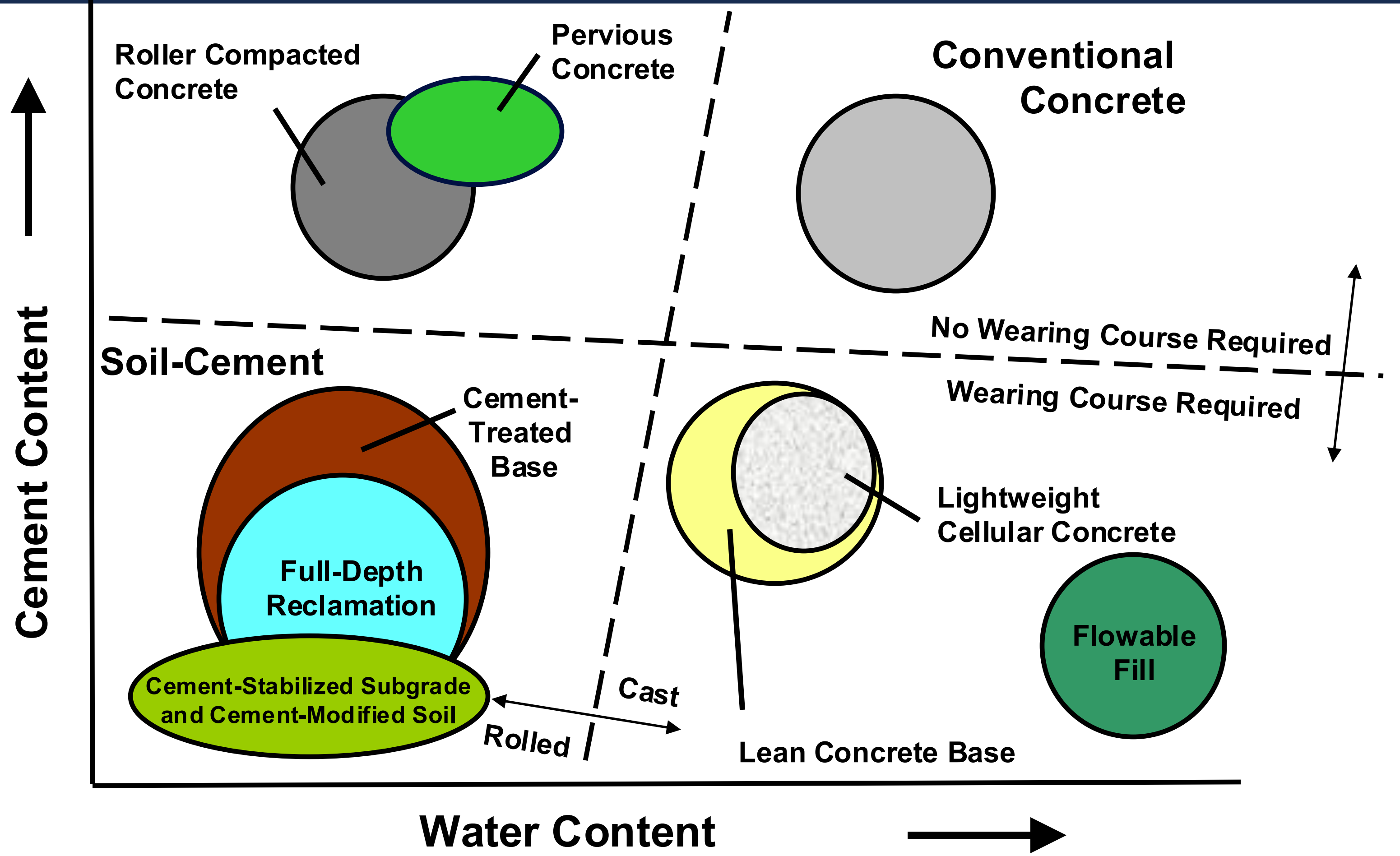
Cement-Based Pavement Materials



Ingredients

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Materials that Can be Cement-Stabilized

- Sand
- Silt
- Clay
- Gravel
- Shell
- Crushed stone
- Slag
- Recycled HMA
- Recycled concrete

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What is Cement Treated Base (CTB)?

- Highly compacted mixture of
  - Aggregate
  - Portland cement
  - Water
- Dense-graded (usually)
- Plant mixed or mixed in place
- Base material for
  - Flexible pavements (asphalt or chip seal surface)
  - Concrete pavements

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CTB Uses Variety of Aggregates

- Sand
- Gravel
- Caliche
- Crushed limestone (flex base)
- Recycled materials
  - Asphalt millings/RAP
  - Crushed concrete

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Why Consider CTB?

- Strongest, most resilient base available
  - High resilient modulus
  - Highly moisture resistant
  - Resists erosion
  - Resists settling
  - Spreads loads to weak subgrades
- Makes use of available local materials
- Less expensive to use the local materials

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Definition of Full-Depth Reclamation

Method of flexible pavement reconstruction that utilizes the existing asphalt, base, and/or subgrade material to produce a new stabilized base course for a chip seal, asphalt, or concrete wearing surface.

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Benefits of FDR with Cement

- Increased rigidity spreads the loads
- Eliminates rutting below the surface
- Reduced moisture susceptibility
- Reduced fatigue cracking in asphalt surfacing
- Allows for thinner pavement sections

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Materials in FDR with Cement Bases

FDR with cement bases are an intimate mixture of recycled asphalt pavement, graded aggregate base, and/or native soils with measured amounts of portland cement and water that harden after compaction and curing to form a strong, durable, water- and frost-resistant pavement material.

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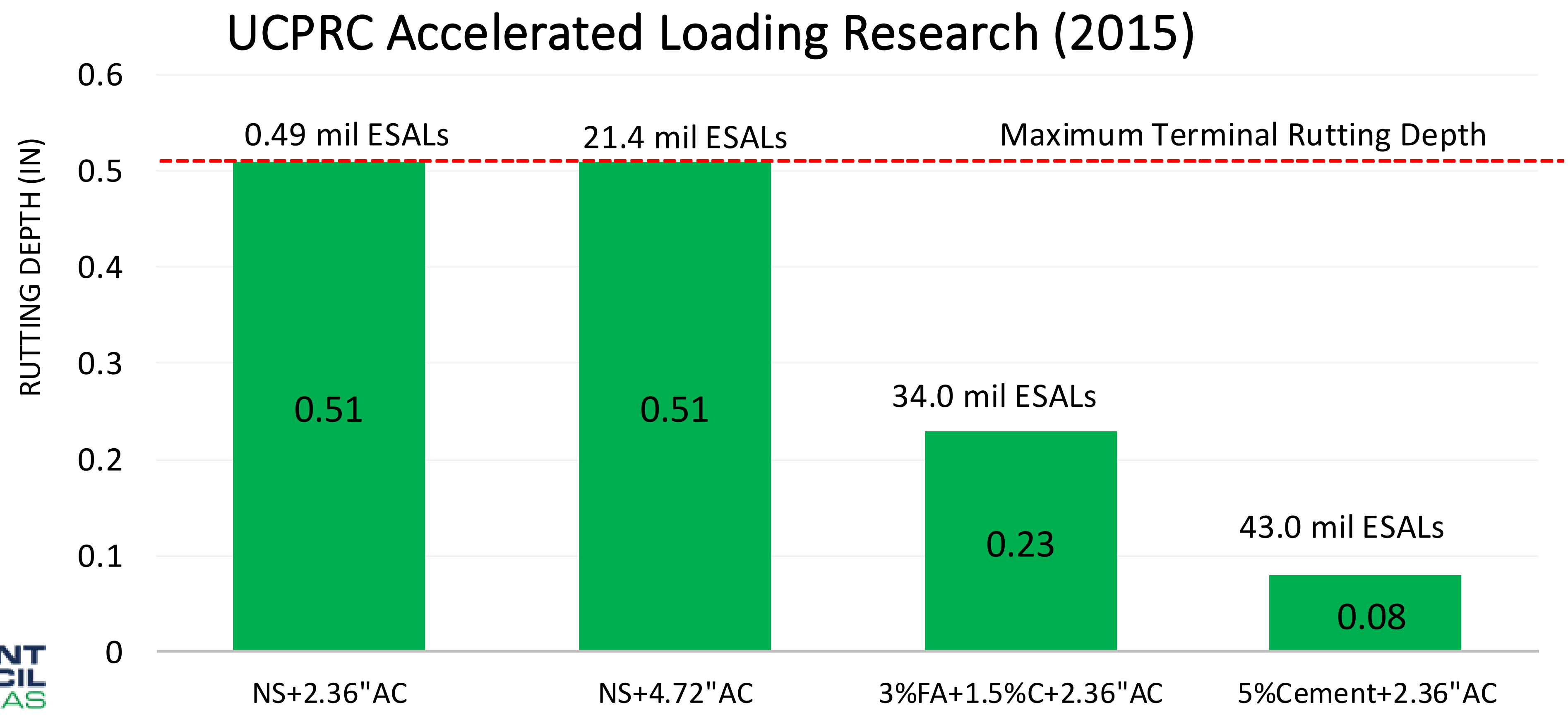
Comparing Different FDR Methods



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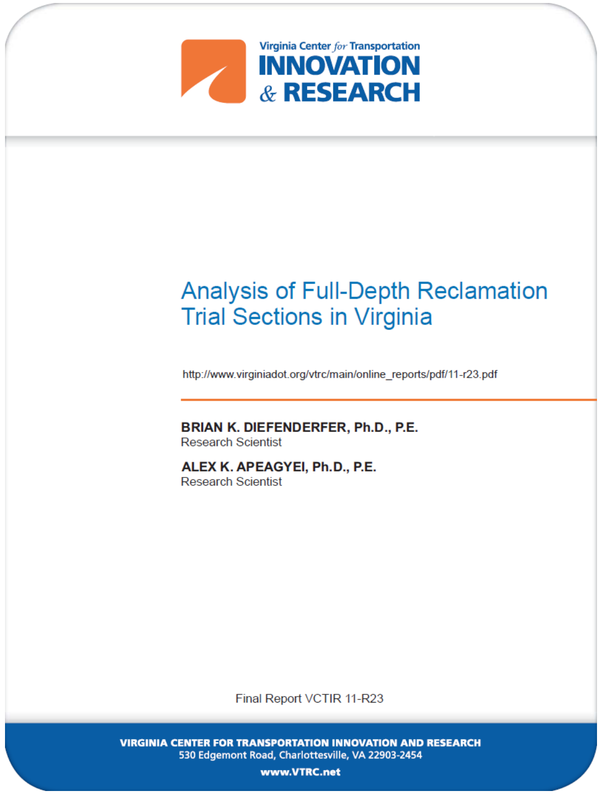
Viriginia DOT Study on FDR

- Stabilizers Tested:
  - Asphalt emulsion, foamed asphalt, Portland cement
- Calculated layer coefficients
  - Asphalt emulsion: 0.12 - 0.29
  - Foamed asphalt: 0.18 – 0.33
  - Portland cement: 0.24 – 0.34
- VDOT potential savings $463K to $1.42M per year with FDR


Virginia Center *for* Transportation
INNOVATION
& RESEARCH

Analysis of Full-Depth Reclamation Trial Sections in Virginia

http://www.virginiadot.org/vtrc/main/online_reports/pdf/11-r23.pdf

BRIAN K. DIEFENDERFER, Ph.D., P.E.
Research Scientist

ALEX K. APEAGYEI, Ph.D., P.E.
Research Scientist

Final Report VCTIR 11-R23

VIRGINIA CENTER FOR TRANSPORTATION INNOVATION AND RESEARCH
530 Edgemont Road, Charlottesville, VA 22903-2454
www.VTRC.net

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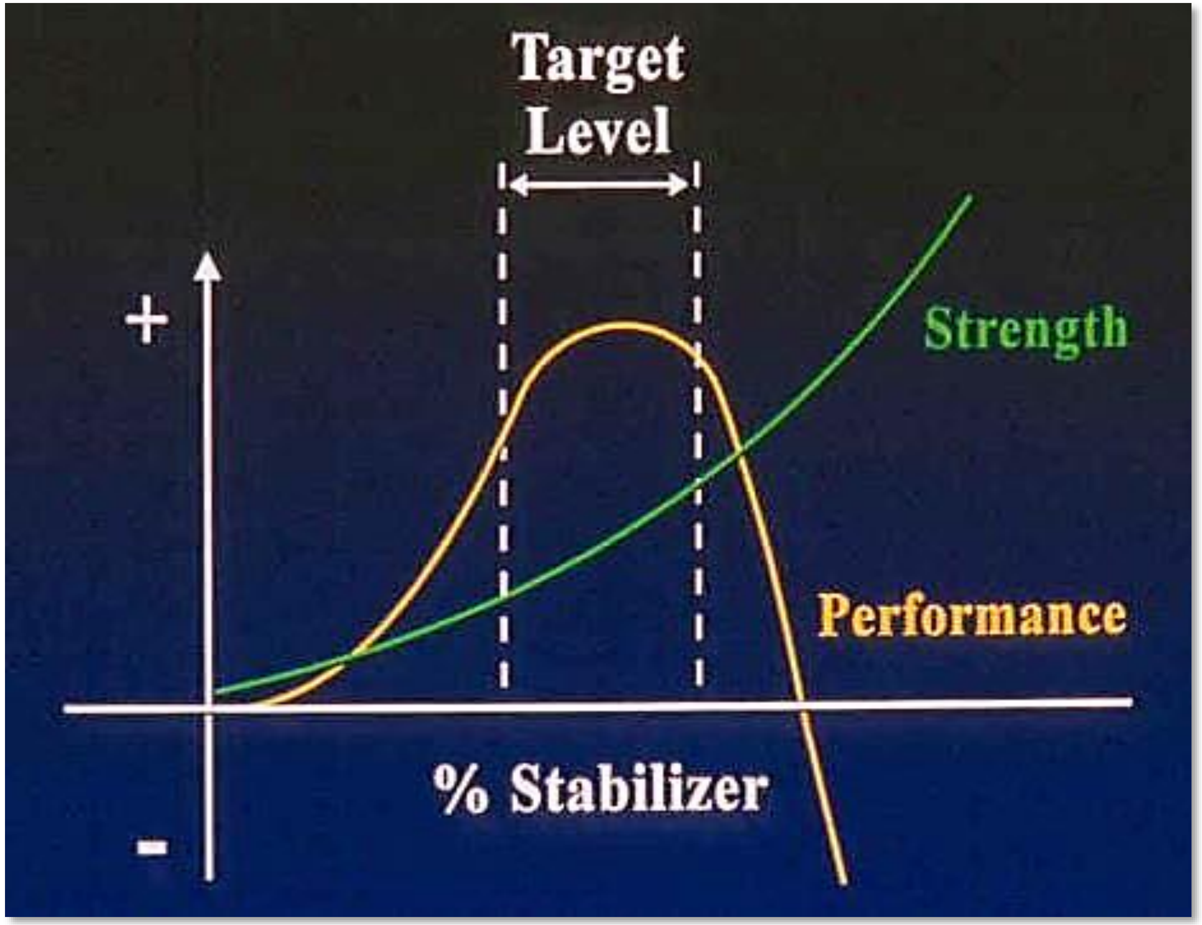
www.virginiadot.org/vtrc/main/online_reports/pdf/11-r23.pdf

Strength and Performance

- The purpose of the mix design procedure is to select the correct amount of cement that most closely balances both strength AND performance for the roadway materials.



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Rigid Pavements
TxDOT Base Layer Requirements

TxDOT recognizes the one of the following layers for concrete slab support:

- 4 in of hot-mix asphalt (HMA) or asphalt stabilized base (ASB)
- Or a minimum 1 in hot-mix asphalt bond breaker over 6 in. of cement treated base (CTB)

Field performance evaluations of concrete pavements have revealed that durable, stabilized, non-erodable base is essential to the long-term performance of concrete pavement.

If the base does not provide good support, the concrete pavement will be compromised, and long-term performance will be compromised.

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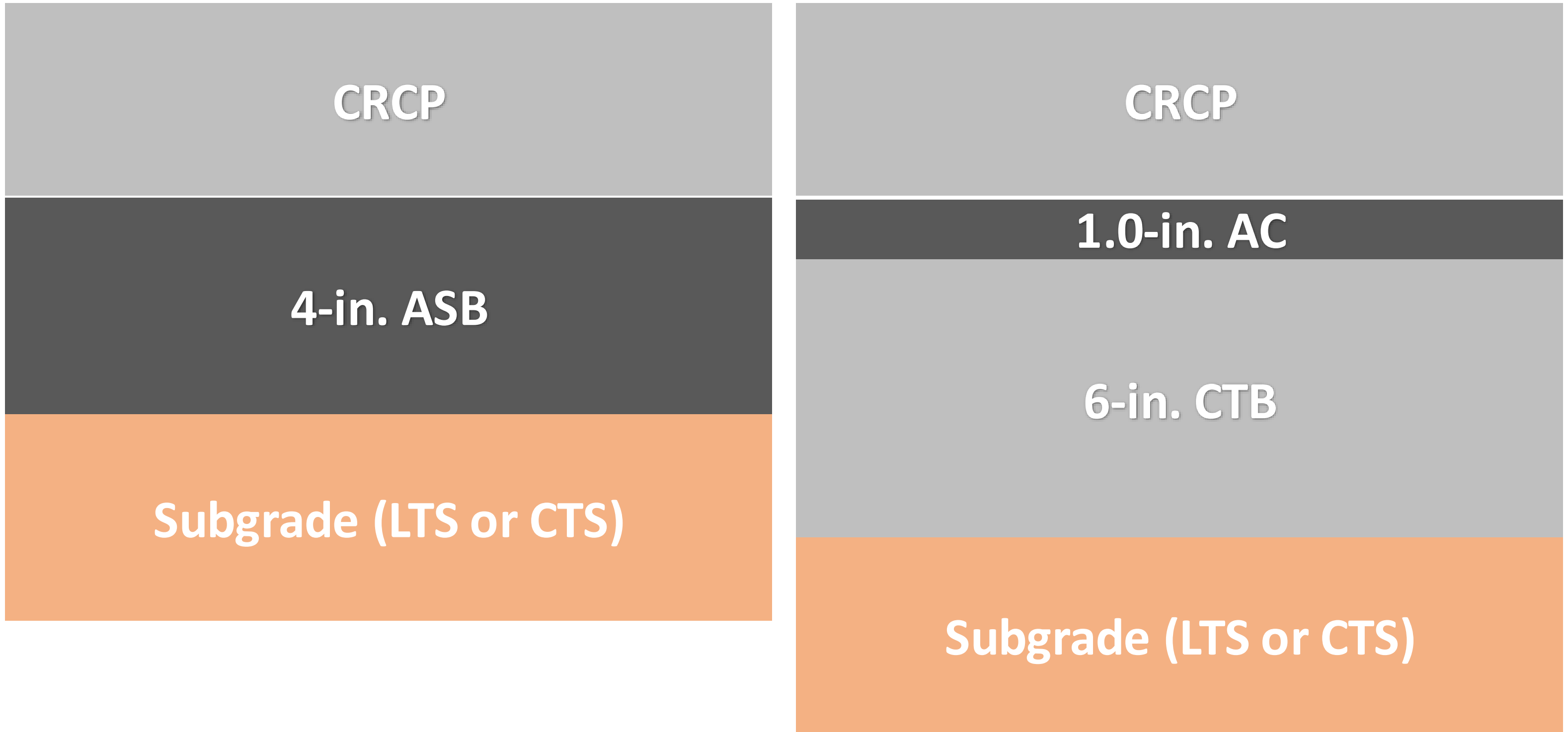
Base Type Selection

- ≥ 4-in. HMA or ASB
- ≥ 1.0-in. HMA or ASB + 6-in. CTB



Improved Pavement Quality with CTB

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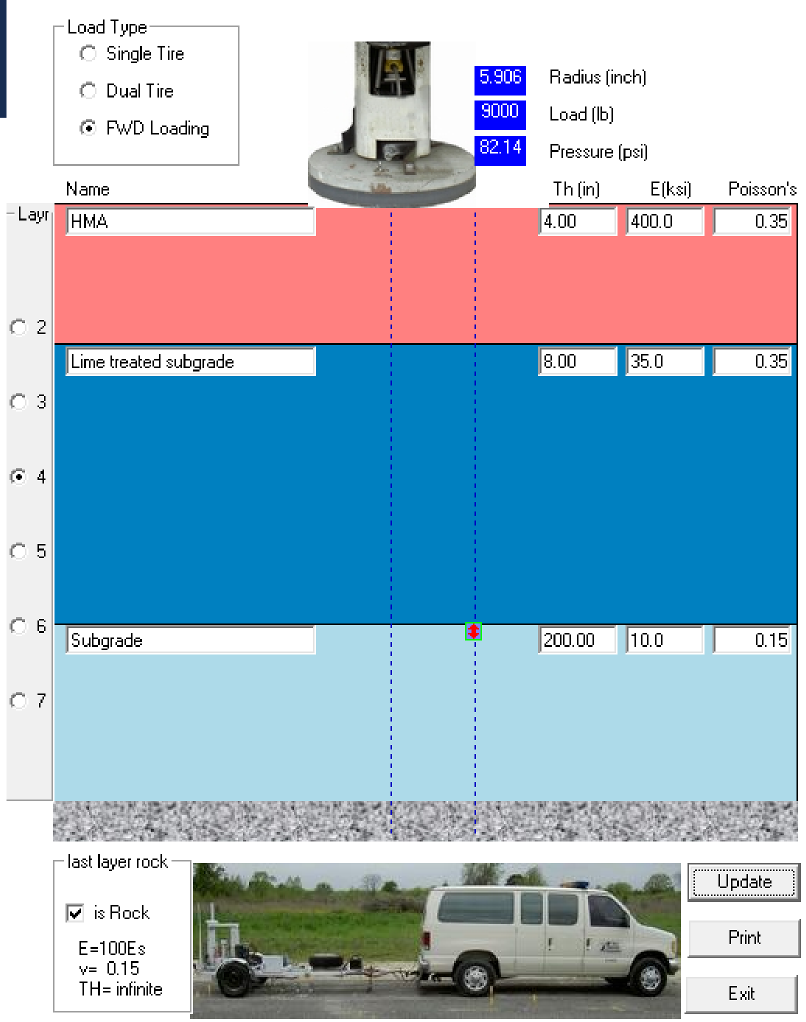
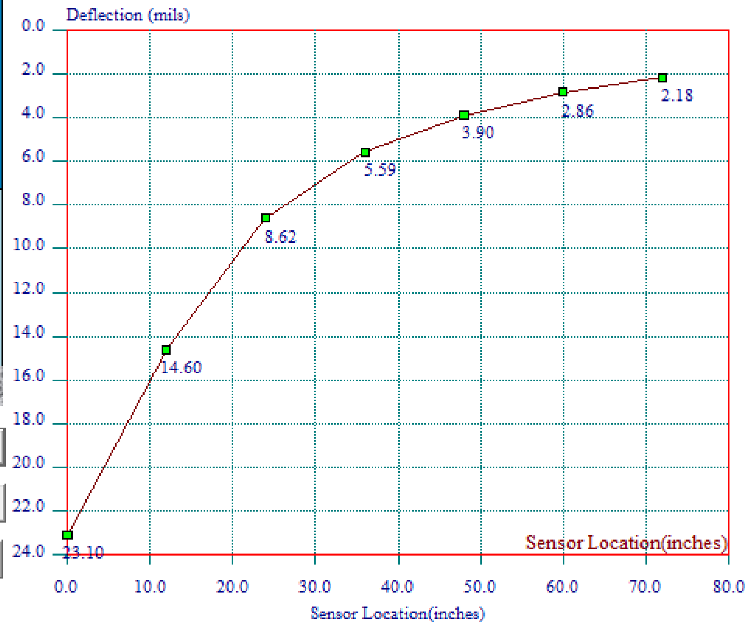
HMA Base + LTS FWD deflection: 23 mils



Pavement Stress Analysis Result

Location	ε_t	ε_v	σ_t	σ_v
Unit	(micro strain)		(psi)	
Btm of HMA	298.00	-375.00	165.00	-34.80
	224.00	-190.00	103.00	-20.30
Btm of Lime trea	317.00	-509.00	12.00	-9.41
	276.00	-395.00	9.77	-7.62
Top of Subgrade	317.00	-1000.00	2.06	-9.41
	276.00	-807.00	1.80	-7.62



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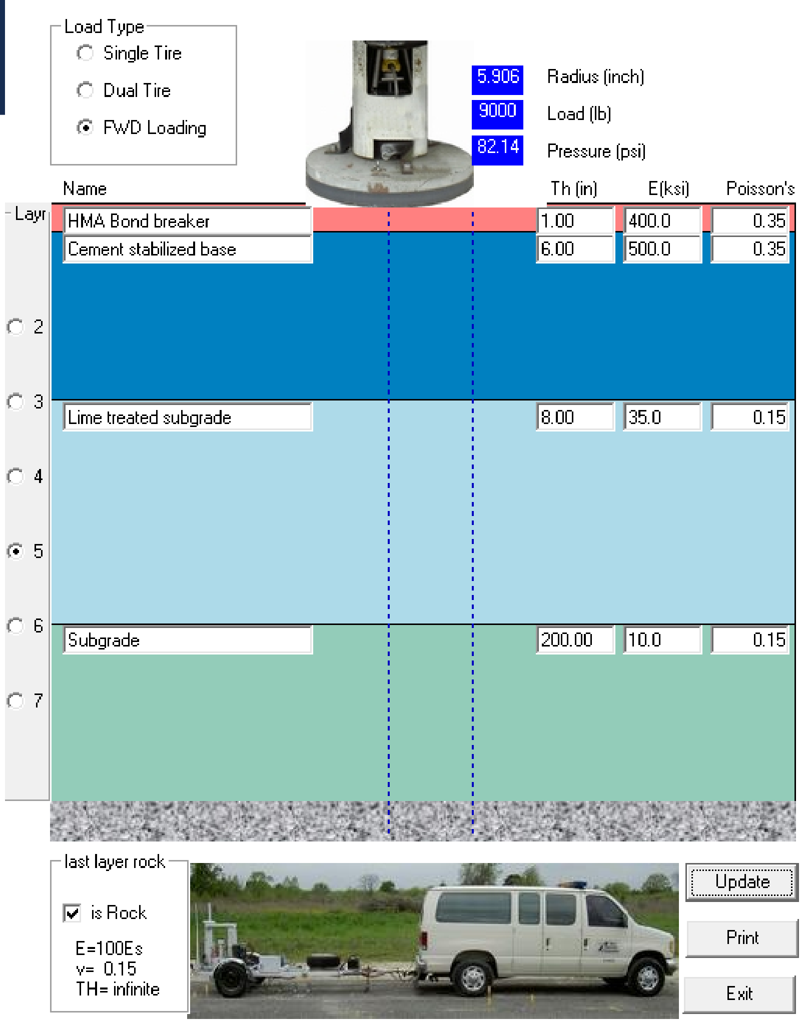
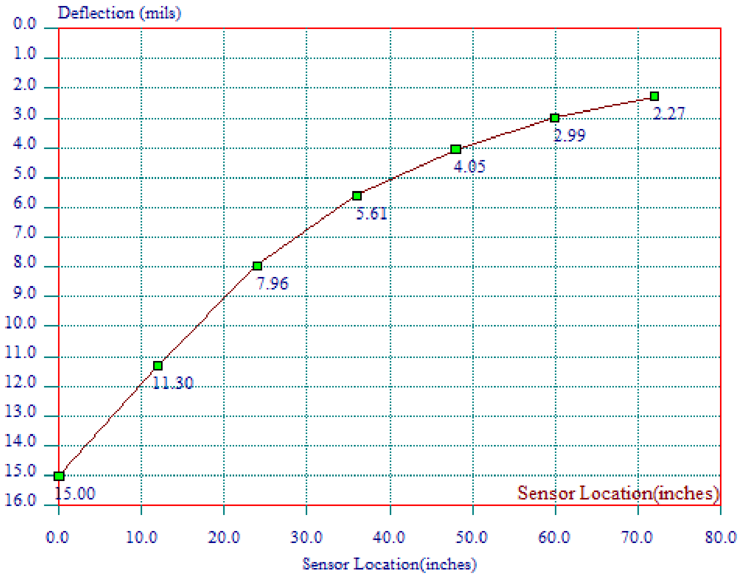
CSB/Bond breaker Base + LTS FWD deflections: 15 mils



Pavement Stress Analysis Result

Location	ε_t	ε_v	σ_t	σ_v
Unit	(micro strain)		(psi)	
Btm of HMA Bond	-107.00	-9.77	-109.00	-79.90
	-71.30	25.30	-66.50	-37.90
Btm of Cement st	161.00	-192.00	116.00	-15.30
	129.00	-122.00	82.60	-10.30
Btm of Lime trea	165.00	-188.00	5.92	-4.81
	151.00	-163.00	5.32	-4.22
Top of Subgrade	165.00	-513.00	1.09	-4.81
	151.00	-449.00	0.99	-4.22



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Construction

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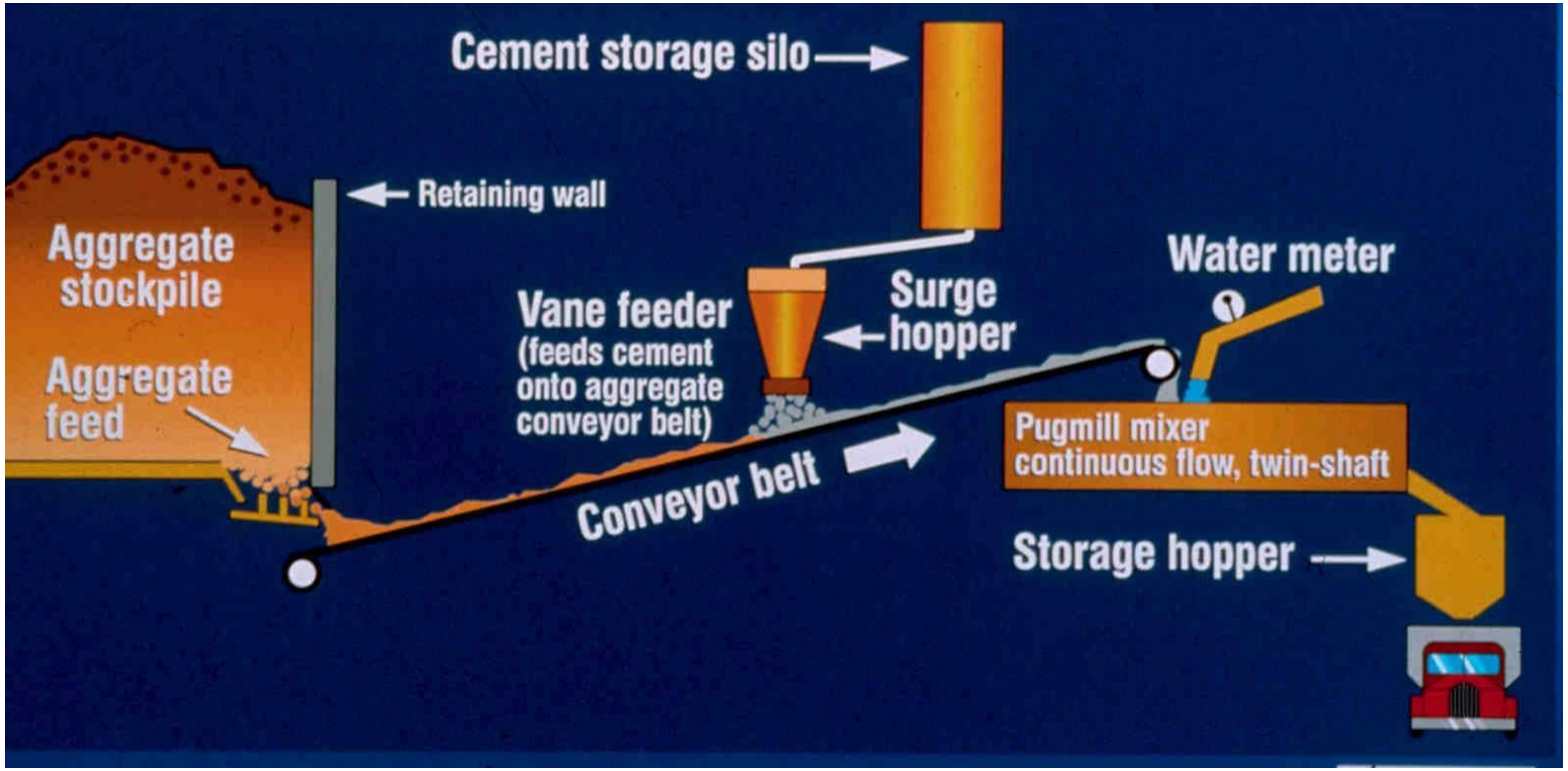
Plant-Mixed CTB



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Plant-Mixed CTB

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Construction Process – Similar to Soil Cement

- Moisture Conditioning (If Necessary)
- Initial Pulverization (If Necessary)
- Preliminary Grading
- Cement Application
- Mixing
- Optimum Moisture Content
- Compaction
- Final Grading
- Curing

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Construction Equipment

- Cement or slurry spreader/distributor truck
- Reclaimer/mixer
- Water truck
- Grader
- Tamping/sheepsfoot/padfoot roller
  - for clayey and silty material
- Smooth drum roller (for granular soils)
- Pneumatic tire roller (optional)

Images: Virginia DOT

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Full Depth Reclamation with Cement Construction Process

- Pulverize the roadbed materials
- Blade to desired roadway template
- Spread cement either dry or as a slurry
- Mix all materials directly on the roadbed
- Bring to optimum moisture content
- Compact to 98% standard Proctor
- Shape the roadway to Plan requirements

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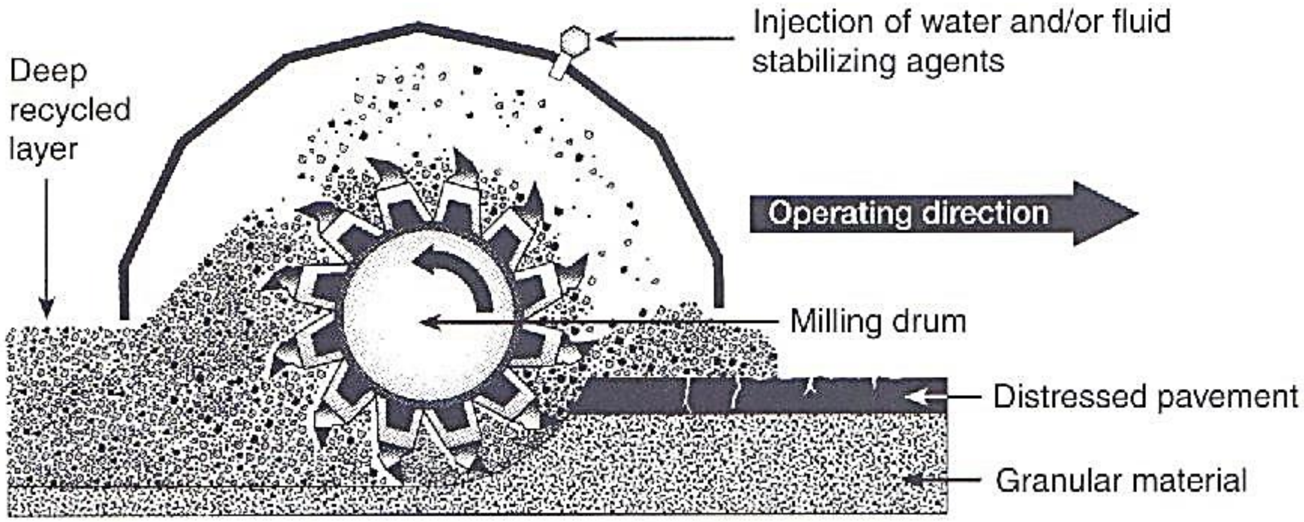
Inside a Reclaimer



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Compaction and Grading

Material is compacted to 96 to 98 percent minimum <u>standard proctor density</u> and then graded to appropriate lines, grades, and cross-sections.

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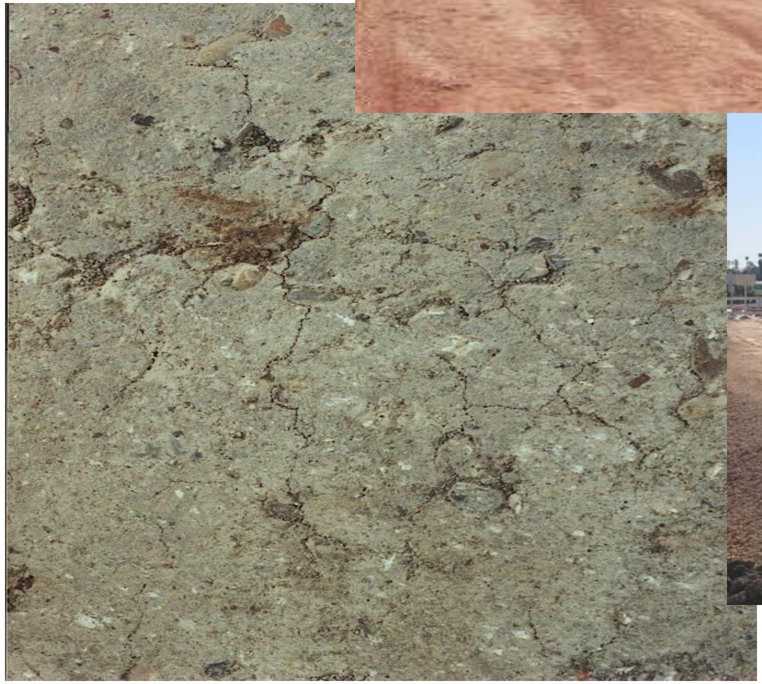
Microcracking Procedure

- 10-to-12-ton vibratory roller
- 24 to 48 hours after placement
- Creep speed
- High amplitude
- Typically, 3 passes



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Ottinger Road Keller, TX

- Reclaimed in Spring 2007
  - 1+ mile road
  - FDR with 4% cement
  - Middle section microcracked after 24 hours
  - End sections reclaimed but not microcracked [control sections]

Ottinger Road
Keller, TX

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Ottinger Road
Non-Microcracked Section

Ottinger Road Microcracked Section

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THICKNESS DESIGN PROCEDURES

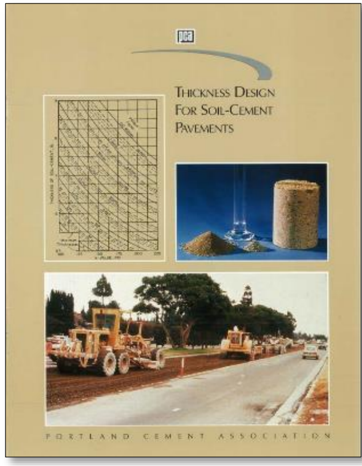
Pavement Thickness Design Procedures

- **Mechanistic**
  - Based on the mechanics of a pavement structure
    (e.g., PCA procedure)
- **Empirical**
  - Based on observed pavement performance
    (e.g., 1993 AASHTO Guide)
- **Mechanistic-Empirical**
  - Based on a combination of both mechanics and observed pavement performance
    (e.g., AASHTOWare Pavement ME Design)

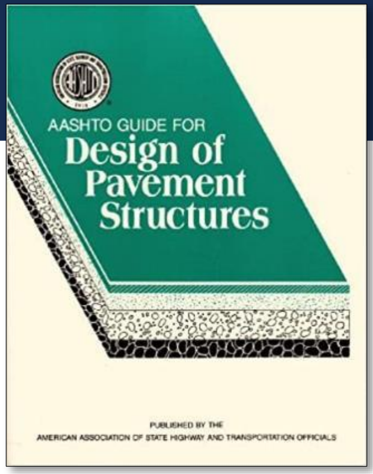
PavementDesigner.org

PCA Thickness Design Procedure

- First published in 1970 as PCA Thickness Design for Soil-Cement Pavements
- Based on research, full-scale tests, design theory, and observed pavement performance
- Fatigue consumption ultimately determines the FDR layer thickness
- Used when FDR will be covered with bituminous surfacing, although the design covers adequate thickness of the stabilized layer



1993 AASHTO Thickness Design Procedure



- AASHTO Guide For Design of Pavement Structures
- Based on AASHO Road Test
- Purely empirical method
- Conservative guidance for FDR material contribution based on unconfined compressive strength
- Must assume layer coefficients
- Simple and quick determination of pavement design thickness

AASHTOWare Pavement ME Design

- Design procedure formerly known as MEPDG
- Ultimate pavement thickness design tool
- Use of layered elastic analysis and developed performance models
- Use critical tensile stress at the bottom of FDR layer
- Requires a great deal of inputs
- Very expensive to access
- Performance checks of all layers must be made

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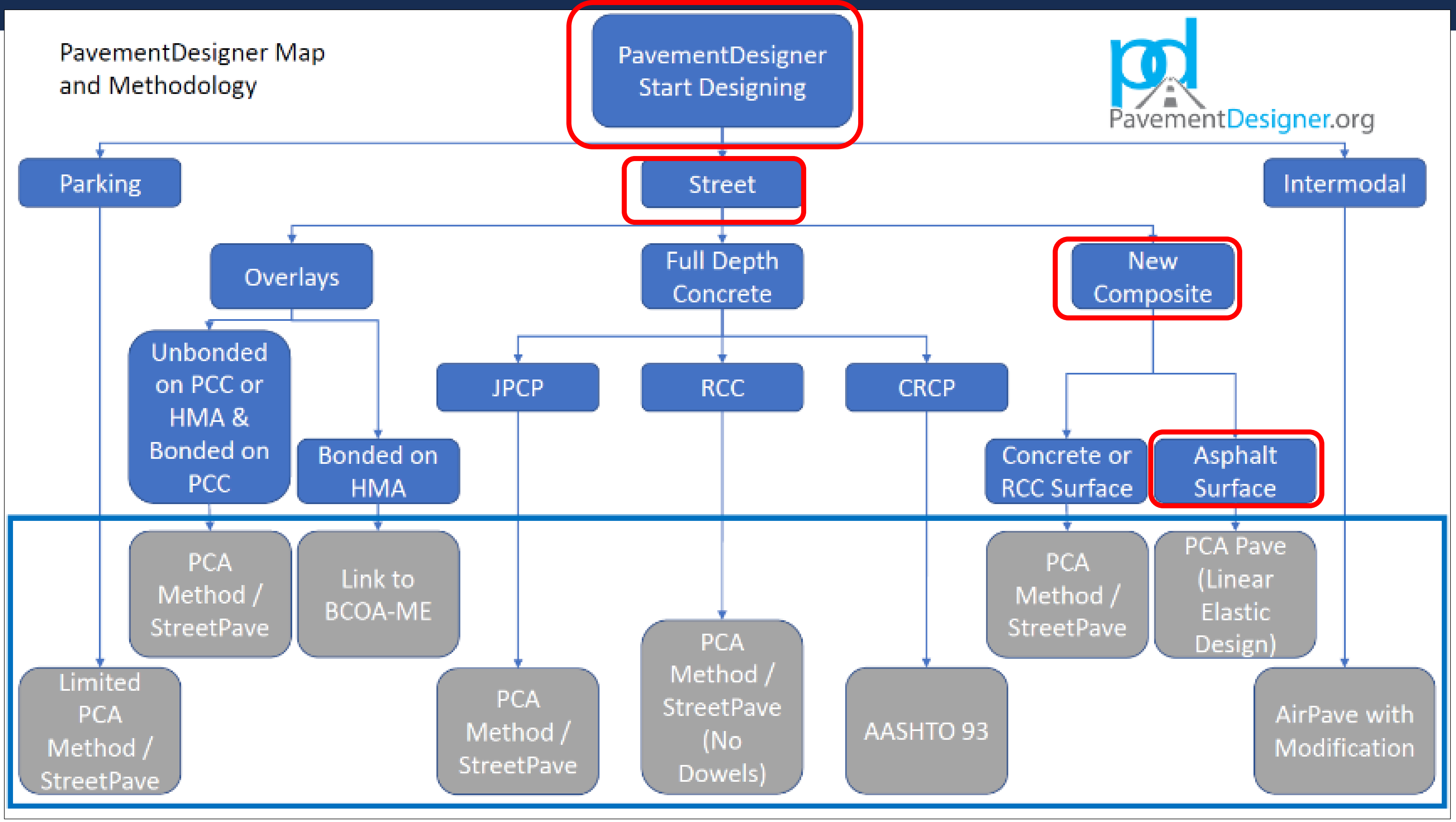
PavementDesigner.org

Created to simplify the cement-based pavement thickness designs for:

- Parking lots
- Roadways
  - JPCP, RCC, CRCP
  - Overlays (bonded / unbonded)
  - Composite pavements
- Industrial / Intermodal yards

The Best Available Online Design Tools



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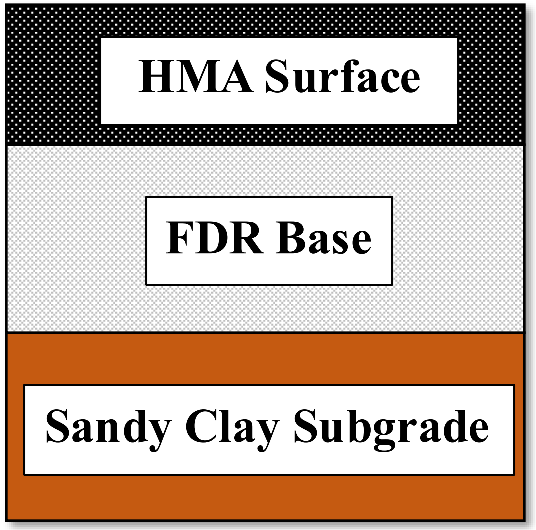
Example Project and Pavement Inputs

- Project Inputs
  - Minor arterial
  - 20-year design life
  - 1,700 trucks/day
  - 2% annual growth
  - Directional distribution = 50%
  - Design lane distribution = 100%



- Pavement Inputs
  - Poisson's ratio of subgrade = 0.30
  - Elastic modulus of subgrade = 14 ksi
  - 1 subbase layer of 8-inch full-depth reclamation

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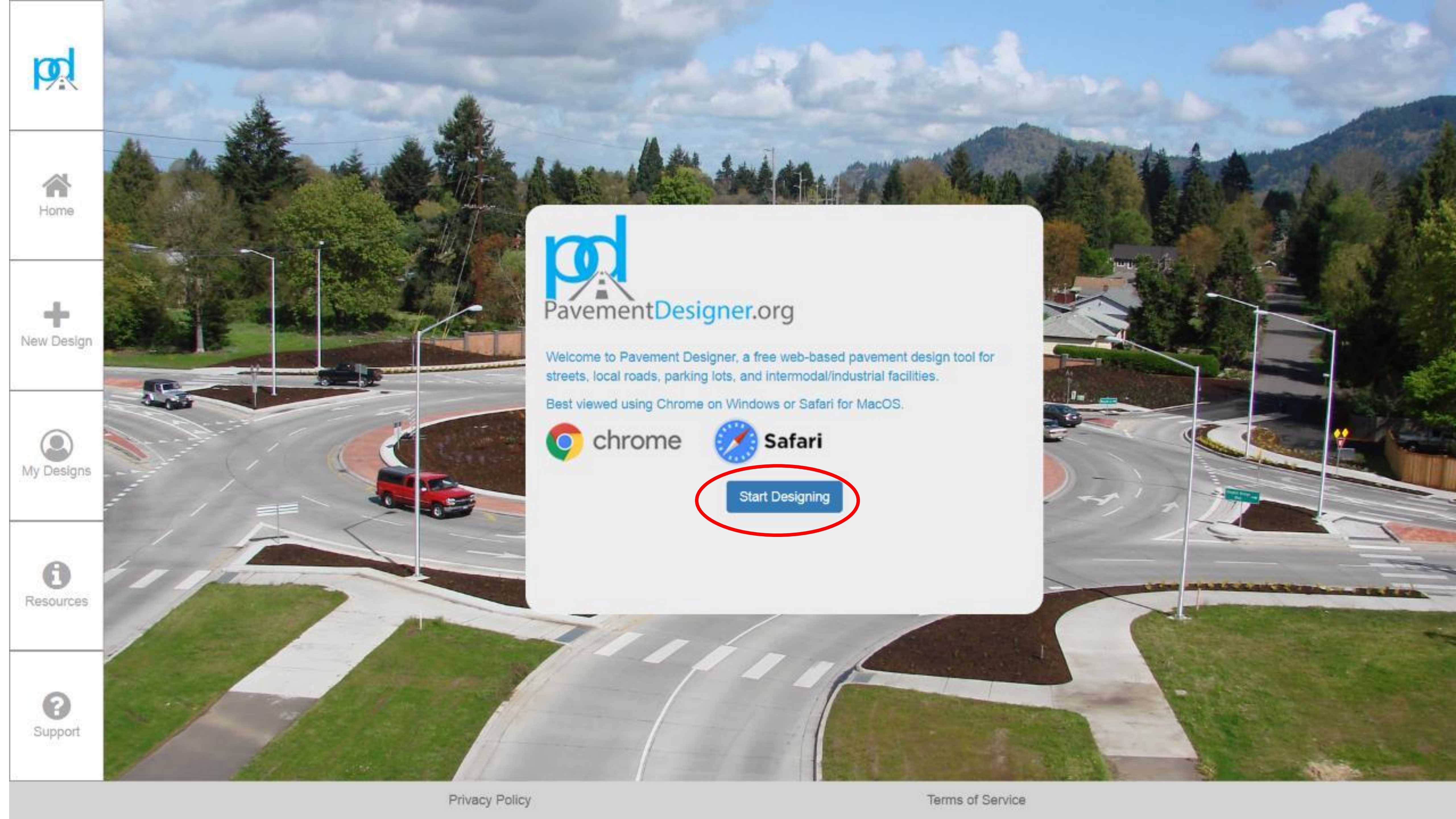
Home
New Design
My Designs
Resources
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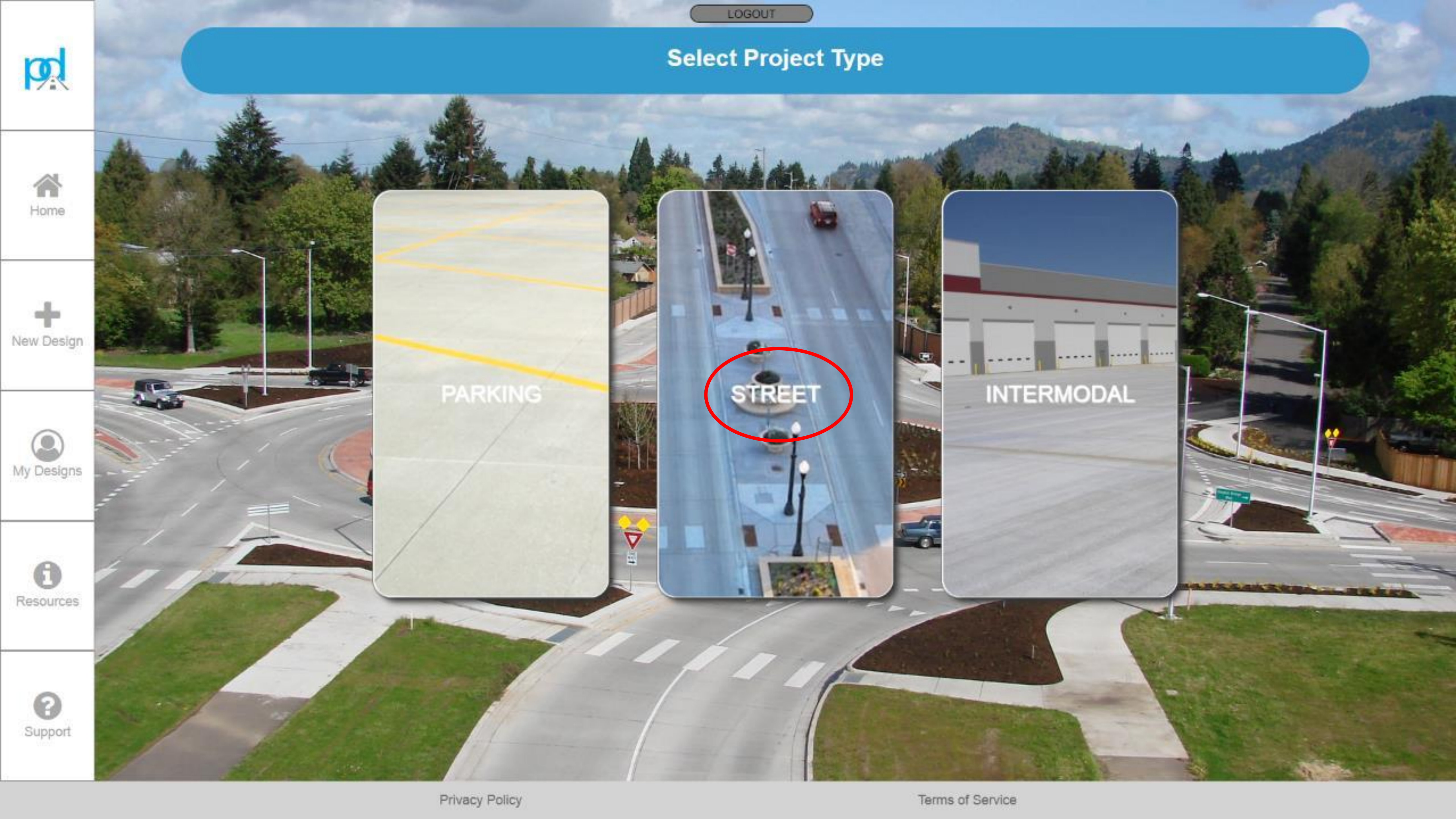
PavementDesigner.org
Welcome to Pavement Designer, a free web-based pavement design tool for streets, local roads, parking lots, and intermodal/industrial facilities.
Best viewed using Chrome on Windows or Safari for MacOS.
chrome
Safari
Start Designing
Privacy Policy
Terms of Service


LOGOUT
Select Project Type
Home
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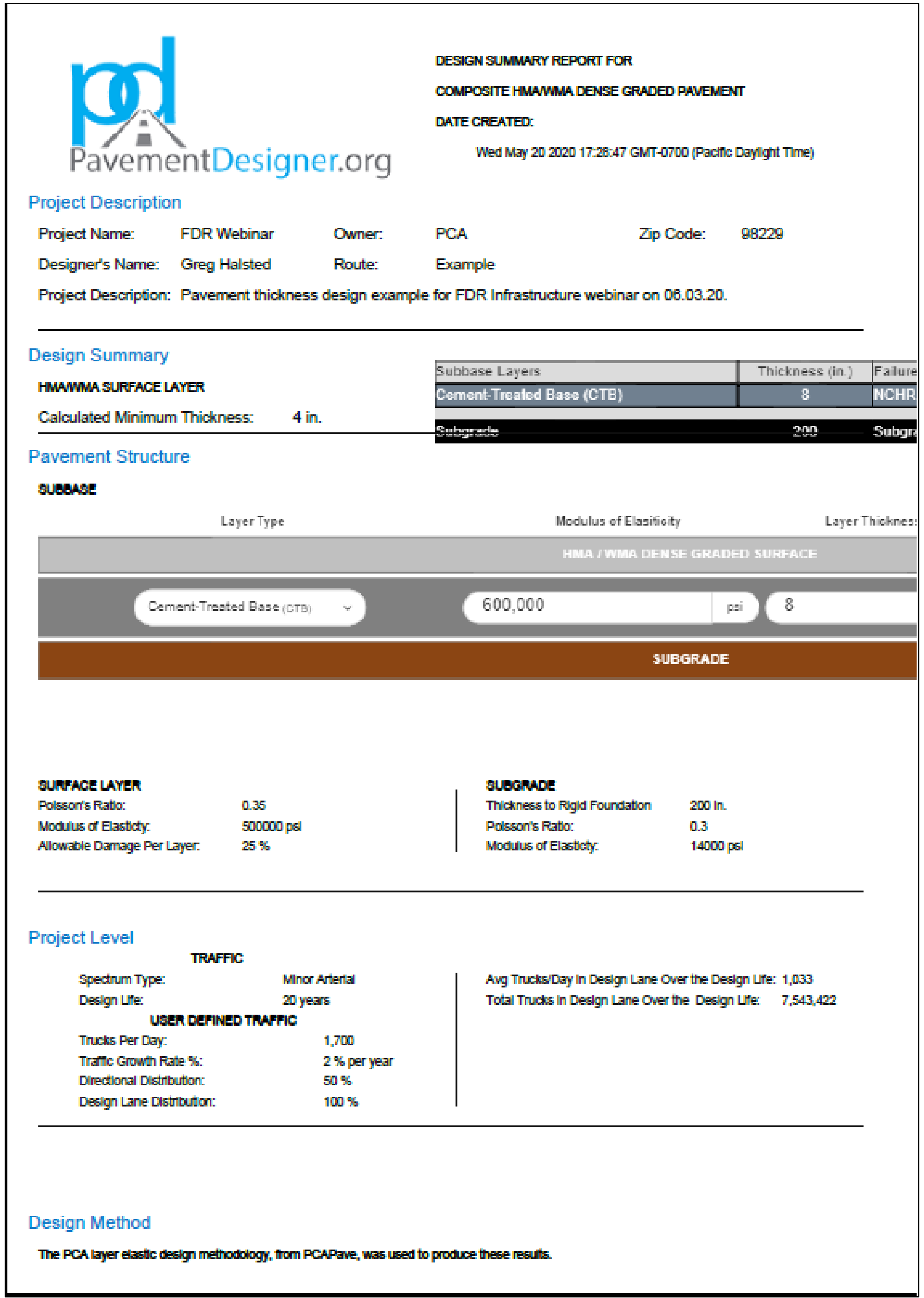
Output Report

- Project Description
- Design Summary
- Calculated minimum thickness of surface layer
- Pavement Structure
  - Subgrade, subbase, and surface layer inputs
- Project Level
- Traffic type
- Design life
- Growth rate
- Design Method



PavementDesigner.org

DESIGN SUMMARY REPORT FOR
COMPOSITE HMA/WMA DENSE GRADED PAVEMENT
DATE CREATED:
Wed May 20 2020 17:26:47 GMT-0700 (Pacific Daylight Time)

Project Description

Project Name:	FDR Webinar	Owner:	PCA	Zip Code:	98229
Designer's Name:	Greg Halsted	Route:	Example		

Project Description: Pavement thickness design example for FDR Infrastructure webinar on 06.03.20.

Design Summary

HMA/WMA SURFACE LAYER

Calculated Minimum Thickness: 4 in.

Subbase Layers	Thickness (in.)	Failure
Cement-Treated Base (CTB)	8	NCHR
Subgrade	200	Subgr

Pavement Structure

SUBBASE

Layer Type	Modulus of Elasticity	Layer Thickness
HMA / WMA DENSE GRADED SURFACE		
Cement-Treated Base (CTB)	600,000 psi	8
SUBGRADE		

SURFACE LAYER

Poisson's Ratio:	0.35
Modulus of Elasticity:	500000 psi
Allowable Damage Per Layer:	25 %

SUBGRADE

Thickness to Rigid Foundation	200 in.
Poisson's Ratio:	0.3
Modulus of Elasticity:	14000 psi

Project Level

TRAFFIC

Spectrum Type:	Minor Arterial
Design Life:	20 years

USER DEFINED TRAFFIC

Trucks Per Day:	1,700
Traffic Growth Rate %:	2 % per year
Directional Distribution:	50 %
Design Lane Distribution:	100 %

Avg Trucks/Day in Design Lane Over the Design Life:	1,033
Total Trucks in Design Lane Over the Design Life:	7,543,422

Design Method

The PCA layer elastic design methodology, from PCAPave, was used to produce these results.

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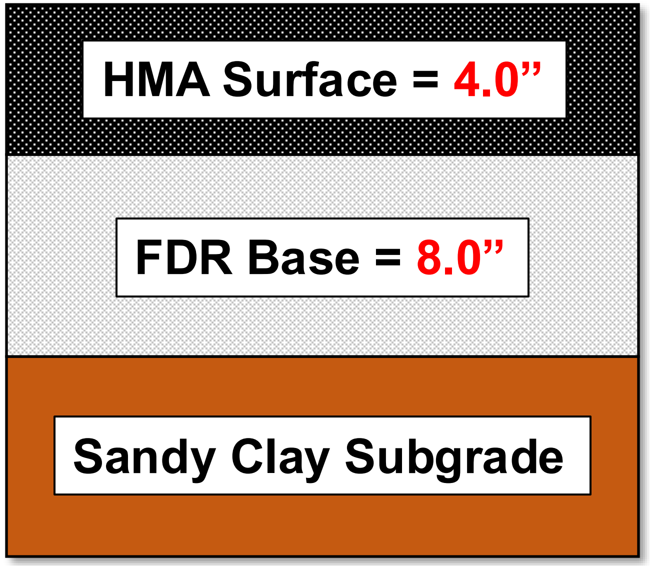
Thickness Design Procedure Comparisons



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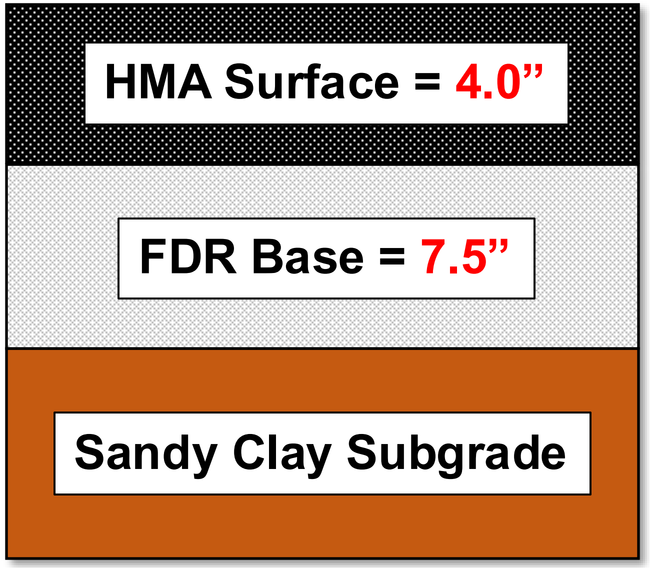

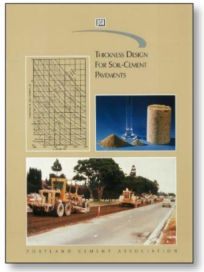

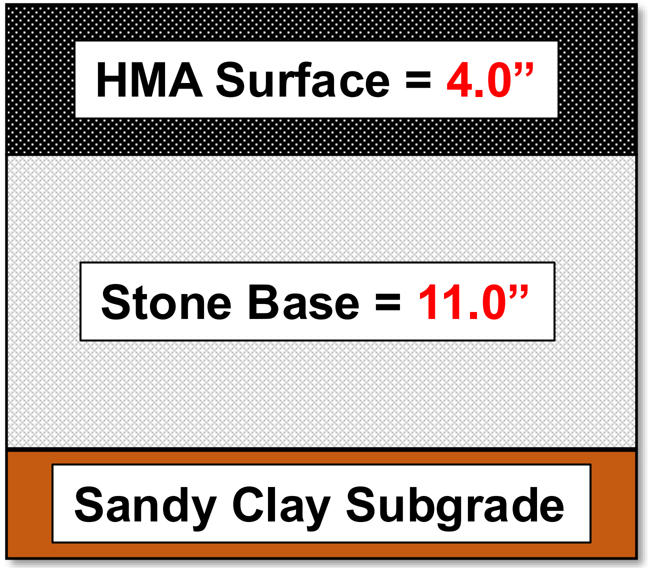

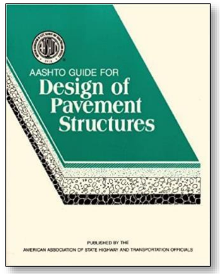

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Projects

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PCA Funded Project

- Study conducted in 2005
- Identified candidate project sites in concert with PCA
  - State (DOT), County, City Agencies, Private
- Interaction with select officials
- Visual Pavement Condition Index (PCI) survey
- Extracted roadway cores for UCS measurements

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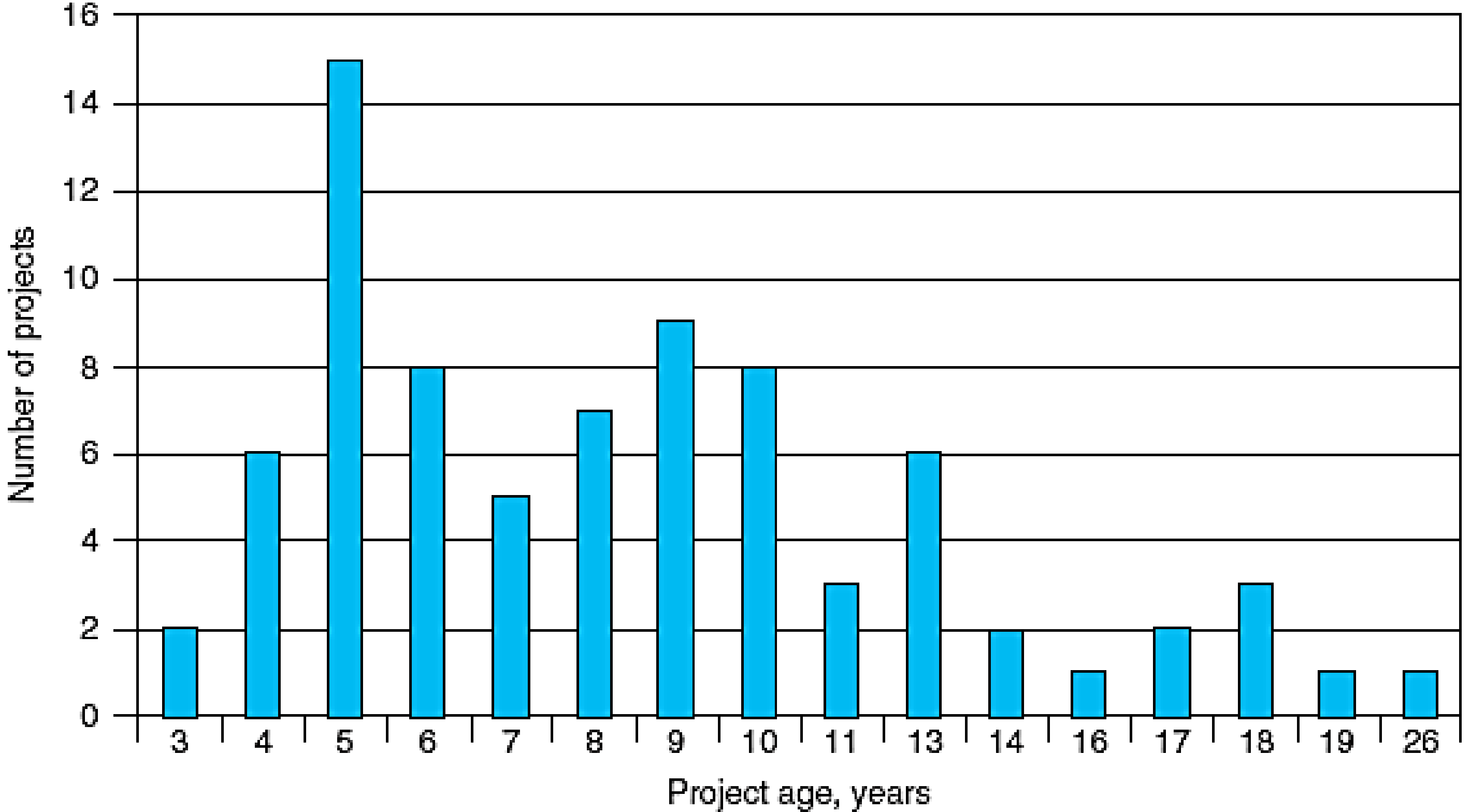
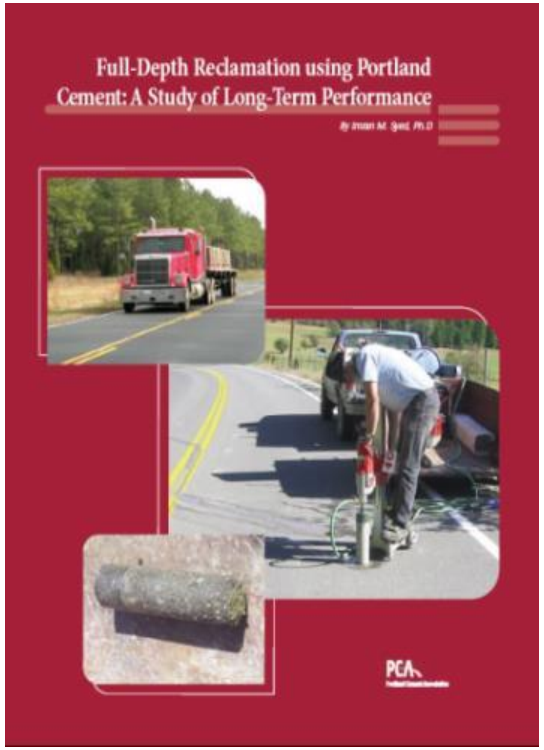
Performance Evaluation

79 Projects Studied



LTP Study Conclusions

- Overall, excellent LTP
- Average Pav't Condition Index of 89
- UCS of cores 260 to over 1,000 psi
- Cement contents 2 to 12% with average being 5%
- Most surface distress was in the asphalt layer
- No major failures attributed to the cement-stabilized base
- Owners are happy with the performance and plan to do more in the future



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Summary

Concluding Comments

- Use of in-place materials
- Wide variety of materials
- Very sustainable process
- Improved pavement performance
- Fast, durable, and strong
- Must know the expected material properties of the FDR layer
- Simple to complex methods to determine FDR thicknesses
- Need a good working knowledge of pavement design principles

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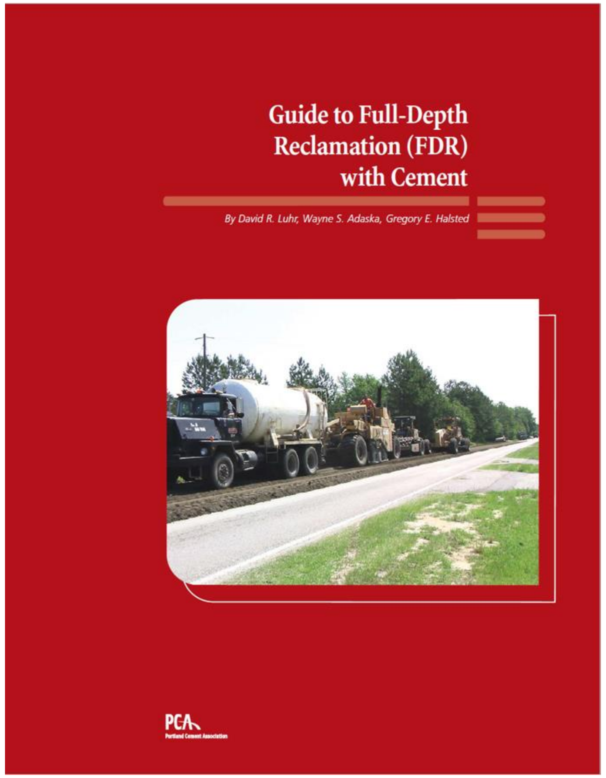
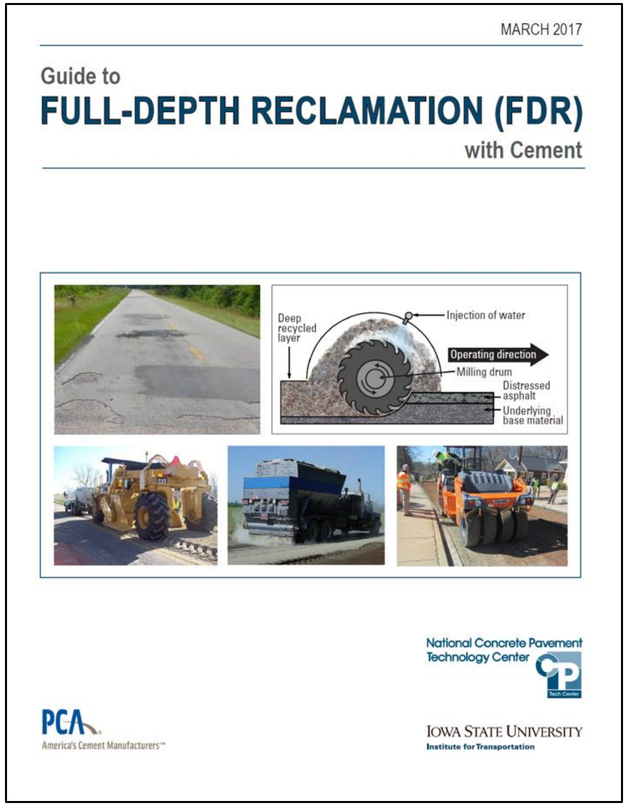
Primary Resource Materials





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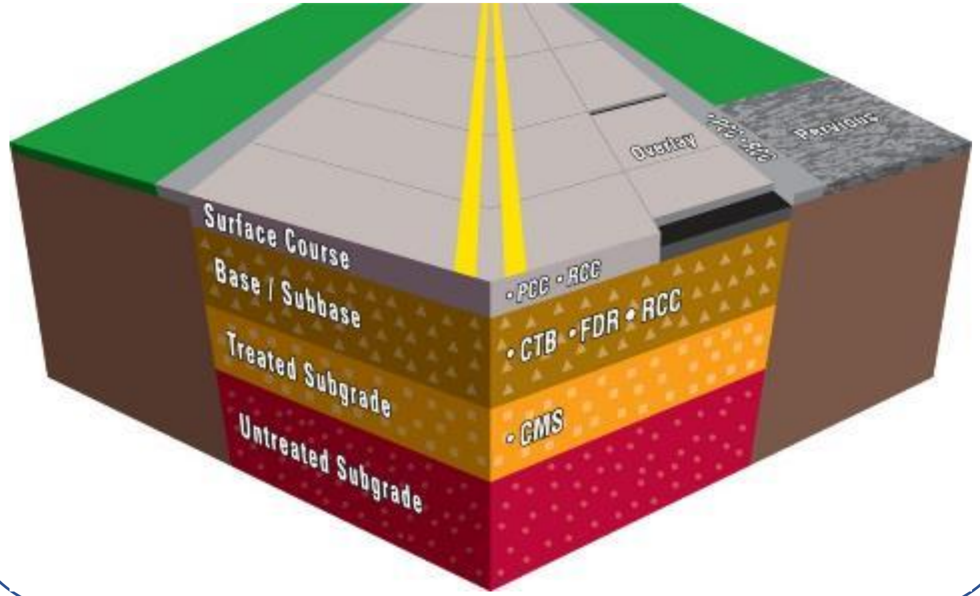
Integrated Pavement Solutions

- Portland Cement Concrete
- Concrete Overlays
- Pervious Concrete
- Roller Compacted Concrete
- Full-Depth Reclamation
- Cement-Treated Base
- Cement-Stabilized Subgrade
- Cement-Modified Soil



"A cement-based solution for every pavement need/challenge"

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