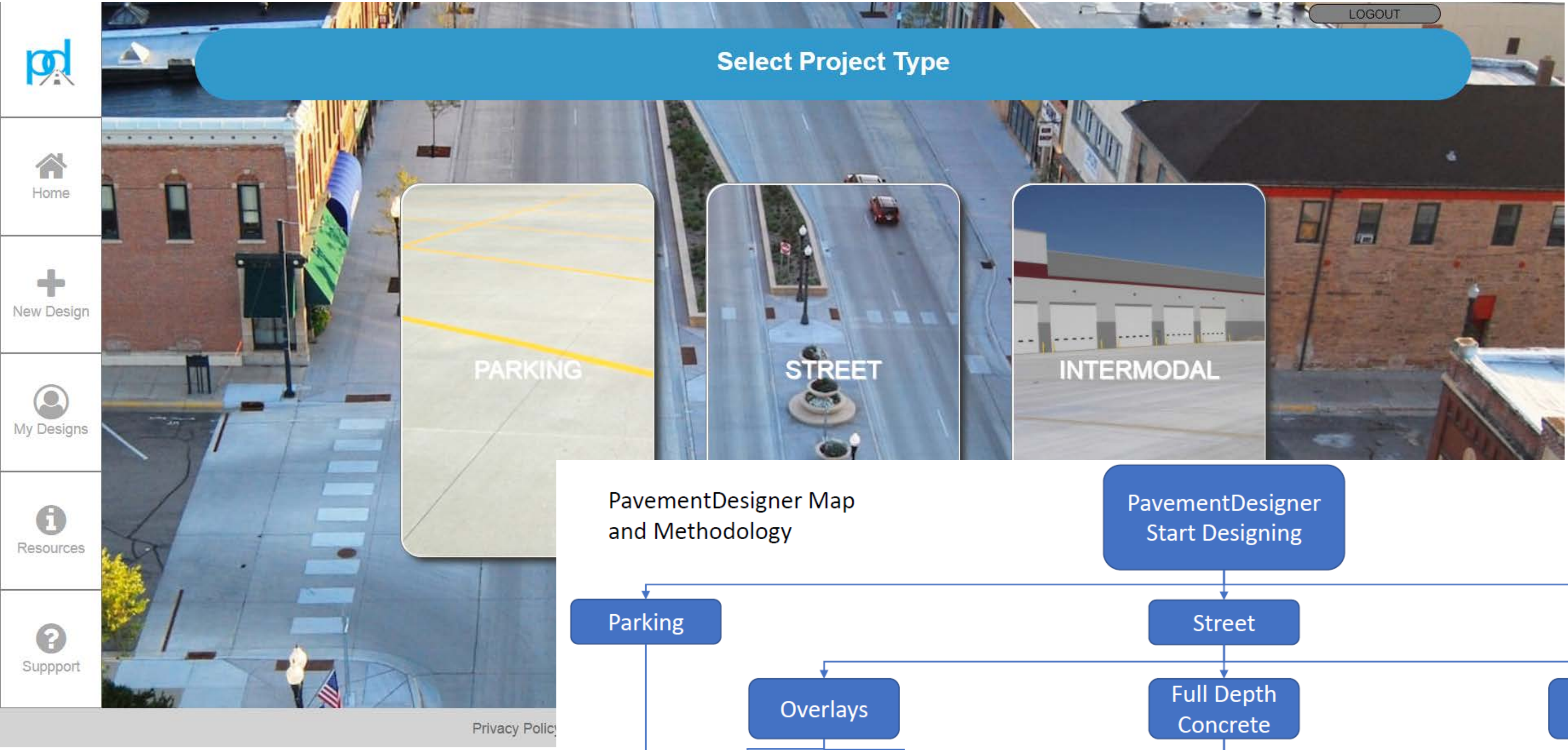
PavementDesigner.org

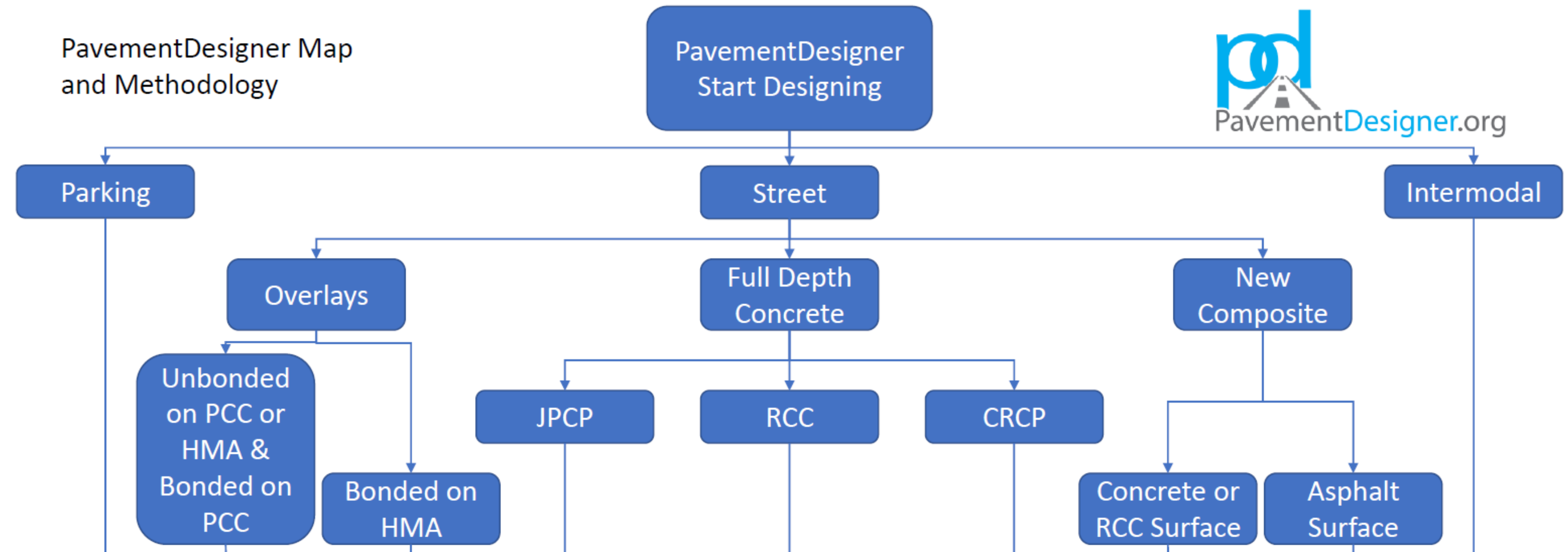
PavementDesigner: A New Web-Based Pavement Design Tool

105th Purdue Road School
West Lafayette, IN
March 6, 2019

Eric Ferrebee, P.E.
Director of Technical Services
American Concrete Pavement Association

PavementDesigner





PavementDesigner Project Leaders

- Industry Team Partners
  - Wayne Adaska, P.E.
    - Portland Cement Association
  - Brian Killingsworth, P.E.
    - National Ready Mix Concrete Association
- Additional Support
  - Jim Mack, P.E. (CEMEX)
  - Feng Mu, PhD, P.E. (PNA Construction Technologies)
  - Randy Riley, P.E. & Jim Powell, P.E.
    - ACPA State/Chapter Associations

Overview and Background

- ACPA, NRMCA, and PCA partnership, with a contribution from the RCC Council to develop a website application to design cement-based solutions for:
  - Municipal Streets and Local Roads
  - Parking Lots
  - Intermodal/Industrial Facilities
- Design guidance and tools for:
  - Jointed-Plain Concrete Pavements
  - Continuously Reinforce Concrete Pavement
  - Concrete Overlays
  - Composite Pavements
  - Roller Compacted Concrete
  - Cement Modified Soils
  - Cement-Treated Base
  - Full-Depth Reclamation

ACPA
AMERICAN CONCRETE PAVEMENT ASSOCIATION

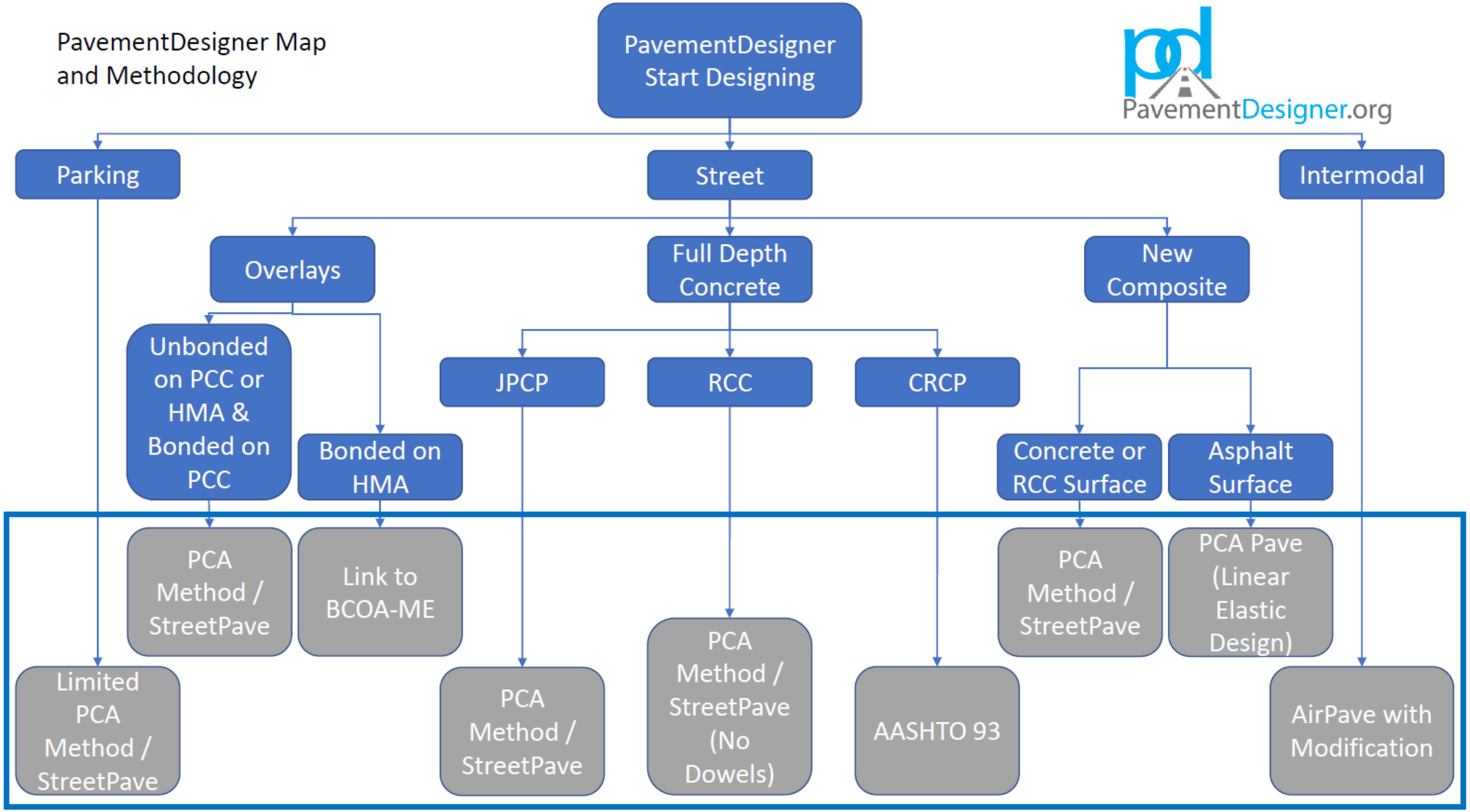
NRMCA

PCA
America's Cement Manufacturers™

RCC Pavement Council

PavementDesigner.org

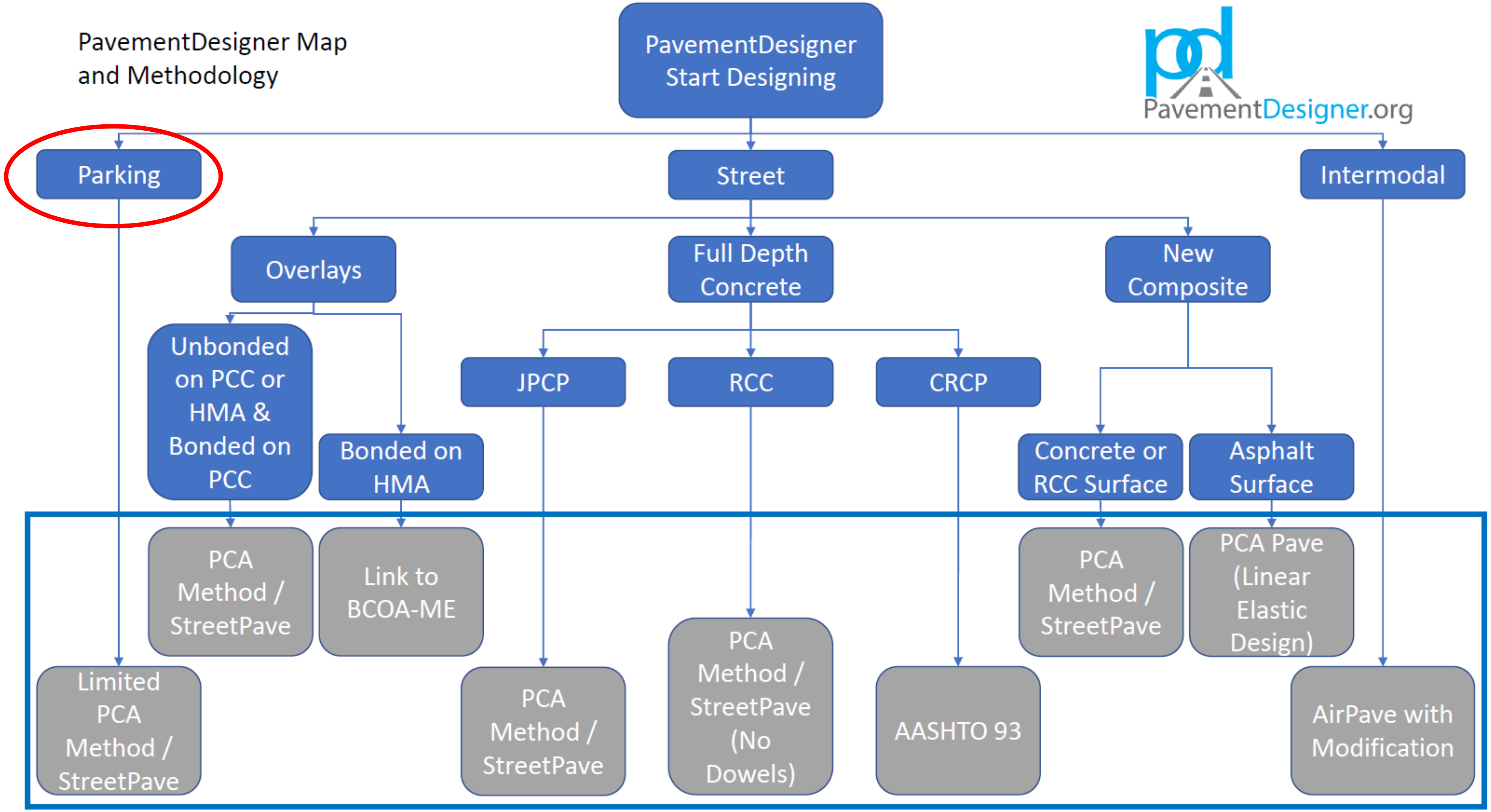
Bringing Online the Best of the Best Available Design Tools



Background and Overview –

- Primary audience is city, county, and consultant engineers who design pavements
- Secondary audience is professors and students
- Unifies design methods, providing promoters with a single source to direct target audience to for consistent answers
- Fills a design void for some products
- Web-based platform, appealing to existing and future generations of design engineers…
- …with broad industry partner support!
- **FREE** and easily accessible!

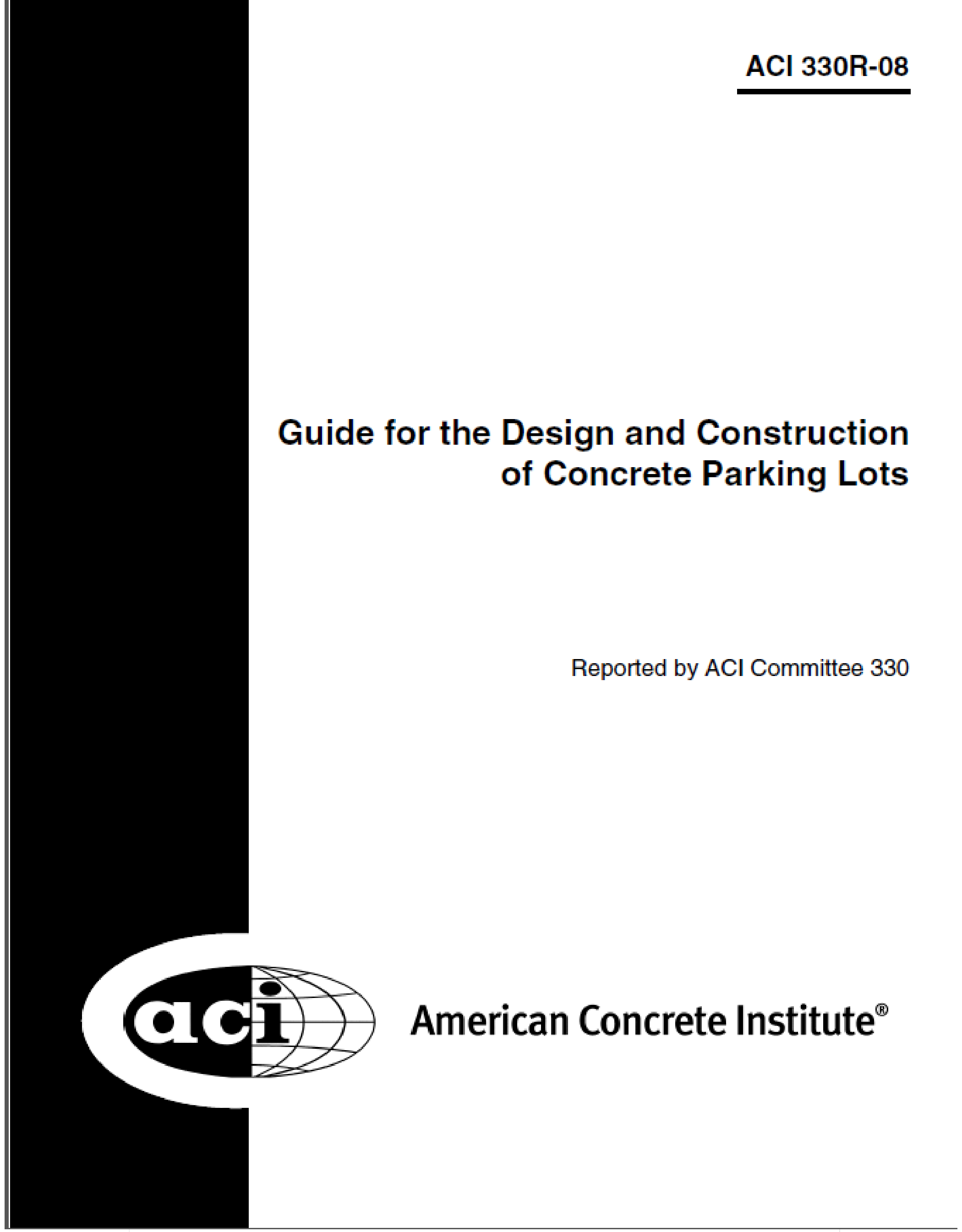
PavementDesigner Map and Methodology



PARKING LOTS

Old Ways of Designing Parking Lots

- AASHTO 93
- ACI 330R-08 & 330R-18
  - Guide for Concrete Parking Lots
- StreetPave


ACI 330R-08

Guide for the Design and Construction of Concrete Parking Lots

Reported by ACI Committee 330

American Concrete Institute®

ACI 330

Table 3.1—Subgrade soil types and approximate support values (Portland Cement Association 1984a,b; American Concrete Pavement Association 1982)

Type of soil	Support	k, psi/in.	CBR	R	SSV
Fine-grained soils in which silt and clay-size particles predominate	Low	75 to 120	2.5 to 3.5	10 to 22	2.3 to 3.1
Sands and sand-gravel mixtures with moderate amounts of silt and clay	Medium	130 to 170	4.5 to 7.5	29 to 41	3.5 to 4.9
Sand and sand-gravel mixtures relatively free of plastic fines	High	180 to 220	8.5 to 12	45 to 52	5.3 to 6.1

BR = California bearing ratio; R = resistance value; and SSV = soil support value. 1 psi = 0.0069 MPa, and 1 psi/in. = 0.27 MPa/m.

Table 3.2—Modulus of subgrade reaction k*

Subgrade k value, psi/in.	Sub-base thickness			
	4 in.	6 in.	9 in.	12 in.
	Granular aggregate subbase			
50	65	75	85	110
100	130	140	160	190
200	220	230	270	320
300	320	330	370	430
	Cement-treated subbase			
50	170	230	310	390
100	280	400	520	640
200	470	640	830	—
	Other treated subbase			
50	85	115	170	215
100	175	210	270	325
200	280	315	360	400
300	350	385	420	490

*For subbase applied over different subgrades, psi/in. (Portland Cement Association 1984a,b; Federal Aviation Administration 1978).
Note: 1 in. = 25.4 mm, and 1 psi/in. = 0.27 MPa/m.

le 3.4—Twenty-year design thickness recommendations, in. (no dowels)

		k = 500 psi/in. (CBR = 50; R = 86)				k = 400 psi/in. (CBR = 38; R = 80)				k = 300 psi/in. (CBR =26; R = 67)			
	MOR, psi:	650	600	550	500	650	600	550	500	650	600	550	500
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	A (ADTT = 10)	4.0	4.0	4.0	4.5	4.0	4.0	4.5	4.5	4.0	4.5	4.5	4.5
	B (ADTT = 25)	4.0	4.5	4.5	5.0	4.5	4.5	5.0	5.5	4.5	4.5	5.0	5.5
	B (ADTT = 300)	5.0	5.0	5.5	5.5	5.0	5.0	5.5	5.5	5.0	5.5	5.5	6.0
	C (ADTT = 100)	5.0	5.0	5.5	5.5	5.0	5.5	5.5	6.0	5.5	5.5	6.0	6.0
	C (ADTT = 300)	5.0	5.5	5.5	6.0	5.5	5.5	6.0	6.0	5.5	6.0	6.0	6.5
	C (ADTT = 700)	5.5	5.5	6.0	6.0	5.5	5.5	6.0	6.5	5.5	6.0	6.5	6.5
	D (ADTT = 700)†	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5

		k = 200 psi/in. (CBR = 10; R = 48)				k = 100 psi/in. (CBR = 3; R = 18)				k = 50 psi/in. (CBR = 2; R = 5)			
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*ADTT = average daily truck traffic. Trucks are defined as vehicles with at least six wheels; excludes panel trucks, pickup trucks, and other four-wheel vehicles. Refer to Appendix A.
k = modulus of subgrade reaction; CBR = California bearing ratio; R = resistance value; and MOR = modulus of rupture.

Parking Lot Design

- ACI 330R-08 Guide based on StreetPave (PD's predecessor) design runs
- StreetPave is another accepted design methodology for Parking Lots
- New guide (ACI 330-R18) is based off PD design runs

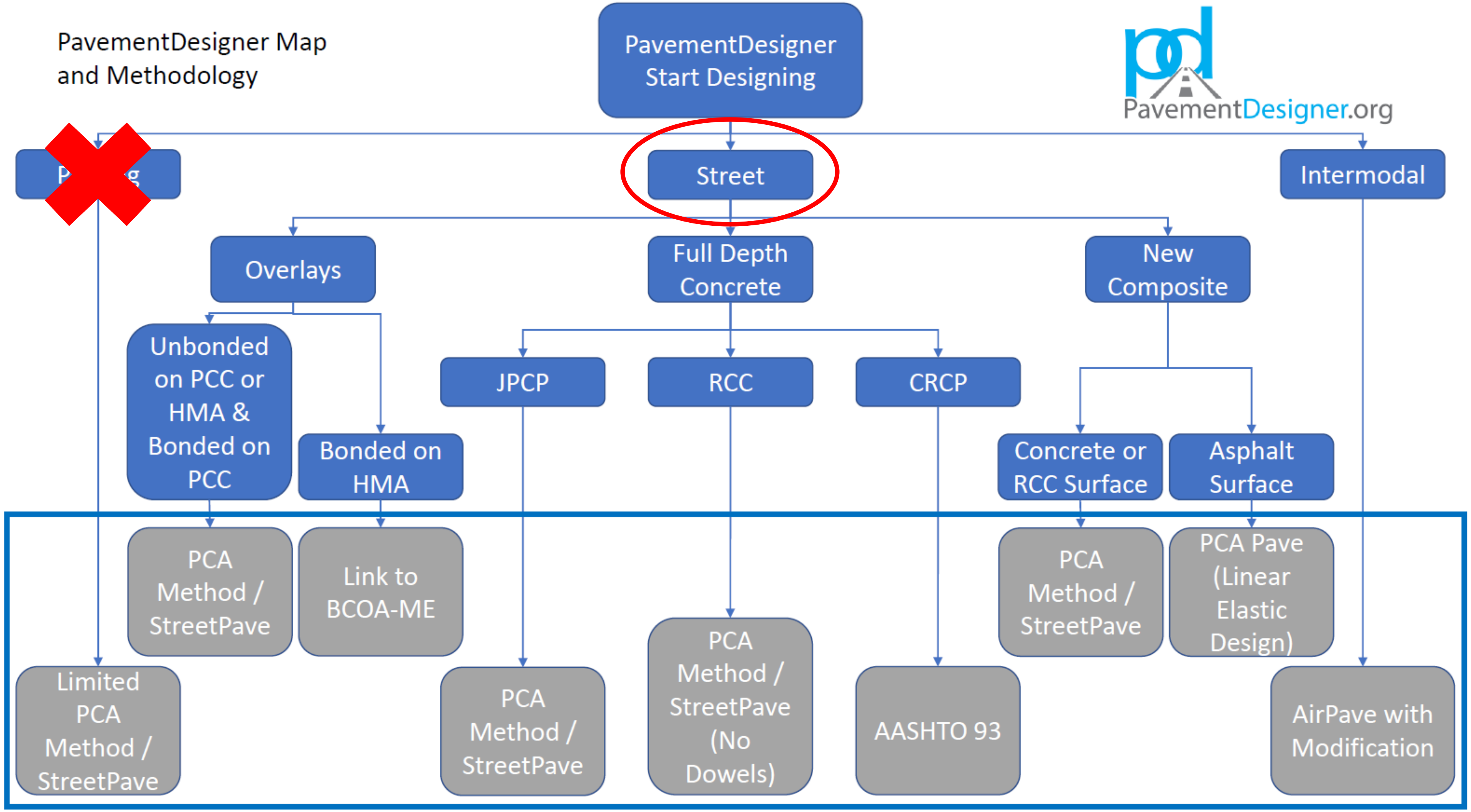
Parking Lot Design with PavementDesigner

- PavementDesigner's Parking design uses a slightly modified version of the Street's Module for the sake of simplicity
  - Allows for various design lives, reliabilities, and percent slabs cracked at the end of the design life

Parking Lot Design with PavementDesigner

- Design a bus terminal (ACI Spectrum-C) that serves ~50 buses a day
- Assume 20 year design life
- Existing subgrade is clay

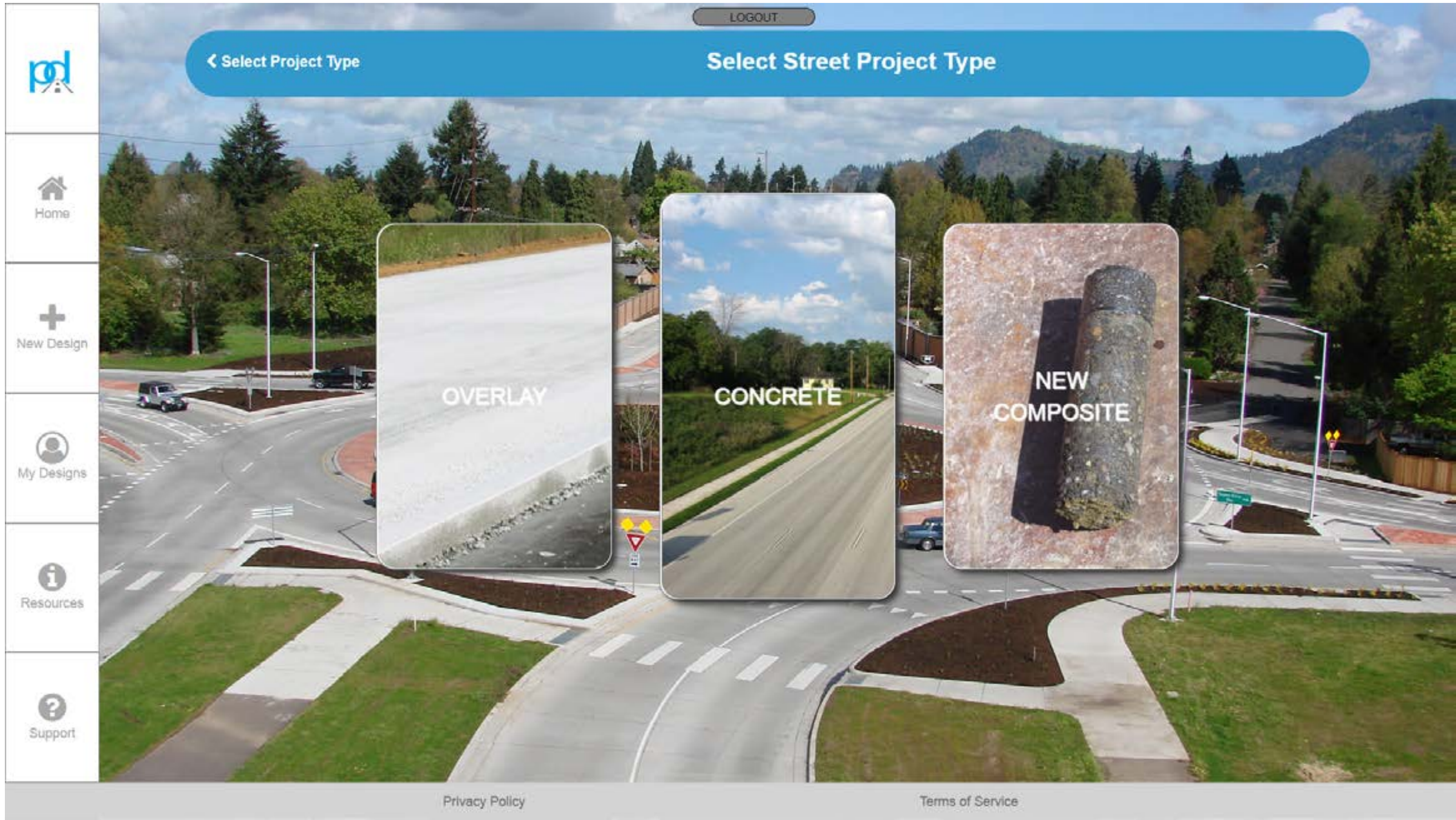
PavementDesigner Map and Methodology



MUNICIPAL STREETS & LOCAL ROADS

Municipal Street Design with PavementDesigner

- Overlays
  - Bonded and Unbonded
  - On Asphalt and Concrete
- Full-Depth Concrete
  - JPCP
  - RCC
  - CRCP
- Composite Pavements

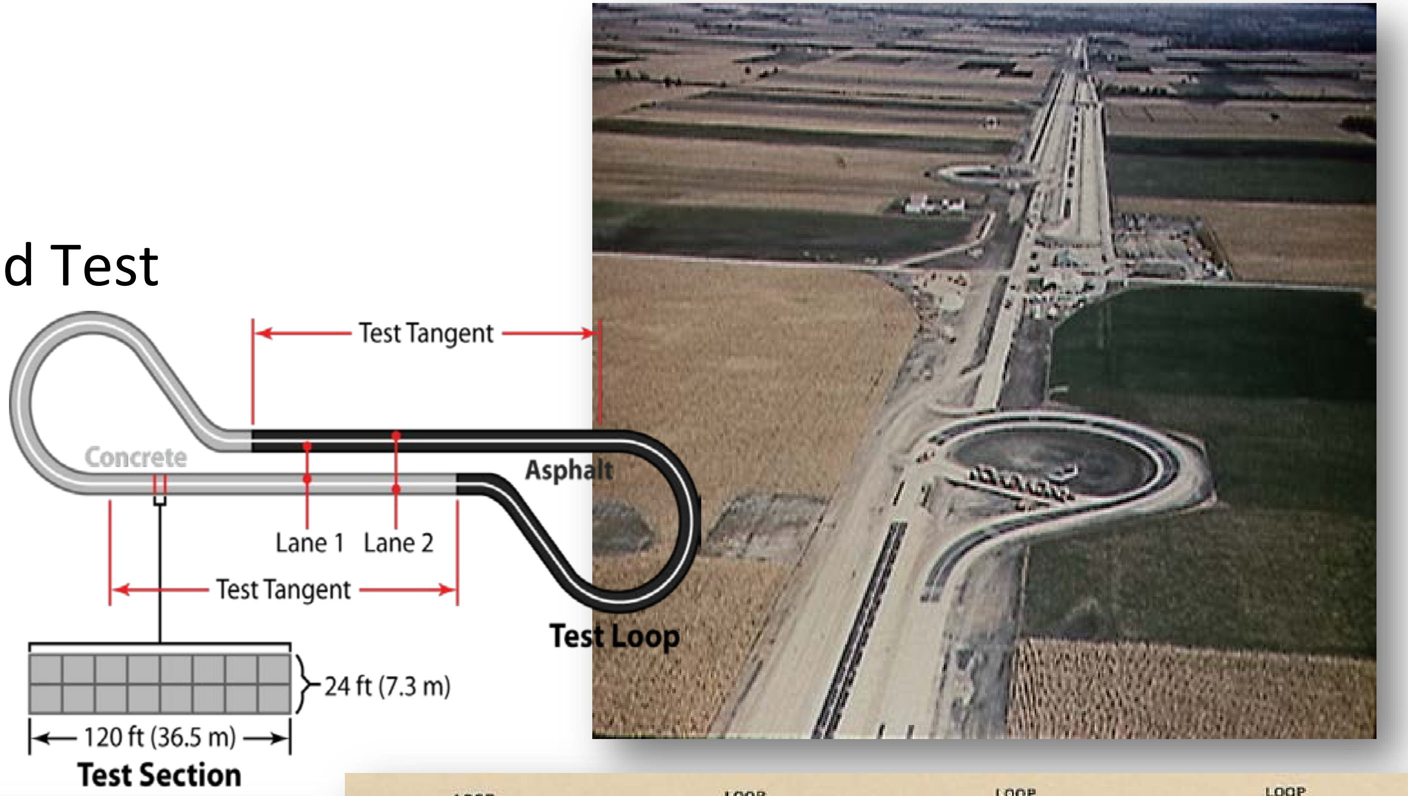


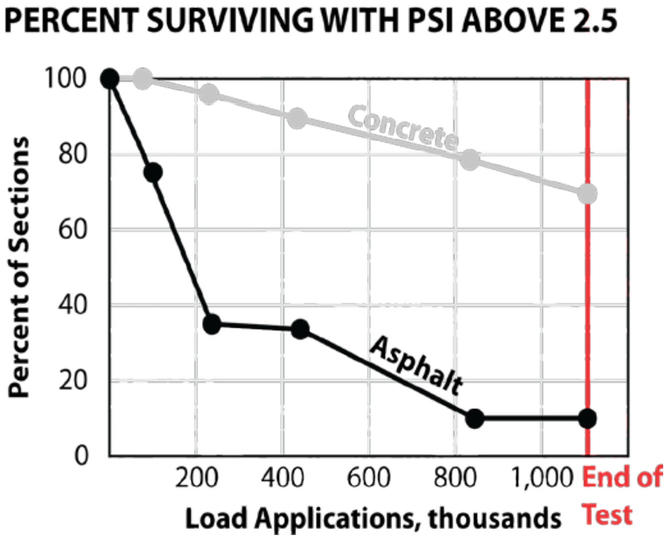
Other Ways of Designing Municipal Streets

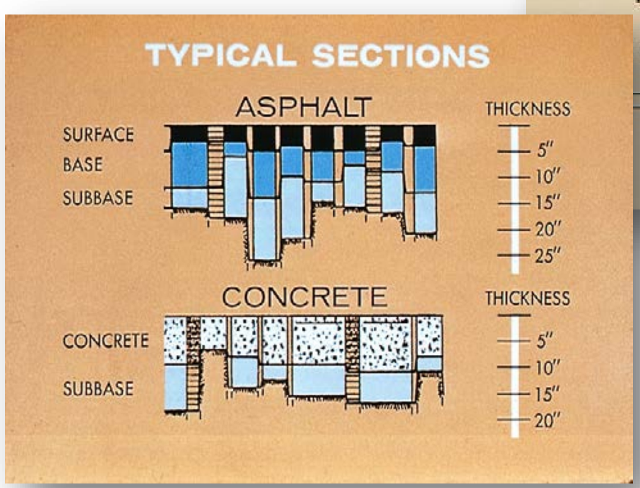
- AASHTO 93
- Pavement ME
- ACI 325.12R-02
  - Guide for Design of Jointed Concrete Pavements for Streets and Local Roads
- StreetPave

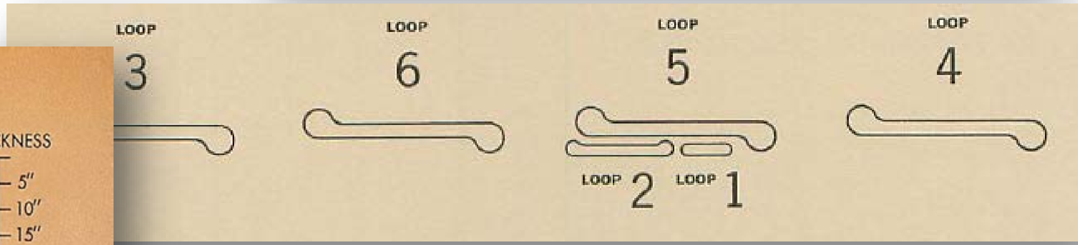
AASHTO 93

- Wholly empirical – AASHO Road Test
- Limited inference space:
  - Materials
  - Structural sections
  - Soils
  - Traffic









Don't Just Take My Word…

United States General Accounting Office

GAO

Report to the Secretary of Transportation

November 1997

TRANSPORTATION INFRASTRUCTURE

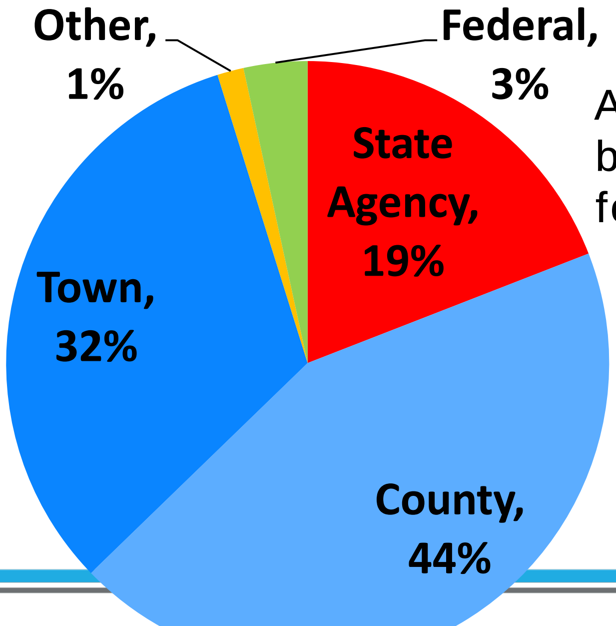
Highway Pavement Design Guide Is Outdated

GAO/RCED-98-9

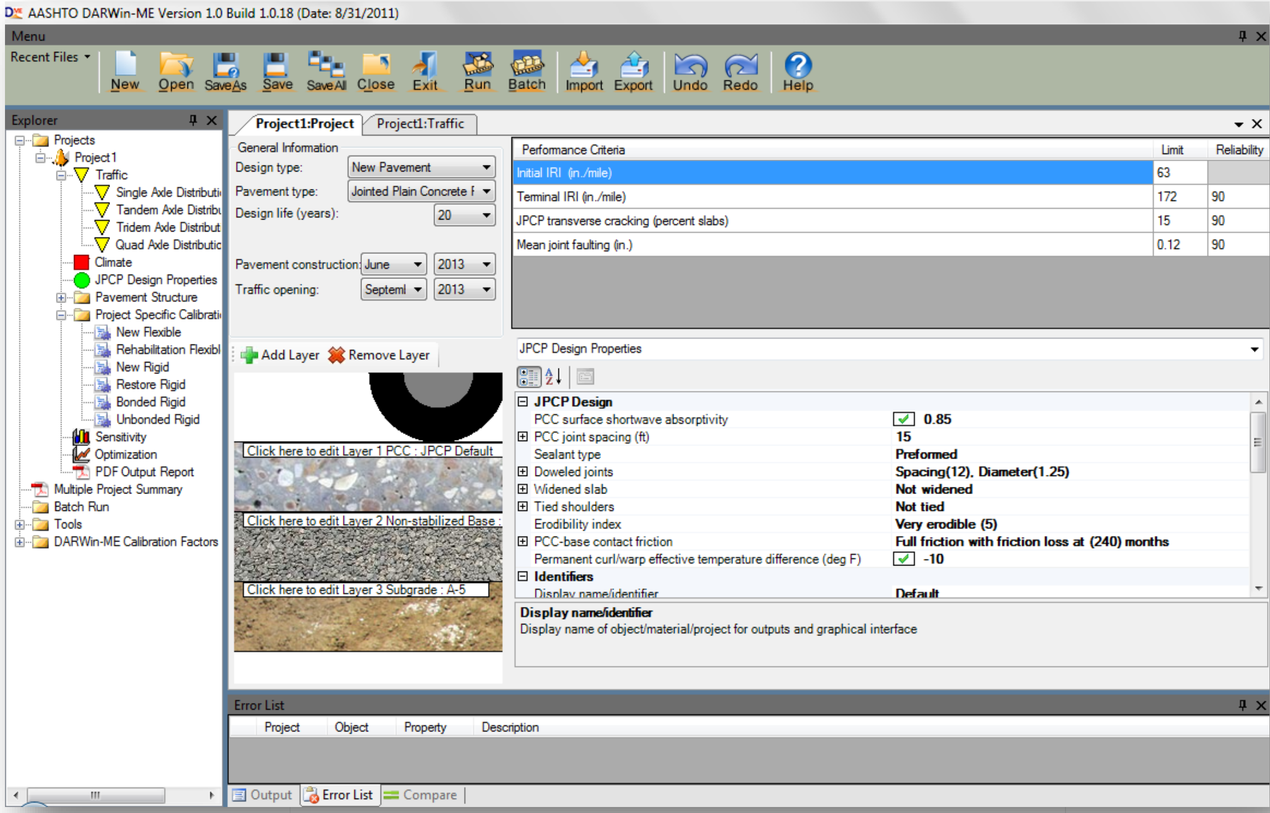
"The current design guide and its predecessors were largely based on design equations empirically derived from the observations AASHTO's predecessor made during road performance tests completed in 1959-60. Several transportation experts have criticized the empirical data thus derived as outdated and inadequate for today's highway system. In addition, a March 1994 DOT Office of Inspector General report concluded that the design guide was outdated and that pavement design information it relied on could not be supported and validated with systematic comparisons to actual experience or research."**…this is why Pavement ME exists!**

AASHTOWare Pavement ME Design

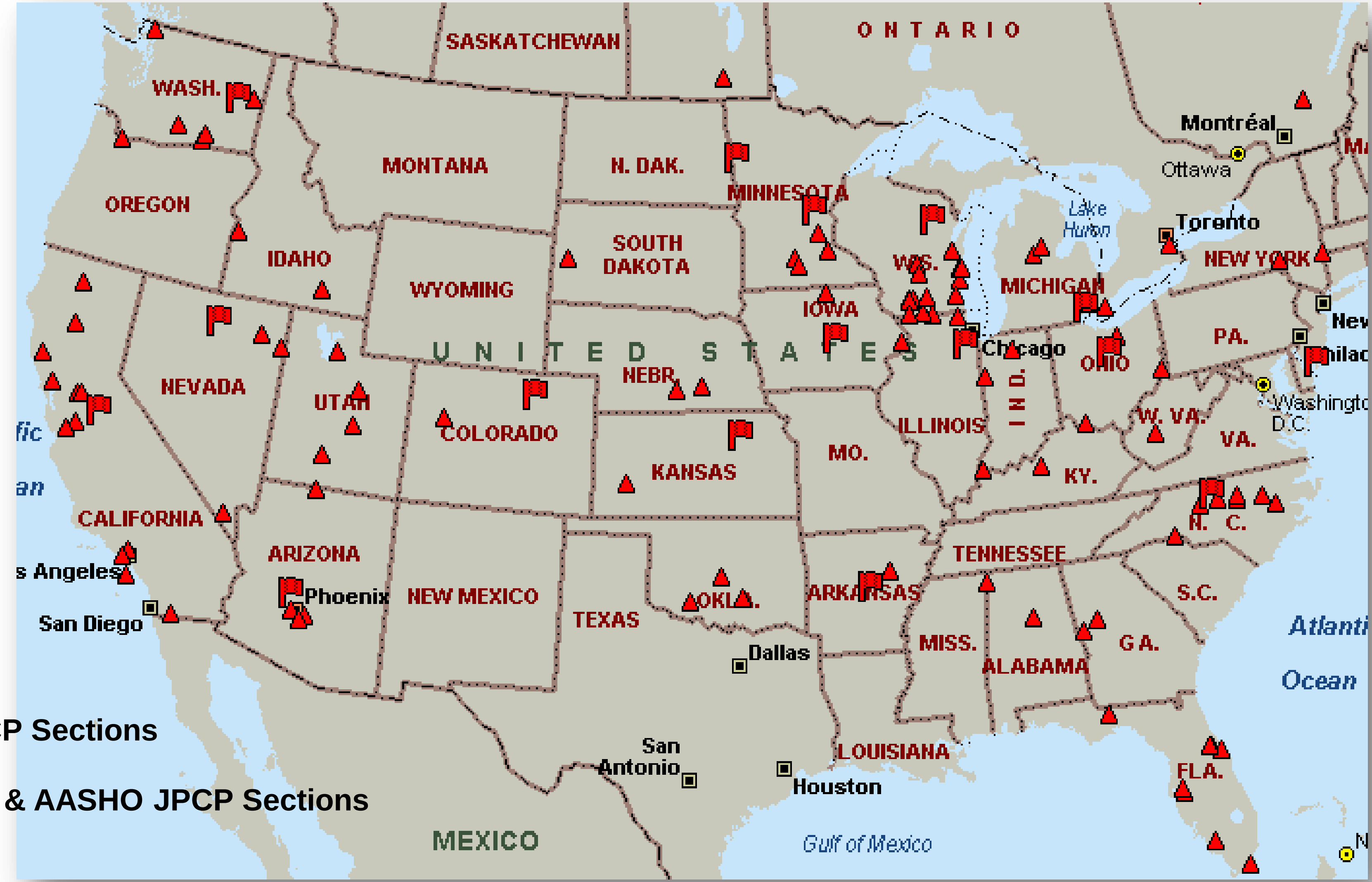
- Developed for Highways
  - NOT street, road, parking lot, etc.
- Complex
- Expensive



AASHTO tools are being developed for these owners…



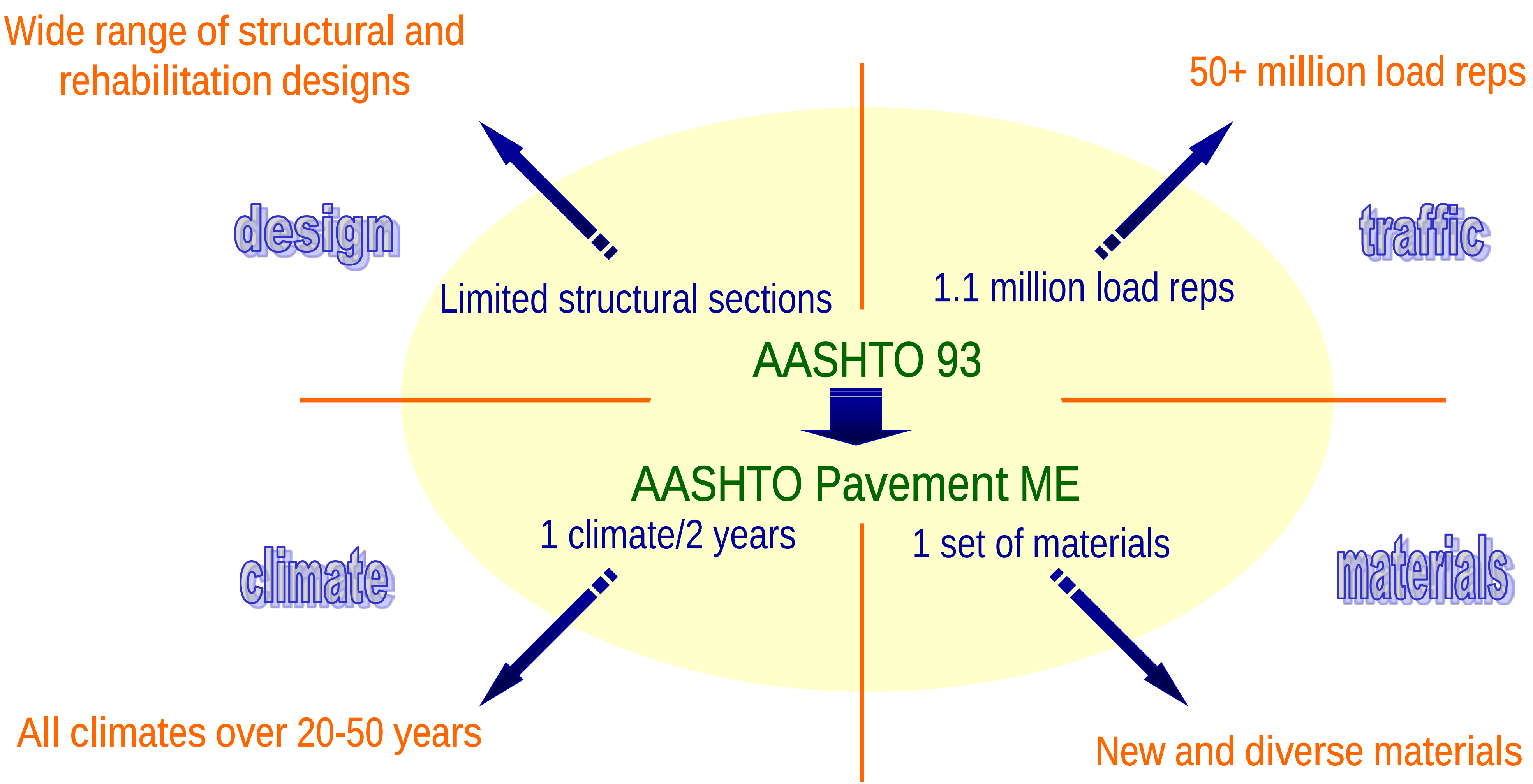
JPCP Calibration – BIG INF. SPACE!



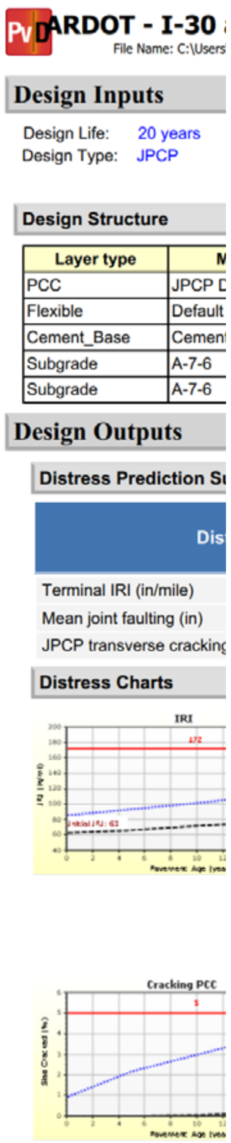
▲ LTPP GPS-3 & RPPR JPCP Sections

LTPP SPS-2, MnROAD, & AASHO JPCP Sections

AASHTO 93 vs. ME



OUTPUTS, OUTPUTS, OUTPUTS!!!

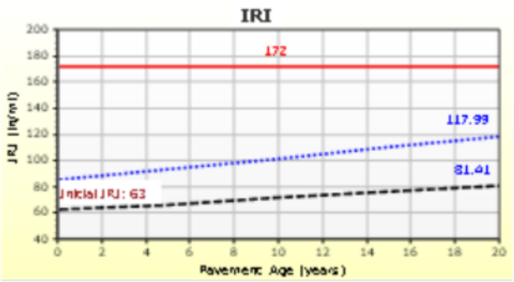


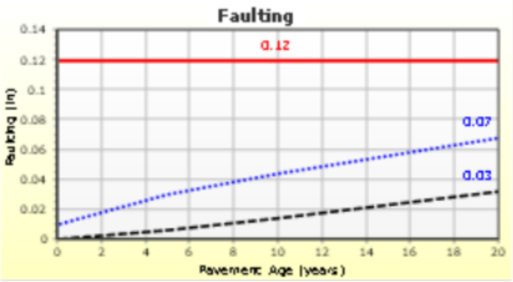
Design Outputs

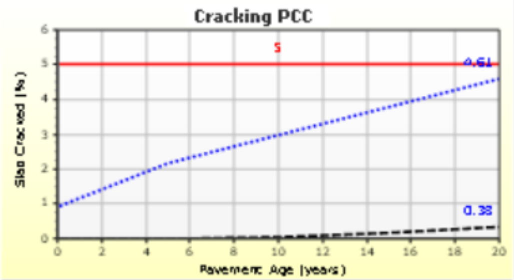
Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	172.00	117.99	90.00	99.92	Pass
Mean joint faulting (in)	0.12	0.07	90.00	99.90	Pass
JPCP transverse cracking (percent slabs)	5.00	4.61	90.00	91.91	Pass

Distress Charts







ACI 325

- Limited design charts
- New guide based on PavementDesigner runs


ACI 325.12R-02

Guide for Design of Jointed Concrete Pavements for Streets and Local Roads

Table 3.4—Twenty-year design thickness recommendations, in. (no dowels)

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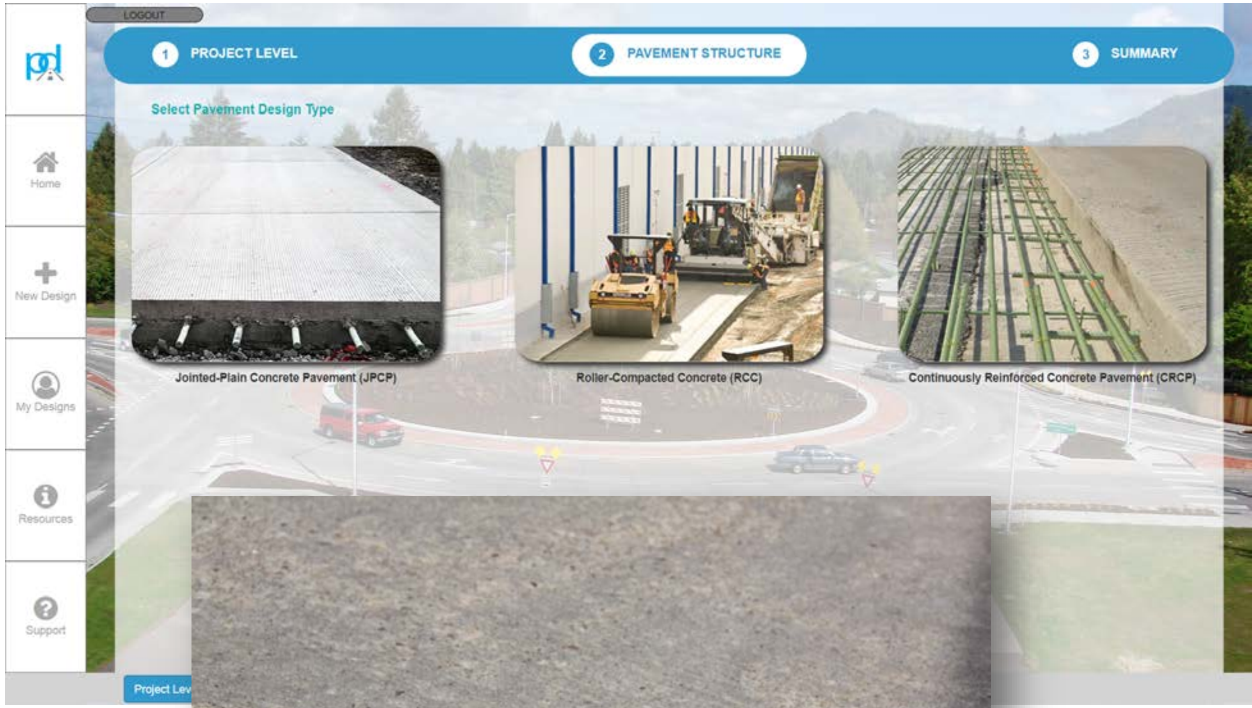
k = modulus of subgrade reaction; CBR = California bearing ratio; R = resistance value; and MOR = modulus of rupture.

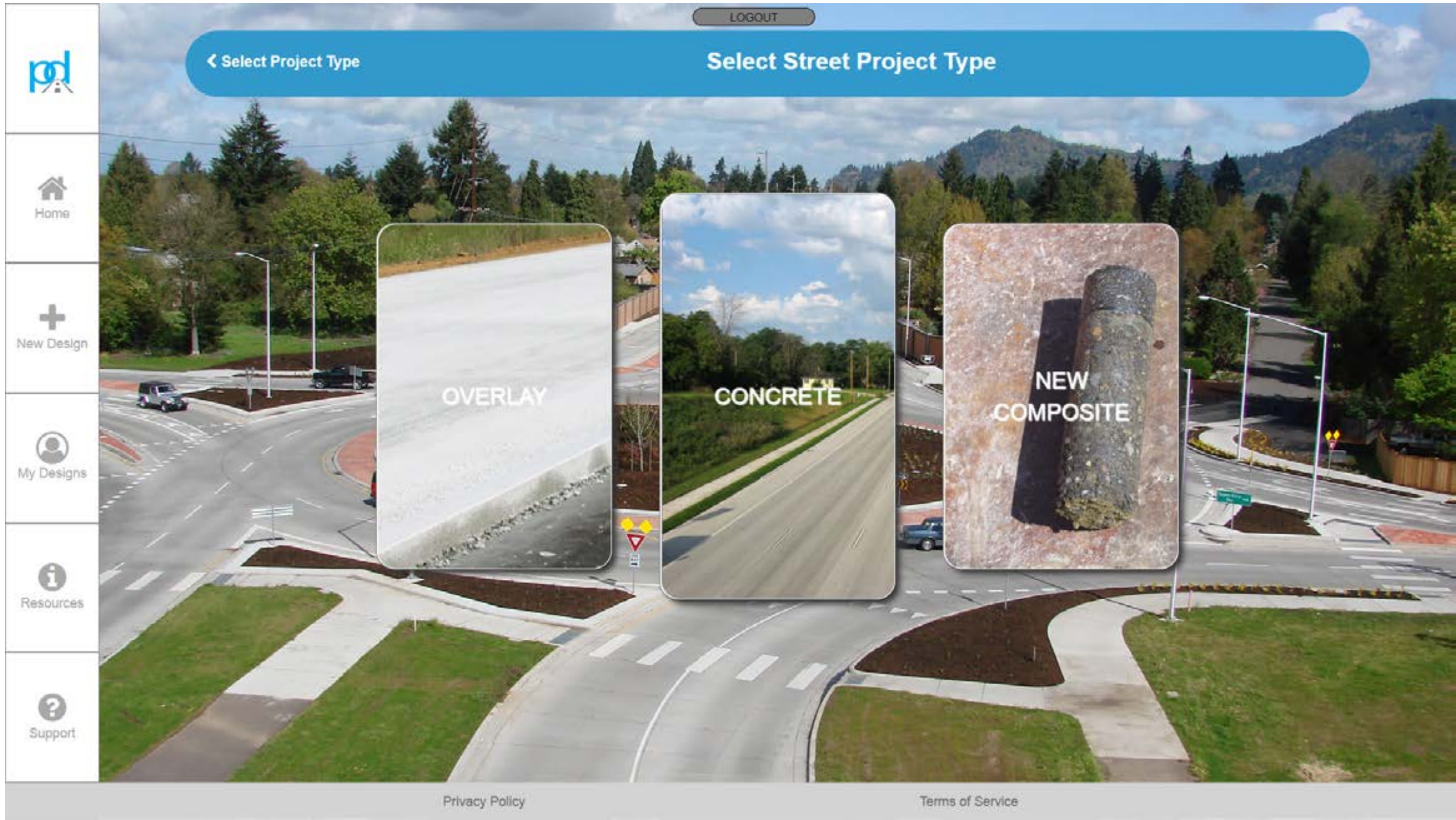
PavementDesigner for Roadways

- Roots date back to the 1960s PCA Method
- Tailored for streets and roads
- Failure modes are cracking and erosion



Municipal Street Design with PavementDesigner

- Design for Overland Parkway with ~100 trucks/day
- Existing Subgrade is poorly graded silt (A-5)



Highway Design with PavementDesigner

- 7,860 trucks (~20M ESALs)
- 90% Reliability
- 5% Slabs Cracked
- 6 lane facility

- R-Value = 20
- MOR = 630 psi
- E_{PCC} = 3,500,000 psi

- Edge Support
- HMA Subbase = 1”
- Cement Stb Subgrade = 6”
- K = 160 psi/in

- Design:
  - AASHTO 93 = 11”

PavementDesigner.org

DESIGN SUMMARY REPORT FOR

JOINTED-PLAIN CONCRETE PAVEMENT (JPCP)

DATE CREATED:

Thu Oct 04 2018 15:10:11 GMT-0500 (Central Daylight Time)

Project Description

Project Name:	ARDOT - I-30 Calculated	Owner:	undefined	Zip Code:	undefined
Designer's Name:	undefined	Route:	undefined		
Project Description:	undefined				

Design Summary

	Doweled	Undoweled		Doweled	Undoweled
Recommended Design Thickness:	8.50 in.	8.50 in.	Maximum Joint Spacing:	15 ft.	15 ft.
Calculated Minimum Thickness:	8.43 in.	8.43 in.			

Pavement Structure

SUBBASE

User-Defined Composite K-Value of Substructure: 160 psi/in

Layer Type	Resilient Modulus	Layer Thickness
JOINTED PLAIN CONCRETE SURFACE		
Hot-Mix or Warm-Mix Asphalt Base	450,000 psi	1 in
Cement Stabilized Subgrade	100,000 psi	6 in
SUBGRADE		

CONCRETE

28-Day Flex Strength: 630 psi
Modulus of Elasticity: 3500000 psi
Edge Support: Yes
Macrofibers in Concrete: No

SUBGRADE

R-Value: 20
Calculated MRSG Value 4,305 psi

Project Level

TRAFFIC

Spectrum Type: Major Arterial
Design Life: 20 years

USER DEFINED TRAFFIC

Trucks Per Day: 7,860
Traffic Growth Rate %: 1 % per year
Directional Distribution: 50 %
Design Lane Distribution: 60 %

GLOBAL

Reliability: 90 %
% Slabs Cracked at End of Design Life: 5 %

Avg Trucks/Day in Design Lane Over the Design Life: 2,596
Total Trucks in Design Lane Over the Design Life: 18,964,076

ARDOT - I-30 and Ramps Concrete Pavement Design Analysis - Optimi

File Name: C:\Users\eferrebee.acpa\Documents\My ME Design\ARDOT - I-30 and Ramps Concrete Pavement Design Analysis - Optimized.dgpx

Design Inputs

Design Life: 20 years
Design Type: JPCP
Existing construction: -
Pavement construction: June, 2020
Traffic opening: September, 2020
Climate Data Sources (Lat/Lon): 34.747, -92.233

Design Structure

Layer type	Material Type	Thickness (in)
PCC	JPCP Default	9.0
Flexible	Default asphalt concrete	1.0
Cement_Base	Cement stabilized	6.0
Subgrade	A-7-6	10.0
Subgrade	A-7-6	Semi-infinite

Joint Design:	
Joint spacing (ft)	15.0
Dowel diameter (in)	1.25
Slab width (ft)	12.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2020 (initial)	7,860
2030 (10 years)	9,775,300
2040 (20 years)	22,134,400

Design Outputs

Distress Prediction Summary

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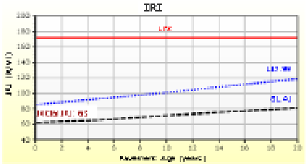
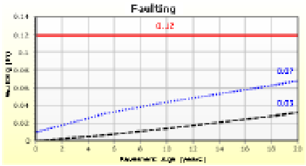
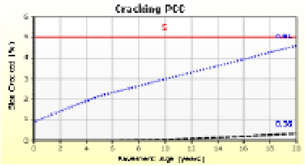
Distress Charts





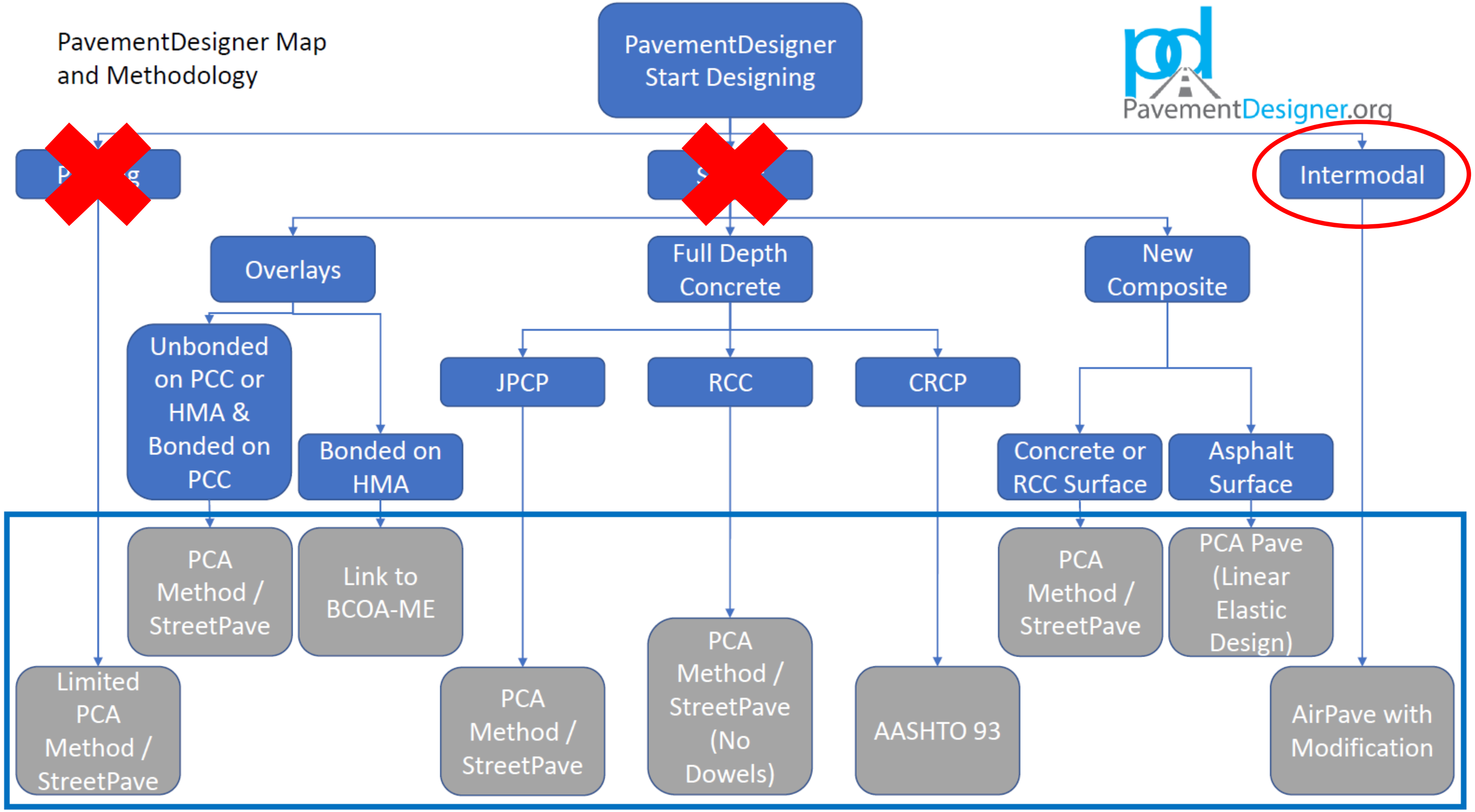


Threshold Value ····· @ Specified Reliability - - - @ 50% Reliability

Differences Between Parking and Street Design

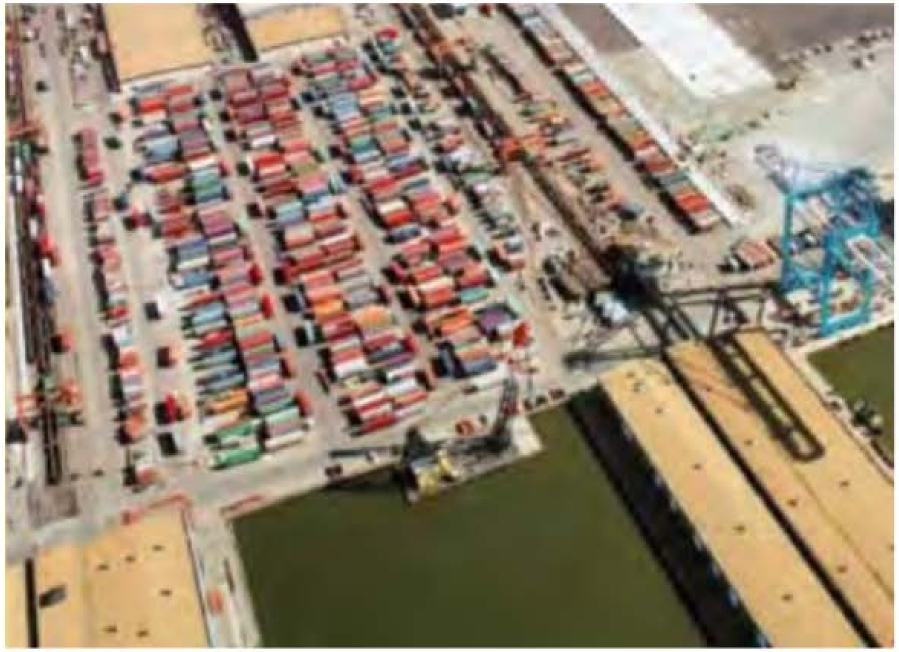
- Simplicity in Parking:
  - Limited Spectrums (for now)
  - Growth Rate = 0%
  - Directional Dist = 100%
  - Design Lane Dist = 100%
  - Fibers not allowed
  - Edge support assumed to be yes
  - Only allows 1 subbase layer

PavementDesigner Map and Methodology



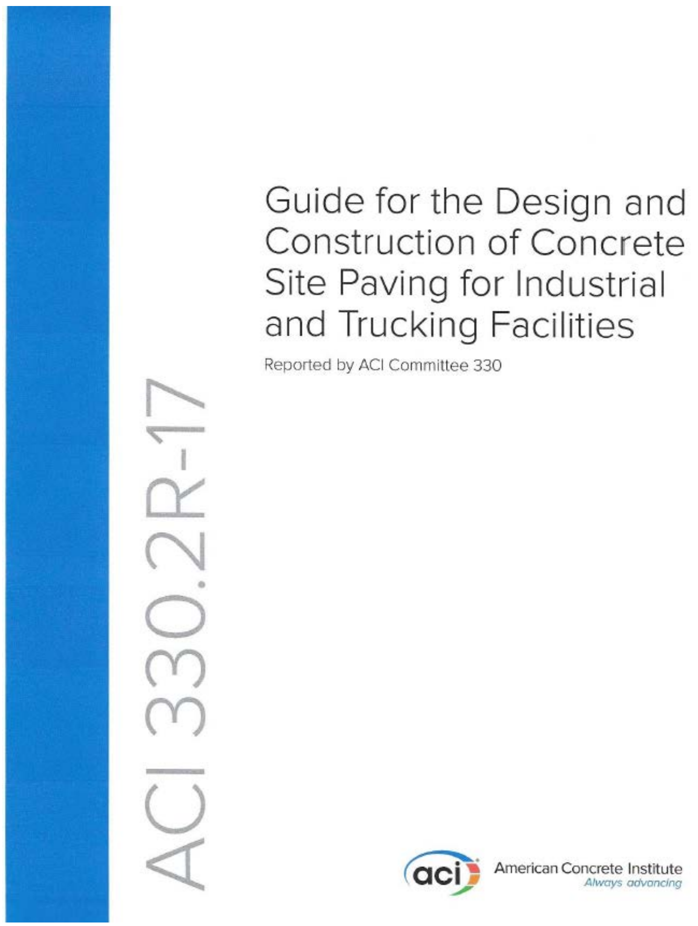
INTERMODAL DESIGN

Intermodal Design?



What Designs are Available for Heavy Intermodal/Industrial Vehicles

- ACI 330.2R-17 – Guide for the Design and Construction of Concrete Site Paving for Industrial and Trucking Facilities
  - Uses design tables (Mainly for Trucks)
  - Lists additional design software:
    - ACPA StreetPave
    - Pavement ME
    - TCPavements / Optipave
    - ACPA AirPave



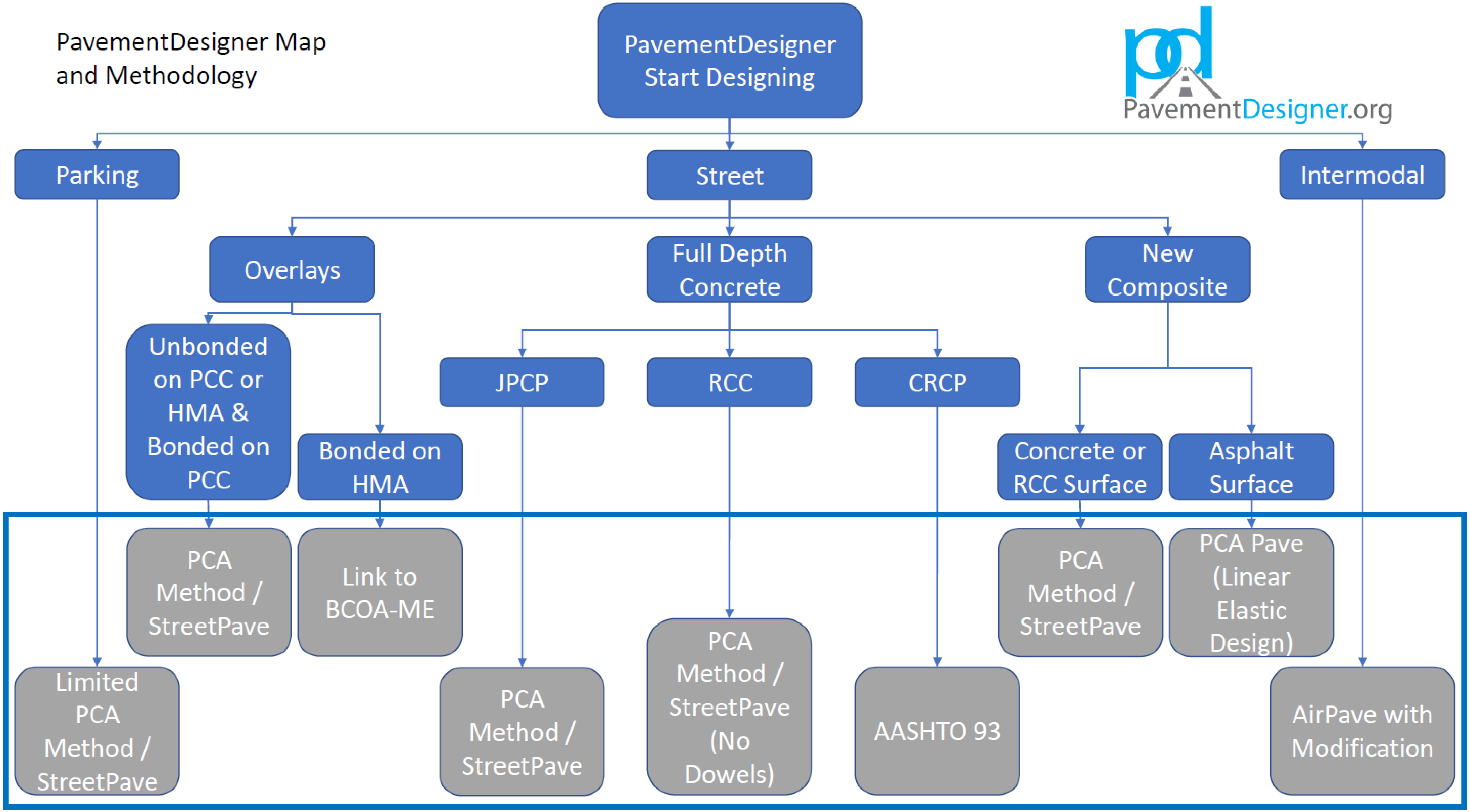
Intermodal Design with PavementDesigner

- Design for a CAT 986 Loader
  - 130,000 lb
  - Wheel base = 12.5 ft
  - Axle width = 10 ft
  - Tire Pressure = 90 psi

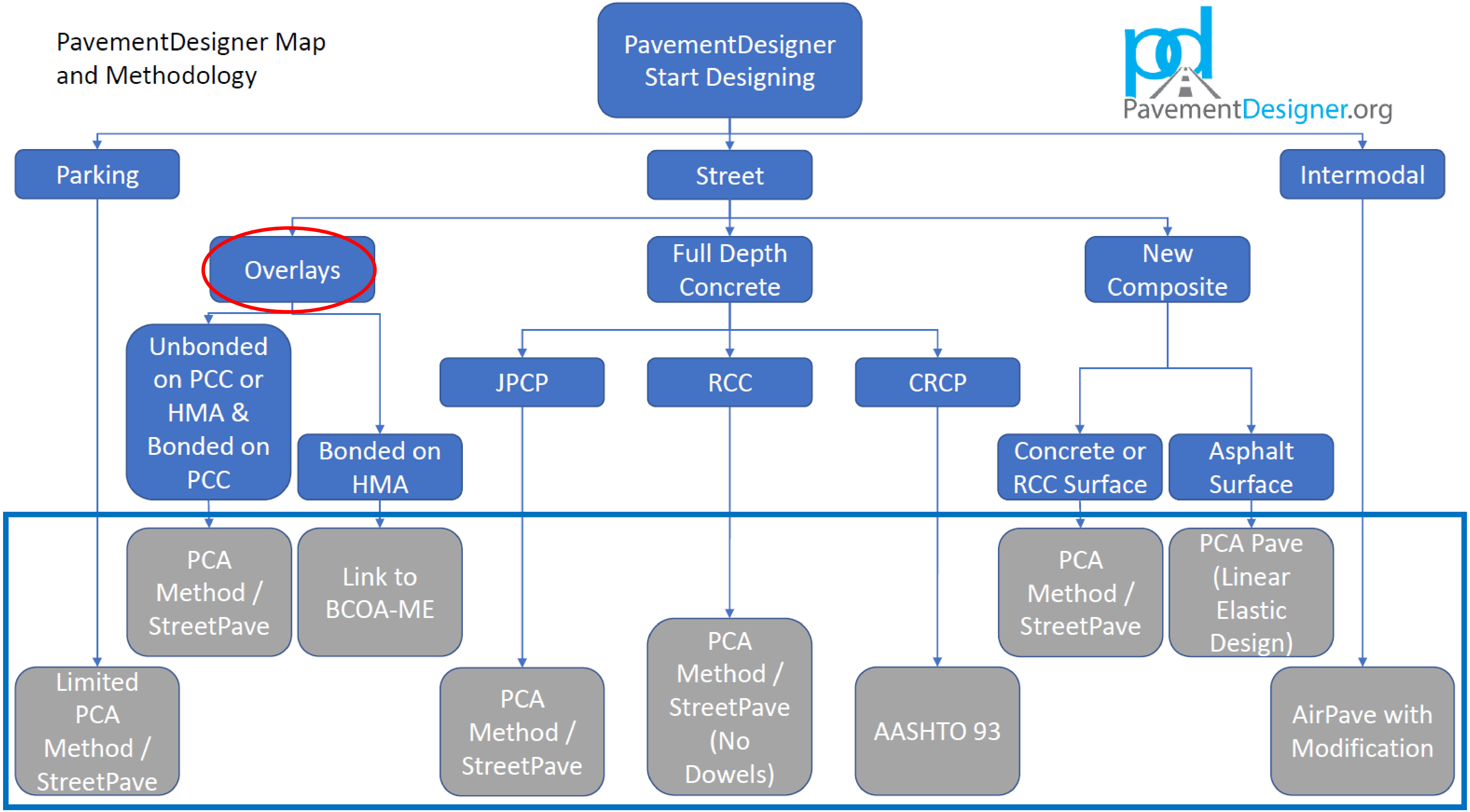
Engine		
Engine Model	Cat® C15 ACERT™	
Gross Power – ISO 14396	329 kW	441 hp
Net Power – SAE J1349	305 kW	409 hp
Buckets		
Bucket Capacities	5-10.3 m^3	6.5-13.5 yd^3

Operating Specifications		
Rated Payload – Quarry Face	10 tonnes	11 tons
Rated Payload – Loose Material (Standard)	12.7 tonnes	14 tons
Rated Payload – Loose Material (High Lift)	11 tonnes	12.1 tons
Operating Weight	43 717 kg	96,379 lb

PavementDesigner Map and Methodology



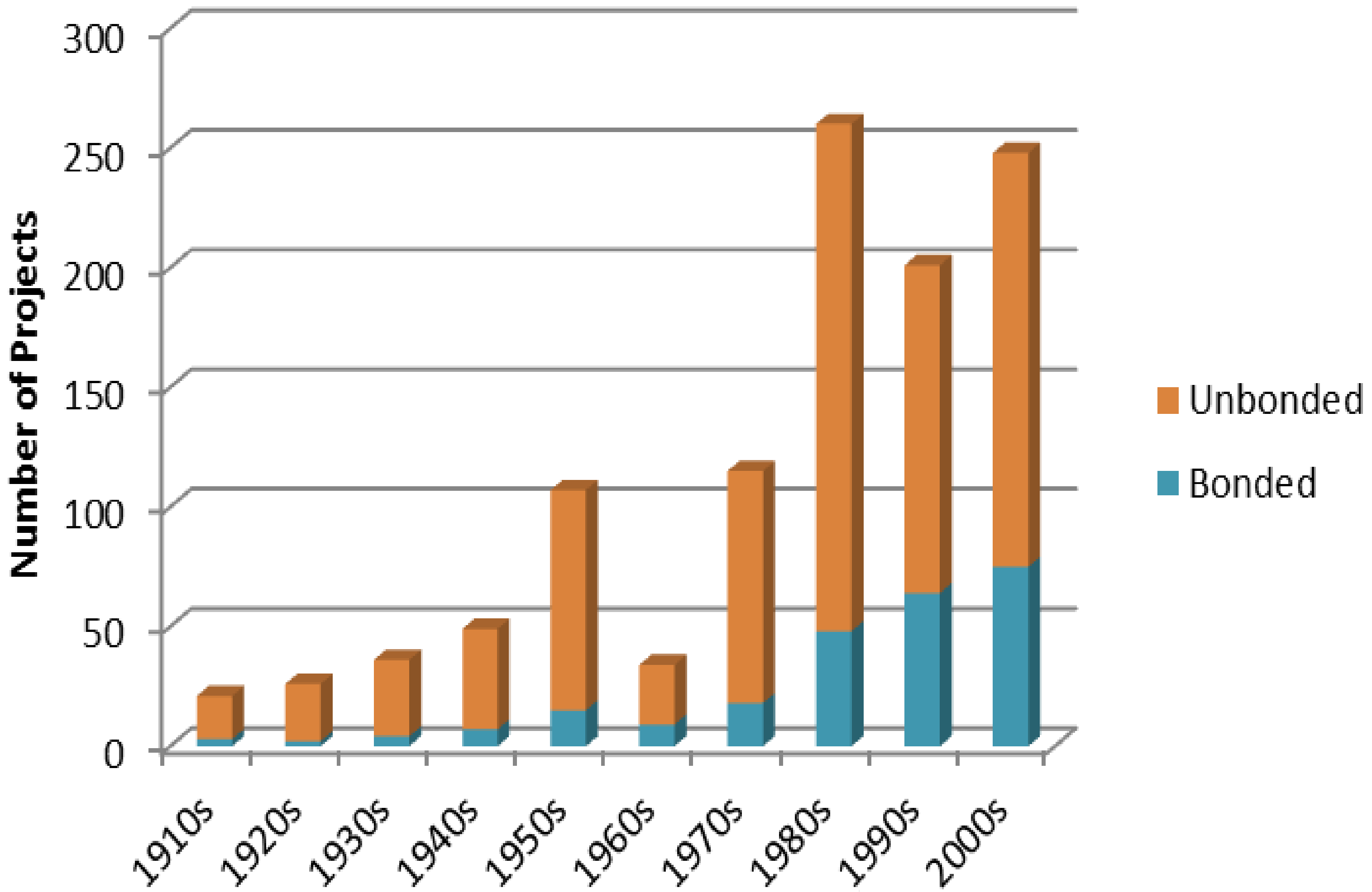
PavementDesigner Map and Methodology



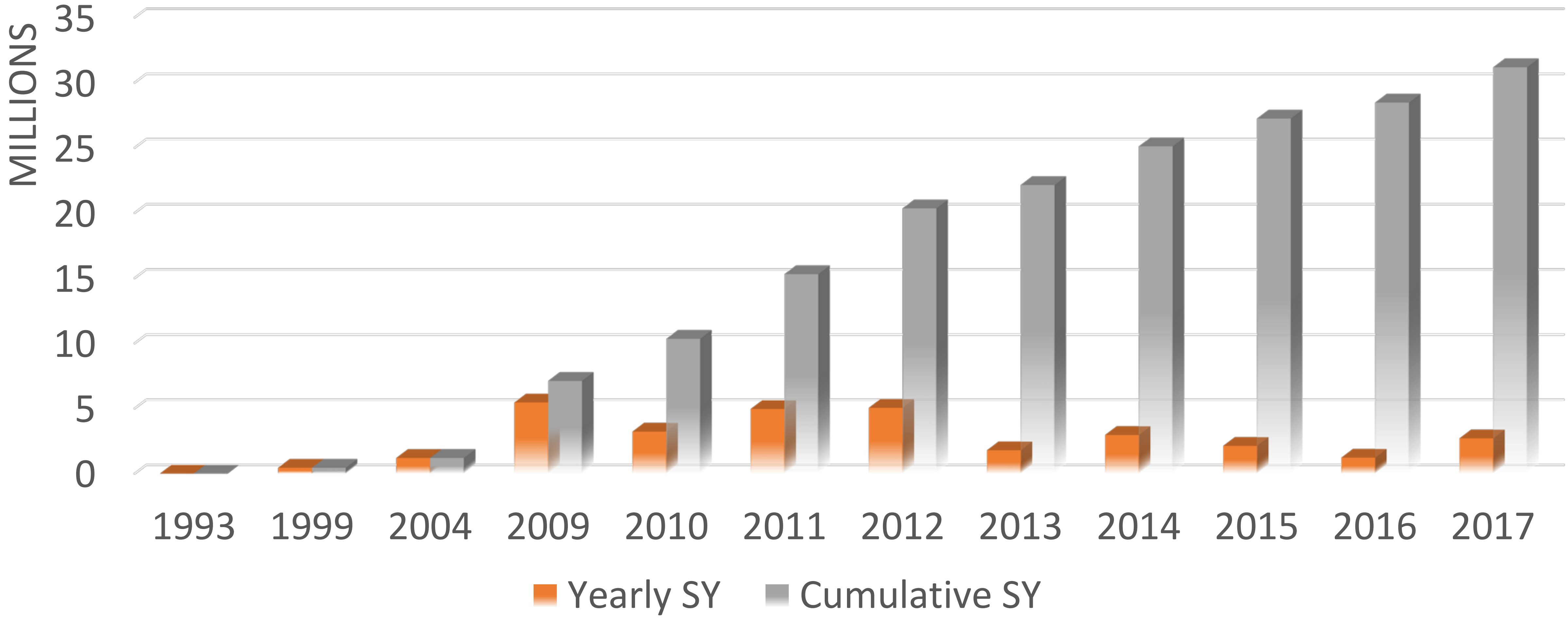
What About Overlay Design?

- PavementDesigner Overlay Design Procedure
  - Utilizes JPCP design with modification to account for existing surface layer's condition and thickness
- Links out to the BCOA-ME
  - Best method available
  - Incorporates ACPA BCOA and 6x6x6 designs

Increasing in Use!



SY OF THIN (<6 IN.) CONCRETE OVERLAYS



1 square yard = 0.84 square meters

Lots of Guidance Available…

Conc

The National Concrete Overlay Explorer

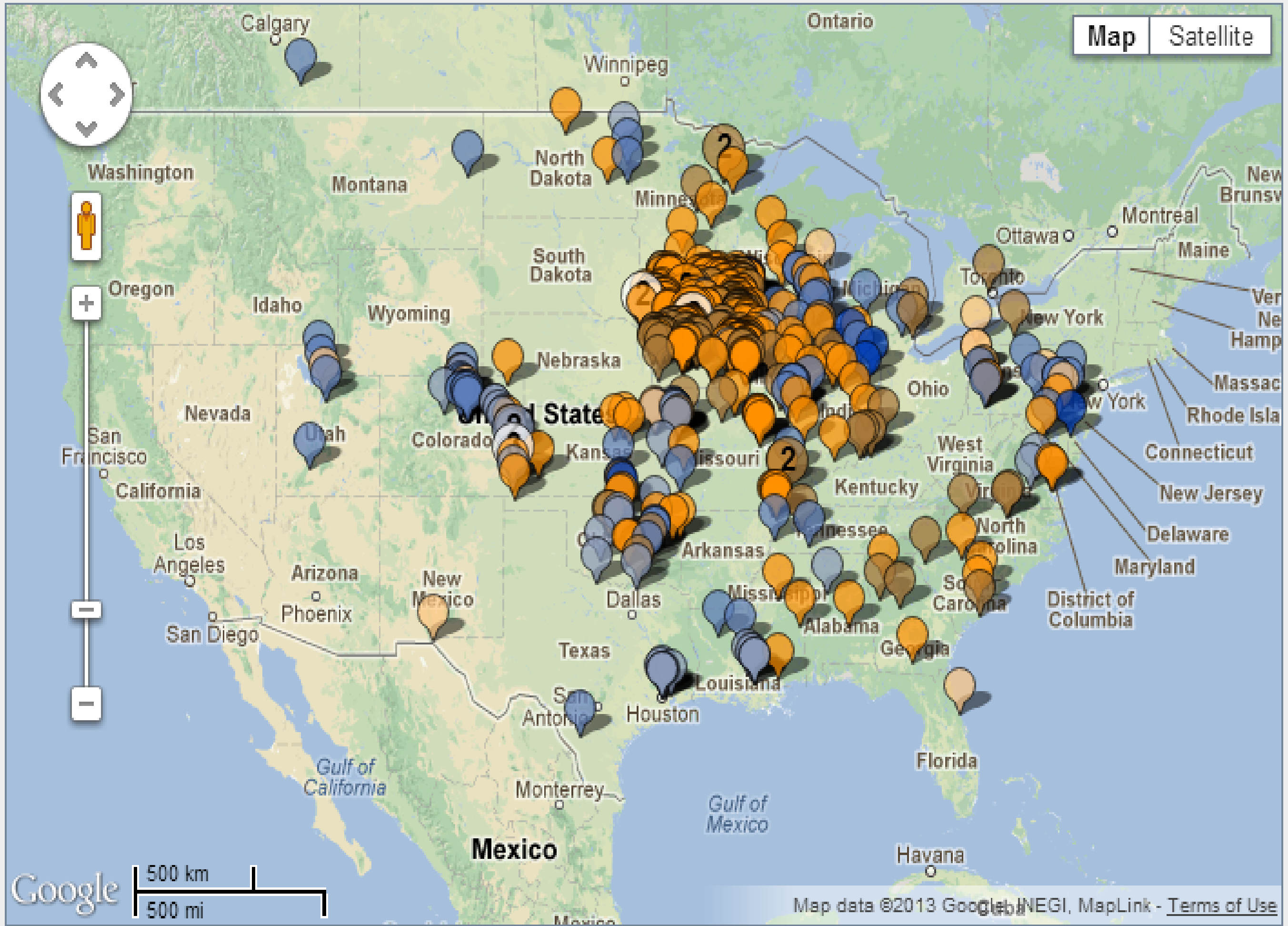
[Instructions]

MAP VIEW • TABLE VIEW • DETAILS VIEW

1147 Items

overlays.acpa.org

658 results out of 1147 cannot be plotted.



Search

Concrete Overlay Type
- 85 Bonded on Asphalt
- 23 Bonded on Composite
- 147 Bonded on Concrete
- 385 Unbonded on Asphalt

Application
- 780 Highway
- 164 Airport
- 148 Street/Road
- 37 NA

State
- 1 AB
- 3 AL
- 12 AR
- 6 AZ

Overlay Thickness (in.)
- 1 0 - 1
- 3 1 - 2
- 46 2 - 3
- 78 3 - 4

Year Constructed
- 15 1900 - 1905
- 2 1910 - 1915
- 4 1915 - 1920
- 9 1920 - 1925

org

Newest Resource Detailing Performance


Concrete Overlay Performance on Iowa's Roadways

Field Data Report
July 2017

National Concrete Pavement Technology Center

IOWA STATE UNIVERSITY
Institute for Transportation

Sponsored by
Iowa Highway Research Board
(IHRB Project TR-698)
Iowa Department of Transportation
(InTrans Project 15-559)

- Detailing overlays with up to 35 years of performance!

Guide to All Things Overlays!

- Overlay types and uses
- Evaluation & selection
- Design guidance
- Miscellaneous design details
- Overlay materials selection
- Work zones under traffic
- Key points for overlay construction
- Accelerated construction
- Specification considerations
- Repairs of overlays
- Free download at:

www.cptechcenter.org