PavementDesigner: A New Web-Based Pavement Design Tool

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PavementDesigner
Project Leaders

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  - Brian Killingsworth, P.E.
    - National Ready Mix Concrete Association

- **Additional Support**
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  - 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
Bringing Online the Best of the Best Available Design Tools

PavementDesigner Map and Methodology

PavementDesigner Start Designing

Parking

Overlays

Unbonded on PCC or HMA & Bonded on PCC

Bonded on HMA

JPCP

RCC

CRCP

New Composite

Full Depth Concrete

Concrete or RCC Surface

Asphalt Surface

Intermodal

Limited PCA Method / StreetPave

Limit to BCOA-ME

PCA Method / StreetPave

PCA Method / StreetPave (No Dowels)

AASHTO 93

PCA Pave (Linear Elastic Design)

AirPave with Modification

PavementDesigner.org
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!
PARKING LOTS
Old Ways of Designing Parking Lots

- AASHTO 93
- ACI 330R-08 & 330R-18
  - Guide for Concrete Parking Lots
- StreetPave
Table 3.1—Subgrade soil types and approximate support values (Portland Cement Association 1984a,b; American Concrete Pavement Association 1982)

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

\(BR = \text{California bearing ratio}; \ R = \text{resistance value};\) and \(SSV = \text{soil support value}.\) 1 psi = 0.0069 MPa, and 1 psi/in. = 0.27 MPa/in.

Table 3.2—Modulus of subgrade reaction \(k^*\)

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

Table 3.3—Twenty-year design thickness recommendations, in. (no dowels)

<table>
<thead>
<tr>
<th>MOR, psi: (k = 500) psi/in. ((CBR = 50; R = 86))</th>
<th>(k = 400) psi/in. ((CBR = 38; R = 80))</th>
<th>(k = 300) psi/in. ((CBR = 26; R = 67))</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (ADTT = 1)</td>
<td>A (ADTT = 10)</td>
<td>A (ADTT = 100)</td>
</tr>
<tr>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>A (ADTT = 10)</td>
<td>B (ADTT = 25)</td>
<td>B (ADTT = 300)</td>
</tr>
<tr>
<td>4.0</td>
<td>4.0</td>
<td>5.0</td>
</tr>
<tr>
<td>A (ADTT = 100)</td>
<td>C (ADTT = 100)</td>
<td>C (ADTT = 300)</td>
</tr>
<tr>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>B (ADTT = 25)</td>
<td>D (ADTT = 700)</td>
<td>D (ADTT = 700)</td>
</tr>
<tr>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
</tr>
</tbody>
</table>

\(k = \text{modulus of subgrade reaction}; CBR = \text{California bearing ratio}; R = \text{resistance value};\) and \(MOR = \text{modulus of rupture.}\)

Note: 1 in. = 25.4 mm, and 1 psi/in. = 0.27 MPa/in.

For subgrade applied over different subgrades, psi/in. (Portland Cement Association 1984a,b; Federal Aviation Administration 1978).

Traffic category\

<table>
<thead>
<tr>
<th>MOR, psi: (k = 200) psi/in. ((CBR = 10; R = 48))</th>
<th>(k = 100) psi/in. ((CBR = 3; R = 18))</th>
<th>(k = 50) psi/in. ((CBR = 2; R = 5))</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (ADTT = 1)</td>
<td>A (ADTT = 10)</td>
<td>A (ADTT = 100)</td>
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<tr>
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<td>B (ADTT = 25)</td>
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</tr>
<tr>
<td>A (ADTT = 100)</td>
<td>C (ADTT = 100)</td>
<td>C (ADTT = 300)</td>
</tr>
<tr>
<td>5.5</td>
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</tr>
<tr>
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<td>D (ADTT = 700)</td>
<td>D (ADTT = 700)</td>
</tr>
<tr>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
</tr>
</tbody>
</table>

\(ADTT = \text{average daily truck traffic}. \text{Tracks are defined as vehicles with at least six wheels; excludes panel trucks, pickup trucks, and other four-wheel vehicles.} \) Refer to Appendix A.
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
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

![Diagram of pavement sections and test loop](image)
Don’t Just Take My Word…

“...this is why Pavement ME exists!

“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.”
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!**

[Map of the United States with markers indicating LTPP GPS-3 & RPPR JPCP Sections and LTPP SPS-2, MnROAD, & AASHO JPCP Sections.]
AASHTO 93 vs. ME

- Wide range of structural and rehabilitation designs
- Limited structural sections
- 1 climate/2 years
- All climates over 20-50 years
- 50+ million load reps
- 1.1 million load reps
- 1 set of materials
- New and diverse materials

AASHTO 93

AASHTO Pavement ME
### Design Outputs

#### Distress Prediction Summary

<table>
<thead>
<tr>
<th>Distress Type</th>
<th>Distress @ Specified Reliability</th>
<th>Reliability (%)</th>
<th>Criterion Satisfied?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal IRI (in/mile)</td>
<td>Target: 172.00</td>
<td>Predicted: 117.99</td>
<td>Target: 90.00</td>
</tr>
<tr>
<td>Mean joint faulting (in)</td>
<td>0.12</td>
<td>0.07</td>
<td>90.00</td>
</tr>
<tr>
<td>JPCP transverse cracking (percent slabs)</td>
<td>5.00</td>
<td>4.61</td>
<td>90.00</td>
</tr>
</tbody>
</table>

#### Distress Charts

- **IRI**
  - Chart showing IRI trend over time.
- **Faulting**
  - Chart showing faulting trend over time.
- **Cracking PCC**
  - Chart showing cracking trend over time.
ACI 325

- Limited design charts
- New guide based on PavementDesigner runs
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
- \( E_{\text{PCC}} = 3,500,000 \text{ psi} \)

- Edge Support
- HMA Subbase = 1”
- Cement Stb Subgrade = 6”
- \( K = 160 \text{ psi/in} \)

- Design:
  - AASHTO 93 = 11”
Highway Design with PavementDesigner

- 7,860 trucks (~20M ESALs)
- 90% Reliability
- 5% Slabs Cracked
- 6 lane facility
- R-Value = 20
- MOR = 630 psi
- EPCC = 3,500,000 psi

Edge Support
- HMA Subbase = 1"
- Cement Stabilized Subgrade = 6"
- K = 160 psi/in

Design:
- AASHTO 93 = 11"
- PavementDesigner = 8.5"
- Pavement ME = 9"

Distress Prediction Summary

<table>
<thead>
<tr>
<th>Distress Type</th>
<th>Distress @ Specified Reliability</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Terminal (in)</td>
<td>172.00</td>
<td>90.00</td>
<td>Pass</td>
</tr>
<tr>
<td>Mean joint faulting (in)</td>
<td>0.12</td>
<td>0.00</td>
<td>Pass</td>
</tr>
<tr>
<td>JIPCP transverse cracking (percent)</td>
<td>5.00</td>
<td>91.91</td>
<td>Pass</td>
</tr>
</tbody>
</table>

Distress Charts

Project Level

Traffic
- Spectrum Type: Major Arterial
- Design Life: 20 years

User Defined Traffic
- Trucks Per Day: 7,800
- Traffic Growth Rate %: 1.5 % per year
- Directional Distribution: 50 %
- Design Lane Distribution: 50 %

Global
- Reliability: 90 %
- % State Cracked at End of Design Life: 5 %
- Avg Trucks/Day In Design Lane Over the Design Life: 2,000
- Total Trucks In Design Lane Over the Design Life: 10,984,078
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
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
PavementDesigner Map and Methodology

Parking

- Overlays
  - Unbonded on PCC or HMA & Bonded on PCC
  - Bonded on HMA
    - PCA Method / StreetPave
    - Limited PCA Method / StreetPave
    - Link to BCOA-ME

- Full Depth Concrete
  - JPCP
  - RCC
  - CRCP
    - Concrete or RCC Surface
    - Asphalt Surface
      - PCA Pave (Linear Elastic Design)

- Intermodal

Start Designing
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!
1 square yard = 0.84 square meters
Lots of Guidance Available...
Newest Resource Detailing Performance

- 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