Design Catalog Based on AASHTO Pavement ME Design

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Office of Infrastructure

Image Source: FHWA
Content

• Background
• Content of the Design Catalog
• Status
• Related work
Rationale for the Design Catalog

• Promote best practices in pavement design
• Provide a tool for design checks
• Facilitate structural design
• Possible application in pavement-type selection evaluation
Recommendations from Scan Tour
High Payoff Items for Implementation

• Two-Lift Construction (as per 1992 SCAN)
  o Scarce quality aggregates for top lift only
  o Recycled/marginal aggregates in lower lift

• Design Features Catalog (1992 SCAN)
  o Standard design features for different types of roads
  o Highlight features necessary for long-life pavements

• High Quality Foundations
  o Minimize/eliminate frost & swelling
  o Basics - good pavements start with good foundations!
German Design Catalog for Concrete Pavement Alternatives

<table>
<thead>
<tr>
<th>Zeile</th>
<th>Bauklasse</th>
<th>SV</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Äquivalente 10-t-Achsübergänge in Mio.</td>
<td>B</td>
<td>&gt; 32</td>
<td>&gt; 10 - 32</td>
<td>&gt; 3 - 10</td>
<td>&gt; 0,8 - 3</td>
</tr>
<tr>
<td>Dicke des frosttech. Oberbaues</td>
<td>55</td>
<td>65</td>
<td>75</td>
<td>85</td>
<td>55</td>
</tr>
</tbody>
</table>

Tragschicht mit hydraulischem Bindemittel auf Frostschatzschicht bzw. Schicht aus frostunempfindlichem Material

<table>
<thead>
<tr>
<th>Betondecke</th>
<th>Vliesstoff</th>
<th>Tragschicht (HGT)</th>
<th>Frostschatzschicht</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td></td>
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<td></td>
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<td>1.2</td>
<td>Verfestigung</td>
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<td></td>
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<td></td>
<td>Schicht aus frostunempfindlichem Material - welt- oder intermittierend gestuf</td>
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<td></td>
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<td>gemäß (DIN 18196)</td>
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<td>Dicke der Schicht aus frostunempfindlichem Material</td>
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</tbody>
</table>

German Design Catalog for Highways
(>32 million ESALs)

ME Design Process

Distress = f(M, a, b, c, ...)

Distress Analysis

Trial section and material properties

Traffic

Transfer Functions

Predicted Performance

EICM
JPCP Cracking Model Calibration

Cracking = \frac{100}{1 + C_1 (FD)^{C_2}}

Percent Slabs Cracked vs. Fatigue Damage
Prediction Errors in JPCP Cracking Model

\[ y = 0.9952x + 0.0884 \]

- \( R^2 = 0.92 \)
- \( \text{SEE} = 4.58\% \)
- \( n = 760 \)
AC Bottom-Up Fatigue Cracking Model

![Graph showing measured and predicted alligator cracking](image)

Legend:
- Measured Alligator Cracking
- Predict Bottom-Up Cracking
Slab Thickness vs. Cracking
Structural Model

Plate on elastic foundation

Elastic Layers

PCC Pavements

AC Pavements

Image Source: FHWA
Keys to Achieving Well-Performing Pavement

Minimize the risk of poor performance

• Effective structural design
  o Good foundation
  o Adequate structural section
  o Appropriate design features

• Durable material
  o Durable surface
  o No material-related problems

• Quality construction
# Slab thickness options for highways

<table>
<thead>
<tr>
<th>Traffic level</th>
<th>Design thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>9 in</td>
</tr>
<tr>
<td>Moderate</td>
<td>10 in</td>
</tr>
<tr>
<td>High</td>
<td>11 in</td>
</tr>
<tr>
<td></td>
<td>12 in</td>
</tr>
</tbody>
</table>

How many different ways can you design an 11-in concrete pavement?
Design Objectives

• Provide safe, smooth, and quiet riding surface
• Requirements – low cost and least amount of interruptions to users:
  o Good performance (low distress) – no, lengthy lane closures for maintenance, repair, or rehabilitation
  o Long-life – relates to congestion, cost, and safety
Current Practice

• Pavements are designed to fail
  o Finite design period
  o Pavements are designed for relatively high levels of distress at the end of the design period
• Repairs are not made until distresses progress to high severity
• Structural overlays are used primarily as a corrective measure
  o Typically used on pavements in poor condition
  o A thicker overlay is generally required
Pavement Condition vs. Age
Pavement Condition vs. Age: Current Practice
Pavement Condition vs. Age Preservation Approach
Pavement Condition vs. Age: Long-life Approach
What Is Needed

• Design pavements to last as long as the materials
  o Pavements should remain distress-free within the design period
  o Utilize design features that ensure good long-term performance

• Build it right

• Apply preventive treatments to preserve the pavement structure
  o For sustainability, preservation is better than reconstruction
  o Prevention is the best preservation strategy
State-of-Good-Repair vs. Good Pavement

State of Good Repair
Condition: Fair
M&R: high
Cost: $$$$$

Good Pavement
Condition: Excellent
M&R: very low
Cost: $$
Two Dimensions of Paving

Coverage: lane-miles -> $/mi

Service Life: years

Unit of Paving = lane-mile-years
Pavement cost = $/lane-mi-yr

A network of x lane-miles of pavement requires an addition of x lane-mile-years of service life each year to maintain status quo

Image Source: A Quick Check of Your Highway Network Health: FHWA-IF-07-006
Cost considerations

• Highway investment decision is a resource allocation problem
  o Minimizing LCC of a single project does not provide the best results for the network level
  o At any given funding level, the optimum solution is one that buys the most service life for the network (total lane-mile-years)
• Relevant parameter is $/lane-mi-years
• Optimizing $/lane-mi-years ensures most value for the investment
Design Catalog

• Intended to promote good pavement designs to ensure good, long-term pavement performance
• Both AC and PCC pavements are included
• Design tables are provided that could be used for design checks
Types of Pavements Considered

- **JPCP**
  - PCC
    - Granular base
  - Stabilized base
  - Subgrade

- **AC**
  - HMA
    - Granular base
    - Subbase
    - Base/Subbase
    - Subgrade
  - Asphalt base

- **JPCP**
  - PCC
    - Granular base
    - Base/Subbase
    - Subgrade
Content of the Design Catalog

Chapter 1: Introduction
Chapter 2: Design considerations
Chapter 3: Subsurface drainage recommendations
Chapter 4: Special subsurface conditions
Chapter 5: Recommendations to reduce early distresses
Chapter 6: Structural design, JPCP
Chapter 7: Structural design, AC pavement
Chapter 8: References
Appendices
Guidelines Are the Catalog’s Main Feature

• Design features for different design conditions
• Material considerations
  o AC and PCC
  o Base and subbase
  o Subgrade
• Special subsurface conditions
  o Subsurface problems and investigations
  o Subsurface water flow and saturated soils
  o Collapsible, swelling, and frost-susceptible soils
  o Variability of soil types
  o Subgrade improvement by stabilization
• Minimizing potential for early distress development
Key Design Parameters Considered

• Design Life
  o 20-year and 40-year (long-life) designs

• Subgrade
  o $M_R$ of 8,000 to 18,000 psi
  o Three categories

• Traffic levels
  o Average Daily Truck Traffic (AADTT) from $\leq 500$ to 10,000
  o Four categories

• Climate
  o Four LTPP climatic zones
Four Climatic Zones Considered (LTPP)

Image Source: From the report in progress.
# Example Design Table

<table>
<thead>
<tr>
<th>Traffic Class (AADTT) Subgrade Resilient Modulus (psi)</th>
<th>≤ 500</th>
<th>1500/2000</th>
<th>4500</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8000</td>
<td>13000</td>
<td>18000</td>
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<td></td>
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<tr>
<td><strong>Feature: Min &quot;h&quot;</strong></td>
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<tr>
<td>AS 7</td>
<td></td>
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<td>TS 7</td>
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<tr>
<td>WS 6/9*</td>
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<tr>
<td>AS 7</td>
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<td>TS 7</td>
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<td>WS 6/9*</td>
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<td>AS 7</td>
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<td>TS 7</td>
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<tr>
<td>WS 6/9*</td>
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<tr>
<td>AS 8</td>
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<tr>
<td>TS 8</td>
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<tr>
<td>WS 7</td>
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<td>AS 8</td>
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<td>TS 8</td>
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<tr>
<td>WS 7</td>
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<tr>
<td>AS 11</td>
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<tr>
<td>TS 11</td>
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<td>WS 9</td>
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<td>AS 11</td>
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<td>TS 11</td>
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<tr>
<td>WS 9</td>
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</tr>
</tbody>
</table>

**Notes:** *With Dowel/Without Dowel*

### PCC with granular base and subbase

<table>
<thead>
<tr>
<th><strong>Granular Base Course</strong></th>
<th><strong>Subbase</strong></th>
<th><strong>Frost Protection Layer</strong></th>
<th><strong>Subgrade</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JPCP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granular Base Course</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subbase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frost Protection Layer</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Total "Thickness" should cover frost depth in Table 1.

**Notes:** see Table 1

### PCC with stabilized base

<table>
<thead>
<tr>
<th><strong>Stabilized Base</strong></th>
<th><strong>Frost Protection Layer</strong></th>
<th><strong>Subgrade</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JPCP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stabilized Base</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frost Protection Layer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total "Thickness" should cover frost depth in Table 1.

**Notes:** see Table 1

### Notes

*With Dowel/Without Dowel*

Granular Base Course
Subbase
Frost Protection Layer
Subgrade

- Subgrade Resilient Modulus (psi): 8000, 13000, 18000
- Traffic Class (AADTT): ≤ 500, 1500/2000, 4500
- Stabilized Base: AS 7/9*, AS 6/8*, AS 6/7*
- Frost Protection Layer: AS 9, AS 8, AS 11, TS 11, TS 8, TS 7
- Subgrade: 4, 6, 8
# Example PCC Design

<table>
<thead>
<tr>
<th>Traffic Class (AADTT)</th>
<th>Subgrade Resilient Modulus (psi)</th>
<th>4500 - 10000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>8000</td>
</tr>
<tr>
<td>JPCP</td>
<td>Total &quot;Thickness&quot; should cover frost depth in Table 1.</td>
<td>Feature Min &quot;h&quot;</td>
</tr>
<tr>
<td>Granular Base Course</td>
<td></td>
<td>AS 14</td>
</tr>
<tr>
<td>Subbase</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Frost Protection Layer</td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>Subgrade</td>
<td></td>
<td>see Table 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>4500 - 10000</td>
</tr>
<tr>
<td>8000</td>
</tr>
<tr>
<td>13000</td>
</tr>
<tr>
<td>18000</td>
</tr>
</tbody>
</table>
Status

• Draft report near completion
  o Guidelines are mostly complete
  o Design tables are being completed

• Anticipated completion of the draft report: December 2018

• Final report will be released March 2019
Related Work

• Improving Foundation Designs
  o *Effective Foundation Design for Concrete Pavements (January 2020)*

• Improving Pavement Strategy (Long Life Pavements)
  o *Strategies for Concrete Pavement Preservation (January 2020)*

• Transportation Pooled-Fund – open solicitation
  o TPF 1469: *Road Foundation Contamination and Drainage – In-Service Evaluation and Best-Practice Recommendations*
Via Apia, built about 312 B.C.
Acronyms

AC: Asphalt concrete
AADTT: Annual average daily truck traffic
ESAL: Equivalent single axle load
HMA: Hot mix asphalt
IRI: International roughness index
JPCP: Jointed plain concrete pavement
LTPP: Long-Term Pavement Performance program
M&R: Maintenance and repair
PCC: Portland cement concrete