“Optimizing” Concrete Pavement Design

By
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Goals & Objectives

- Define the concept of “Optimizing” concrete pavements.
- Why “Optimize”?
- Give you some “Optimizing” ideas for concrete pavements.
- Show you what’s being done in some other states and agencies.
- Show you some tools that are available to help you “Optimize.”
“Optimizing”

- What is it, or how do we define it?
  - Not just about lowering the cost of concrete pavement.
  - It’s about using science/technology, experience, performance history, and research to lower the cost of concrete pavement without sacrificing performance (improve performance).
  - We want to “economize” our product not “cheapen” it.
“Optimizing”

- What is it, or how do we define it?
  - In a traditional sense, really what we’d like to do is “optimize” the design to focus on the design features that can lead to better or improved performance.
    - Take cost out of features that don’t affect performance (or are over-design) and maybe add cost to features or items that do.
  - Can also apply this concept to the design life concept (John’s presentation)
Where are we “Optimizing?”

“Optimizing” is being done both in the Design and Construction phases.

Examples:
- Reduced shoulder thicknesses (Design)
- Use of joint former v. sawing (Construction)
“Optimizing” Design Features

- Dowel Bar Optimization
  - Reduced number of dowels
  - Optimized Dowel Spacing
  - Alternate Dowel Bar Shapes (elliptical, plate, etc.)
  - Optimize Dowel Bar Diameter & Length
  - Epoxy Coating & Basket Standardization
Dowel Bar Optimization

![DowelCAD 2.0](image)

**Dowel Comparison Analysis and Design**

<table>
<thead>
<tr>
<th>Dowel Spacing:</th>
<th>12 inches</th>
<th>Joint Opening:</th>
<th>0.25 inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Elastic Modulus:</td>
<td>4000000 psi</td>
<td>Wheel Load:</td>
<td>9000 lbs</td>
</tr>
<tr>
<td>Slab Thickness:</td>
<td>12 inches</td>
<td>Tire Pressure:</td>
<td>90 psi</td>
</tr>
<tr>
<td>Slab Support Reaction Modulus:</td>
<td>300 psi/inch</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Green = Acceptable Option
- Yellow = Acceptable for Wide Lanes, Tied Shoulders, Good Support, and/or Low Traffic
- Red = Unacceptable Option

### Dowel Diameter(s) (inches):

<table>
<thead>
<tr>
<th>Diameter (inches)</th>
<th>1</th>
<th>1.25</th>
<th>1.5</th>
<th>1.75</th>
<th>2</th>
<th>1.41</th>
<th>1.66</th>
<th>1.98</th>
</tr>
</thead>
</table>
| **Load Transfer (%)**
| Deflection LTE: | 71.6 | 77.2 | 80.8 | 83.2 | 84.8 | 75.3 | 75.9 | 79.1 |
| Stress LTE:     | 26.1 | 30.1 | 33.1 | 35.4 | 37.1 | 28.6 | 29.0 | 31.6 |
| Effectiveness:  | 46.2 | 47.0 | 47.5 | 47.8 | 48.0 | 46.7 | 46.8 | 47.2 |

### Bearing Stress (psi)

<table>
<thead>
<tr>
<th>Loading Type</th>
<th>1479</th>
<th>1060</th>
<th>788</th>
<th>602</th>
<th>469</th>
<th>1246</th>
<th>758</th>
<th>565</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edge Loading</td>
<td>2469</td>
<td>1744</td>
<td>1284</td>
<td>975</td>
<td>755</td>
<td>2060</td>
<td>1252</td>
<td>926</td>
</tr>
</tbody>
</table>

**Count on Concrete**
Dowel Bar Optimization

DowelCAD 2.0
Dowel Comparison Analysis and Design

Analysis Type
- Corner Dowel Spacing
- Center Lane Dowel Leave-Out
- Alternate Dowel Spacings

Dowel Spacing Alternatives
- 12 Dowels, uniform (baseline)
- 11 Dowels (Alternate A)
- 9 Dowels (Alternate B)
- 8 Dowels (Alternate C)

Dowel Selection
- Dowel Size/Shape: 1.25" Round
- Avg. Slab (~3")

Dowel Bearing Stress (psi)

Plot: Peak Dwl. Br. Stress
Steel Savings: 25%

Baseline Configuration

Alternative Configuration

2717
12 Dowels (Baseline)

2647
9 Dowels (Alt. B)

-3%
Dowel Bar Optimization

McLeod Co. in Minnesota
Dowel Bar Optimization

South Dakota DOT
Standard Detail
Dowel Bar Optimization

IL Tollway Projects
Dowel Bar Optimization

Utah DOT Standard
Dowel Bar Optimization

Donahoo Road in KCK - 2010
## Dowel Geometries

<table>
<thead>
<tr>
<th>Dowel Type</th>
<th>Plan View</th>
<th>Cross Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round Dowel Bar</td>
<td><img src="image" alt="Round Dowel Bar Plan View" /></td>
<td><img src="image" alt="Round Dowel Bar Cross Section" /></td>
</tr>
<tr>
<td>Square Dowel Bar</td>
<td><img src="image" alt="Square Dowel Bar Plan View" /></td>
<td><img src="image" alt="Square Dowel Bar Cross Section" /></td>
</tr>
<tr>
<td>Rectangular Plate Dowel</td>
<td><img src="image" alt="Rectangular Plate Dowel Plan View" /></td>
<td><img src="image" alt="Rectangular Plate Dowel Cross Section" /></td>
</tr>
<tr>
<td>Diamond Plate Dowel</td>
<td><img src="image" alt="Diamond Plate Dowel Plan View" /></td>
<td><img src="image" alt="Diamond Plate Dowel Cross Section" /></td>
</tr>
<tr>
<td>Tapered Plate Dowel</td>
<td><img src="image" alt="Tapered Plate Dowel Plan View" /></td>
<td><img src="image" alt="Tapered Plate Dowel Cross Section" /></td>
</tr>
</tbody>
</table>
Dowel Resource

Guide to Dowel Load Transfer Systems for Jointed Concrete Roadway Pavements

SEPTEMBER 2011

NATIONAL CONCRETE CONSORTIUM

IOWA STATE UNIVERSITY
Institute for Transportation

National Concrete Pavement Technology Center
New Mechanistic-Empirical Tie Bar Design Approach
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ACPA Application Library

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ACPA Members and customers of affiliated ACPA Chapter/State Paving Associations: Visit ACPA’s Concrete Pavement Resource Center to search and browse a collection of over 1,000 concrete pavement related technical references published by ACPA, FHWA, IPIF, IGGA, CP Tech Center, and other Industry groups.

Note: There is a known compatibility issue with Internet Explorer 10. To mitigate the issue, please run IE10 in compatibility mode or download and use Google Chrome.
New Mechanistic-Empirical Tie Bar Design Approach
New Mechanistic-Empirical Tie Bar Design Approach

Description

The subgrade drop theory (SDT) currently is the most widely used tie bar design methodology for concrete pavements. However, the SDT fails to account for the effects of thermally induced stresses and loading conditions, variables that are essential to a logical tie bar design procedure. The research report, "A Mechanistic-Empirical Tie Bar Design Approach for Concrete Pavements," highlights the need for a more rational procedure for tie bar design based on mechanistic-empirical (M-E) concepts. This new M-E tie bar design is a practical procedure that balances the need to ensure joint integrity over the life of the pavement with excessive restraint caused by tying multiple lanes together. Because this design tool is based wholly on the previously referenced research report, this design is limited to the assumed variables used in the finite element analyses conducted during the research project; thus, only certain design inputs/outputs are available for some variables, such as subbase type and tie bar steel grade.

Terms of Use

The user accepts ALL responsibility for decisions made as a result of the use of this design tool.
New Mechanistic-Empirical Tie Bar Design Approach

ACPA

Description

The subgrade drag theory (SDT) currently is the most widely used tie bar design methodology for concrete pavements. However, the SDT fails to account for the effects of thermally-induced shrinkage and loading conditions, variables that are essential to a logical tie bar design procedure. This research report, "Mechanistic-Empirical Tie Bar Design Approach for Concrete Pavements," fulfills the need for a more rational procedure for tie bar design based on mechanistic-empirical (M&E) concepts. This new M&E tie bar design is a practical procedure that balances the need to ensure joint integrity over the life of the pavement with excessive restraint caused by tying multiple lanes together. Because this design tool is based wholly on previously referenced research reports, this design is limited to the assumed variables used in the finite element analysis conducted during the research project. Thus, only certain design input/output are available for some variables, such as subbase type and tie bar ideal grade.

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???
New Mechanistic-Empirical Tie Bar Design Approach

Concrete Pavement Structure Details
- Concrete Pavement Thickness (in.): 8
- Lane Configuration: Four Tied 12-ft Lanes
- Subbase Type/Thickness: Unstabilized (Granular) Subbase - 6 in.

Construction Details
- Month of Construction: June
- Curing Procedure: Curing Compound

Calculate Design
- Total Free Strain: 800 Rounded up from 782.88
- Tie Bar Size: #5 Tie Bar Spacing*: 45
- Tie Bar Length: 24 Steel Grade: 60

The longitudinal joint in this design contains 0.082 in.² of steel per foot; this value may be used to determine equivalent designs for alternate tie bar sizes.

* The provided tie bar spacing shown is a maximum value. A slightly shorter tie bar spacing may be necessary, depending on slab length and the required distance between tie bars and dowel bars at transverse joints.

NOTE: The original research investigating the impact of cement type on ultimate shrinkage did not constitute a Test US cement because you have selected Test US cement. The cement used for this test was not consistent.
Sealed & Unsealed Joints
Sealed & Unsealed Joints

- Both MO and KS allow for unsealed joints.
  - In MO – Joints can be left unsealed if joint width is < ¼” (any subbase)
  - In KS – Joints can be left unsealed if joint width is < ¼” (only over treated subbases)
Sealed & Unsealed Joints

15-year old pavement in KS
Optimized Shoulder Design

- Using concept in both MO and KS.
  - In MO – Using 5-3/4” (A2) and 4” (A3) untied shoulders (PCC, HMA or RCC)
  - In KS – Using 6” (mainline thickness ≤ 10”) and 8” (mainline thickness > 10”) tied PCC shoulders
Optimized Shoulder Design

Typical 6” KDOT Section
4-inch PCC Shoulder in MO
4-inch PCC Shoulder in MO
4-inch PCC Shoulder in MO
RCC Shoulder Option

Georgia DOT
What Changes Have We Made?

- In MO:
  - Saw or tool shoulder transverse joints
  - No longer require saw and seal of longitudinal construction joints

Edged joint not sawed or sealed
What Changes Have We Made?

- Shoulders (KS):
  - Allow tooling of transverse joint w/ no seal
  - Reduced cementitious content (min.)
    - 600# to 520#
    - 520# to 480# (optimized mix)
Supplementary Cementitious Mat’ls

- SCM’s (up to 40% replacement)
  - Fly Ash
    - Class F
    - Class C
  - Slag Cement
- Binary & Ternary Mixes
Concrete Overlays

**Thinner**
- Bonded Overlay System
  - Bonded Concrete Overlay of Concrete Pavements
  - Bonded Concrete Overlay of Asphalt Pavements
  - Bonded Concrete Overlay of Composite Pavements

**Thicker**
- Unbonded Overlay System
  - Unbonded Concrete Overlay of Concrete Pavements
  - Unbonded Concrete Overlay of Asphalt Pavements
  - Unbonded Concrete Overlay of Composite Pavements

Bond is integral to design

Old pavement is base
Separator Layer Options

Missouri DOT
Geotextile Separator Layers
Route 79 in Hannibal, MO - 5” UBOL on Fabric Interlayer (2013)
Joint Former
Optimized Design

- **Mainline (MO):**
  - Reduced pavement thickness
  - Incorporated AASHTO Pavement ME
    - Reduced slab thickness by 2”-3”

- **StreetPave Design (ACPA)**
Two-lift Paving
Recycled Aggregates

- Recycled Concrete Aggregate (RCA)
- Recycled HMA Aggregate (FRAP)
Questions????