A Platform for Competition Using DarwinME

Jerry W. Reece
Executive Director
NCConcrete Pavement Assn

Tennessee Concrete Pavement & Cement-Based Pavement Solution Conference
February 1, 2013
Nashville, TN
North Carolina DOT owns over 79,200 centerline miles of Roadways

- Total centerline miles of “High Type Paved” Roadways = 21,348

- Asphalt = 20,231 miles
  - Interstate = 813
  - Non-interstate = 19,418

- Concrete = 738 miles
  - Interstate = 465
  - Non-interstate = 273

- Composite = 379 Centerline miles
  - Interstate = 229
  - Non-interstate = 150
Standing the test of time......

Hwy 21 Bypass – 50 years old
The “Original” I-77
The Early NC Highway System

Highway 32 – Chowan County – 80 years old
Part of the original King’s Highway
Why so few PCC roads?

Pavement Management Design Guide Policy

“Life Cycle cost analysis will be conducted for all projects in which both flexible and rigid pavements are considered.”

“This cost analysis will typically be required on all projects where the structural number equals or exceeds 6.0”
**What is a Structural Number?**

- SN is an abstract number expressing the structural strength of a pavement.
- Factors influencing SN include soil support, traffic, serviceability, and environment.
- SN does not predict cost or performance.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3” Asphalt Surface</td>
<td>(S12.5D PG 76-22)</td>
</tr>
<tr>
<td>3” Asphalt Inter.</td>
<td>(I19.0D PG 70-22)</td>
</tr>
<tr>
<td>5.5” Asphalt Bases</td>
<td>(B25.0C PG 64-22)</td>
</tr>
<tr>
<td>8” Aggregate Base</td>
<td>(B25.0B)</td>
</tr>
<tr>
<td>7” Cement Stab. SG or 8” Lime Stab. SG</td>
<td></td>
</tr>
<tr>
<td>AASHTO A-4 Subgrade</td>
<td>(CBR = 10)</td>
</tr>
</tbody>
</table>
Life Cycle Cost Analysis for Pavements: An Overview

December 8, 2009

Leif Wathne, Director of Highways
ACPA, Washington, DC

Jerry Reece, Executive Director
ACPA-NC Chapter – Greensboro, NC

A Presentation to the
NC Joint Legislative Transportation Oversight Committee
The “Ask” ...........

- Consider a new Life Cycle Policy for selection of pavements
- Consider pavements that are COMPARABLE in performance
- Do away with the “Structural Number” policy which limits competition

The “Outcome” ........

- House of Representatives forms a Life Cycle Committee to study ways of saving money in all areas of construction, including pavements.
- LCCA Committee mandates that the NCDOT consider alternatives
- NCDOT begins study of MEPDG, later DarwinME as the design method
Problems with pavement comparison

NC has an “asphalt” culture for pavements

- PCC maintenance consisted of asphalt patches & overlays
- Asphalt materials are still indexed
- Historical maintenance periods were not relevant
- No “performance” basis for comparison

Old PCC roadways left many bad examples

- Long joints – broken slabs, spalled joints
- Lack of load transfer – slabs moving
- Improper base layers – too stiff, too erodible

Lack of familiarity with DarwinME
Steps taken by NCDOT

1. NCDOT abandons AASHTO 72 as the design method and adopts DarwinME as new design guide.
2. NC Toll Authority allows DarwinME for use on Design-Build Projects.
3. NCDOT forms industry committee for review of DarwinME issues.
4. NCDOT commissions a “Maintenance History” study.
So What is DarwinME?

A pavement design software that provides a direct means of comparison between different pavement types – asphalt versus concrete.

Combines what we know from calculated parameters of pavement design with what is known from thousands of actual field pavements.

Utilizes traffic, environment, materials and design thicknesses to estimate performance.
MECHANISTIC EMPIRICAL PAVEMENT DESIGN GUIDE (MEPDG)
New design procedure based on advanced models & actual field data collected across the US
Adopted by AASHTO in April 2011 as its Official Pavement Design Guide

MEPDG Facts

State-of-the-practice design procedure based on advanced models & actual field data collected across the US
- Adopted by AASHTO in 2008 as the Interim Pavement Design Guide
- New and rehabilitated pavements
- Calibrated with more than 2,400 asphalt and concrete pavement test sections across the U.S. and Canada, ranging in ages up to approximately 37 years

Based on mechanistic-empirical principles that account for site specific:
- Traffic
- Climate
- Materials
- Proposed structure (layer thicknesses and features)

Provides estimates of performance during the analysis period
- Performance predicted for cracking, faulting, IRI, cumulative damage, load transfer, and punchouts (CRCP)
- Can match rehabilitation activities to performance

MEPDG gives estimates of performance so designer can evaluate different design features

MEPDG Performance Curve

Predicted Cracking

- Percent slabs cracked
- Cracked at specified reliability
- Limit percent slabs cracked

Defined Failure Limit

Predicted Distress at given reliability (e.g., 90%)

Predicted Performance

Pavement age, years

Blue Line - The actual level of distresses predicted (the most likely distress level)

Magenta Line - The level of distresses at the given reliability level (i.e., 90%)

Red Line - Defined Failure Limit. Hitting this distress level does not mean the pavement is no longer functioning. It is the level defined as to when major rehabilitation is needed (i.e., patching & DG or overlay).
## Darwin Predicts How a Pavement Will Perform Over Time

<table>
<thead>
<tr>
<th><strong>Asphalt</strong></th>
<th><strong>Concrete</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt / Base thickness (Input)</td>
<td>Slab / Base thickness (Input)</td>
</tr>
<tr>
<td>Thermal Cracking</td>
<td>Cracking</td>
</tr>
<tr>
<td>Fatigue Cracking</td>
<td>Percent of slabs cracked</td>
</tr>
<tr>
<td>Bottom – Up</td>
<td>Slab Faulting</td>
</tr>
<tr>
<td>Top - Down</td>
<td>Smoothness (IRI)</td>
</tr>
<tr>
<td>Deformation (Rutting)</td>
<td></td>
</tr>
<tr>
<td>Subgrade</td>
<td></td>
</tr>
<tr>
<td>Asphalt</td>
<td></td>
</tr>
<tr>
<td>Total Deformation</td>
<td></td>
</tr>
<tr>
<td>Smoothness (IRI)</td>
<td></td>
</tr>
</tbody>
</table>
Goldsboro Bypass
Design Build / Alternate Pavement Bid

Asphalt Designs
- Design 1
  - 8-in ABC with 9-in ACC (rap)
- Design 2
  - 8-in CTABC w/ 9-in ACC (rap)
- Design 3
  - 12-in Full Depth Asphalt

Concrete Design
- Design 1
  - 10-in PCC w/ 4-in ACC
  - Stabilized subgrade

No LCCA Correction Factor was applied
R-2554BB CONCRETE

Design Inputs

- **Design Life:** 30 years
- **Existing construction:** -
- **Pavement construction:** September, 2013
- **Traffic opening:** March, 2014
- **Climate Data Sources (Lat/Long):** 34.58, -78.53

**Design Structure**

<table>
<thead>
<tr>
<th>Layer type</th>
<th>Material Type</th>
<th>Thickness (in.)</th>
<th>Joint Design:</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCC</td>
<td>JPCP Default</td>
<td>10.0</td>
<td>Joint spacing (ft) 15.0</td>
</tr>
<tr>
<td>Flexible</td>
<td>B325B asphalt</td>
<td>4.0</td>
<td>Dowel diameter (in.) 1.50</td>
</tr>
<tr>
<td>Subgrade</td>
<td>A-2-4</td>
<td>12.0</td>
<td>Slab width (ft) 12.0</td>
</tr>
<tr>
<td>Subgrade</td>
<td>A-2-4</td>
<td>Semi-infinite</td>
<td></td>
</tr>
</tbody>
</table>

**Traffic**

- **Age (year):**
  - 2014 (Initial): 3,000
  - 2029 (15 years): 13,076,200
  - 2044 (30 years): 34,050,000

**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>Target</td>
<td>Predicted</td>
<td>Target</td>
<td>Achieved</td>
</tr>
<tr>
<td>Terminal IRI (in./mile)</td>
<td>172.00</td>
<td>128.23</td>
<td>90.00</td>
</tr>
<tr>
<td>Mean joint faulting (in.)</td>
<td>0.12</td>
<td>0.08</td>
<td>90.00</td>
</tr>
<tr>
<td>JPCP transverse cracking (percent slabs)</td>
<td>16.00</td>
<td>6.23</td>
<td>90.00</td>
</tr>
</tbody>
</table>

**Distress Charts**

- **Predicted IRI**
- **Predicted Faulting**
- **Predicted Cracking PCC**

Report generated on: 9/14/2011 11:23 AM
Created by: 8/32/2011 3:22 PM
Approved by: 8/32/2011 2:22 PM
Page 1 of 15
R-2554BB ABCwRAP

Design Inputs

- **Design Life**: 30 years
- **Design Type**: Flexible Pavement
- **Base construction**: May, 2013
- **Pavement construction**: September, 2013
- **Traffic opening**: March, 2014
- **Climate Data Sources**: Lat/lon 34.59, -78.53

Traffic

<table>
<thead>
<tr>
<th>Age (year)</th>
<th>Heavy Trucks (cumulative)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014 (initial)</td>
<td>3,960</td>
</tr>
<tr>
<td>2029 (15 years)</td>
<td>13,076,200</td>
</tr>
<tr>
<td>2044 (30 years)</td>
<td>34,050,000</td>
</tr>
</tbody>
</table>

Traffic Structure

<table>
<thead>
<tr>
<th>Layer Type</th>
<th>Material Type</th>
<th>Thickness (in.)</th>
<th>Volumetric at Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible</td>
<td>RS9.5C</td>
<td>3.0</td>
<td>11.6 Effective binder content (%)</td>
</tr>
<tr>
<td>Flexible</td>
<td>RI9C</td>
<td>3.0</td>
<td>7.0 Air voids (%)</td>
</tr>
<tr>
<td>Flexible</td>
<td>RS25B</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>NonStabilized</td>
<td>ABC</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>Subgrade</td>
<td>A-2-4</td>
<td>12.0</td>
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Design Outputs

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<th>Criterion Satisfied?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal IRI (in./mile)</td>
<td>Target 172.0</td>
<td>Predicted 177.12</td>
<td>90.00 87.19</td>
</tr>
<tr>
<td>Permanent deformation - total pavement (in.)</td>
<td>0.75</td>
<td>0.59</td>
<td>90.00 90.00</td>
</tr>
<tr>
<td>AC bottom-up fatigue cracking (percent)</td>
<td>26.68</td>
<td>2.08</td>
<td>90.00 100.00</td>
</tr>
<tr>
<td>AC thermal fracture (ft/mile)</td>
<td>250.0</td>
<td>27.17</td>
<td>90.00 100.00</td>
</tr>
<tr>
<td>AC top-down fatigue cracking (ft/mile)</td>
<td>2000.00</td>
<td>1240.99</td>
<td>90.00 98.11</td>
</tr>
<tr>
<td>Permanent deformation - AC only (in.)</td>
<td>0.25</td>
<td>0.04</td>
<td>90.00 100.00</td>
</tr>
</tbody>
</table>

Distress Charts

- Predicted IRI
- Predicted Total Rutting (Permanent Deformation)
- Predicted AC Bottom-Up Cracking (Alligator)
- Thermal Cracking: Total Length vs. Time
R-2554BB ABCwRAP-National

Design Inputs

- **Design Life:** 30 years
- **Design Type:** Flexible Pavement
- **Base construction:** May, 2013
- **Pavement construction:** September, 2013
- **Traffic opening:** March, 2014
- **Climate Data Sources:** (Lat/Lon) 34.50, -78.53

Design Structure

- **Layer type**  | **Material Type** | **Thickness (in.)**
  - Flexible      | RS9 SC           | 3.0
  - Flexible      | RS19C           | 3.0
  - Flexible      | RS25B           | 3.0
  - NonStabilized | ABC             | 8.0
  - Subgrade      | A-2-4           | 12.0
  - Subgrade      | A-2-4           | Semi-infinite

- **Volumetric at Construction:**
  - Effective binder content (%) 11.6
  - Air voids (%) 7.0

<table>
<thead>
<tr>
<th>Age (year)</th>
<th>Heavy Trucks (cumulative)</th>
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</tr>
<tr>
<td>2044 (30 years)</td>
<td>34,050,000</td>
</tr>
</tbody>
</table>

Design Outputs

Distress Prediction Summary

- **Terminal IRI (in./mile):**
  - Target 172.00
  - Predicted 208.26
  - Reliability 64.16
  - Achieved 90.00
  - Satisfied? No

- **Permanent deformation - total pavement (in.):**
  - Target 0.76
  - Predicted 1.36
  - Reliability 60.00
  - Achieved 2.89
  - Satisfied? No

- **AC bottom-up fatigue cracking (percent):**
  - Target 25.00
  - Predicted 2.08
  - Reliability 90.00
  - Achieved 100.00
  - Satisfied? Yes

- **AC thermal fracture (ft/mile):**
  - Target 250.00
  - Predicted 27.17
  - Reliability 90.00
  - Achieved 100.00
  - Satisfied? Yes

- **AC top-down fatigue cracking (ft/mile):**
  - Target 2000.00
  - Predicted 1286.90
  - Reliability 90.00
  - Achieved 98.14
  - Satisfied? Yes

- **Permanent deformation - AC only (in.):**
  - Target 0.25
  - Predicted 0.88
  - Reliability 90.00
  - Achieved 0.89
  - Satisfied? No

Distress Charts

- **Predicted IRI**
  - Initial IRI: 71.4
  - Target Value
  - 50% Reliability

- **Predicted Total Rutting (Permanent Deformation)**

- **Predicted AC Bottom-Up Cracking (Alligator)**

- **Thermal Cracking: Total Length vs. Time**

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FINAL PAVEMENT PERFORMANCE COMPARISONS
Most agencies do repairs when IRI ~ 120 in/mi (red dotted)

Asphalt Design (From NCDOT)

<table>
<thead>
<tr>
<th>Estimated Costs</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Cost</td>
<td>$24,006,921.20</td>
</tr>
<tr>
<td>Est. Alternate Designs &amp; Cost</td>
<td></td>
</tr>
<tr>
<td>8.5&quot; JPCP / 6&quot; Granular Base</td>
<td>$21,008,822.94</td>
</tr>
<tr>
<td>9&quot; JPCP / 6&quot; Granular Base</td>
<td>$21,334,588.71</td>
</tr>
<tr>
<td>9&quot; JPCP / 1.5 AC / 4&quot; Granular Base</td>
<td>$23,205,188.53</td>
</tr>
<tr>
<td>9&quot; JPCP / 3&quot; AC</td>
<td>$23,912,222.31</td>
</tr>
<tr>
<td>9&quot; JPCP / 4&quot; AC</td>
<td>$25,934,999.56</td>
</tr>
</tbody>
</table>

Concrete Designs

No structural repair required
(in line with NCDOT LCCA practices)
What were the outcomes of Goldsboro Bypass

**Asphalt**
- NCDOT realized that local calibrations were inaccurate and accepted the national calibrations for asphalt design.
- Confirmed that standard agency asphalt designs would require overlay at <10 yrs.
- The cheapest, worst performing design was chosen for the project.

**Concrete**
- NCDOT accepted that thinner slabs could be attained with widened travel lanes.
- Shorter joint spacing dramatically improved long-term smoothness – (15-ft spacing reduced to 13-ft).
- Confirmed that PCC pavements could be competitive on initial cost.
Most important outcome to Goldsboro was..........

That NCDOT needed to study actual performance of their pavements.
Results of SAS Study – NC Roads

### Asphalt
- Study of 8752 miles
- Traffic: Above/Below 2400 Truck
- Low-volume roads (<2400)
  - Mill & Fill at 11.78 years
- High-volume roads (>2400)
  - Mill & fill every 10.11 years
- Unknown (5864 miles - 67%)
  - Mill & fill every 12.28 years

### Concrete
- Study of 800 miles
- Traffic: Above/Below 8100 Trucks
- Low-volume roads (<8100)
  - Treatment ** at 17.86 years
- High-volume roads (>8100)
  - Treatment at 17.54 years
- Unknown (50%) 17.13 years

**Treatment is defined as patch/seal or grind as separate events (17+yrs per event)**
Where are we now?

- Many more Alternate Bid jobs
- Formation of Rigid Pavement Committee
- All major projects are designed with Darwin
- NCDOT will introduce NEW Life Cycle policy soon
- In-depth study of system pavement performance
- Concrete being maintained as concrete
- Local road design / construction specs on the way
- Expanded use of more cement-based solutions
- Concrete has proven to have equal initial costs
Fred Alexander Blvd – City of Charlotte
Morrisville, NC – International Drive
Summary

Darwin is a tool that compares pavement performance

Maintenance history is vital to any LCCA or pavement performance comparison

Design alternatives can save money while maintaining long-term performance
Thanks to you, and the Tennessee Concrete Pavement Association.

Questions?

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