Structural Coefficient Recalibration & Alabama’s Implementation

Dr. David Timm, P.E.
Tuesday, March 1
2016 Louisiana Transportation Conference
Background

- Current ALDOT pavement thickness design based on AASHO Road Test
  - 1993 AASHTO Design Guide

- Structural coefficients ($a_i$) are key inputs
  - Express relative “strength” of component layers
  - Used to determine required thicknesses of layers

- In 2009, ALDOT was using values set in 1990
  - No changes between 1990 and 2009
Pavement Design in the U.S.

Pavement Design Methods

- 28: Empirical
- 11: Empirical & MEPDG
- 1: MEPDG Only
- 7: Empirical & Other ME

Pierce and McGovern, 2013
NCHRP Project 20-05, Topic 44-06
1993 Design Guide Based on AASHO Road Test

Figure 1. Looking east, Loops 5 and 2 in foreground.

HRB, 1962
Figure 92. Automatic batch-type plant used to produce binder course mixture; dryers in tandem.
Figure 95. Depositing mixture in paver from outside shoulder.
Figure 1–F. Individual present serviceability rating form.
## AASHO HMA Coefficients

<table>
<thead>
<tr>
<th>Loop</th>
<th>Layer Coefficient ($a_1$)</th>
<th>Test Sections</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.83</td>
<td>44</td>
<td>0.80</td>
</tr>
<tr>
<td>3</td>
<td>0.44</td>
<td>60</td>
<td>0.83</td>
</tr>
<tr>
<td>4</td>
<td>0.44</td>
<td>60</td>
<td>0.90</td>
</tr>
<tr>
<td>5</td>
<td>0.47</td>
<td>60</td>
<td>0.92</td>
</tr>
<tr>
<td>6</td>
<td>0.33</td>
<td>60</td>
<td>0.81</td>
</tr>
</tbody>
</table>

HRB, 1962
### ALDOT Recommended Values (1990)

<table>
<thead>
<tr>
<th>Input</th>
<th>Recommended Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA layer coefficient ($a_1^*$)</td>
<td></td>
</tr>
<tr>
<td>414 and 416 mixes (plant mix)</td>
<td>0.44</td>
</tr>
<tr>
<td>411 mixes</td>
<td>0.30</td>
</tr>
<tr>
<td>Base layer coefficient ($a_2^*$)</td>
<td></td>
</tr>
<tr>
<td>Granular base</td>
<td>0.14</td>
</tr>
<tr>
<td>Bituminous treated base</td>
<td>0.30</td>
</tr>
<tr>
<td>Cement or lime treated base</td>
<td>0.23</td>
</tr>
<tr>
<td>Subbase layer coefficient ($a_3^*$)</td>
<td></td>
</tr>
<tr>
<td>Granular subbase</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Holman, 1990
Flexible Pavement Design Curves

Figure 23. Main factorial experiment, relationship between design and axle load applications at $p = 1.5$ (from Road Test equations).

HRB, 1962
Structural Coefficient in Design

\[ SN_3 = a_1 D_1 \]

\[ SN_2 = a_1 D_1 + a_2 D_2 \]

\[ SN_3 = a_1 D_1 + a_2 D_2 + a_3 D_3 \]

\[ D_1 = \frac{SN_1}{a_1} \]
AASHTO Design Equation

\[
56 \log (V + 1) - 0.20 + \frac{\log \left( \frac{1.42 - 1.5}{0.4 + \frac{1}{0.100+1}} \right)}{5.19} + 2.32 \left( \frac{D}{R} \right) - 8.07
\]
Problem Statement

• Given new advances in mixture technology (Superpave, SMA, polymer-modification), there is a need to update the structural coefficient to reflect *actual* performance in Alabama.
Past Recalibration Efforts

• Many studies, few changes

• Most studies focus on computing $a_1$ from deflection data

• Previous values range from 0.44 to 0.60

• Previous Test Track study found 0.59 using very thick sections from 2000 experiment
  – Calibrated to deflection *not* performance
Recalibration Procedure

Actual Traffic (Loads, Repetitions)

AASHTO ESAL Equation

Measured Traffic

Actual Performance (weekly IRI measurements)

$PSI = 5e^{-0.0041IRI}$

$P_t$, $\Delta PSI$

AASHTO Design Equation

Predicted Traffic

Calibrated

Uncalibrated

Predicted Traffic

Measured Traffic
## N1 – Predicted and Measured Traffic

### a₁ = 0.44 (R² = 0.08)

<table>
<thead>
<tr>
<th>Predicted ESALs</th>
<th>Measured ESALs</th>
<th>Difference</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>802,367</td>
<td>2,267,922</td>
<td>1,465,555</td>
<td>65%</td>
</tr>
<tr>
<td>1,126,574</td>
<td>2,837,091</td>
<td>1,710,517</td>
<td>60%</td>
</tr>
<tr>
<td>1,270,712</td>
<td>2,963,064</td>
<td>1,692,352</td>
<td>57%</td>
</tr>
<tr>
<td><strong>1,638,661</strong></td>
<td><strong>3,212,141</strong></td>
<td><strong>1,573,480</strong></td>
<td><strong>49%</strong></td>
</tr>
<tr>
<td>2,340,290</td>
<td>4,321,771</td>
<td>1,981,481</td>
<td>46%</td>
</tr>
</tbody>
</table>

### a₁ = 0.50 (R² = 0.74)

<table>
<thead>
<tr>
<th>Predicted ESALs</th>
<th>Measured ESALs</th>
<th>Difference</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,314,680</td>
<td>2,224,691</td>
<td>910012</td>
<td>41%</td>
</tr>
<tr>
<td>2,007,491</td>
<td>2,806,554</td>
<td>799065</td>
<td>28%</td>
</tr>
<tr>
<td>2,332,763</td>
<td>2,939,906</td>
<td>607145</td>
<td>21%</td>
</tr>
<tr>
<td><strong>3,203,489</strong></td>
<td><strong>3,207,147</strong></td>
<td><strong>3661</strong></td>
<td><strong>0%</strong></td>
</tr>
<tr>
<td>4,996,650</td>
<td>4,353,456</td>
<td>643194</td>
<td>15%</td>
</tr>
</tbody>
</table>
Layer Coefficient

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.50</td>
<td>0.59</td>
<td>0.56</td>
<td>0.63</td>
<td>0.62</td>
<td>0.58</td>
<td>0.59</td>
<td>0.58</td>
<td>0.43</td>
<td>0.48</td>
<td>0.48</td>
<td>0.44</td>
<td>0.41</td>
<td>0.68</td>
</tr>
</tbody>
</table>

Average: 0.54
Calibrated ($a_1=0.54$)

Measured ESALs vs. Predicted ESALs

- N1 2003
- N1 2006
- N2 2003
- N2 2006
- N3 2003-2006
- N4 2003-2006
- N5 2006
- N6 2003-2006
- N7 2003-2006
- N8 2003
- N8 2006
- N9 2006
- N10 2006
- S11 2006
Further Justification for $a_1 = 0.54$

1993 AASHTO Design Guide

Structural Layer Coefficient, $a_1$, for Asphalt Concrete Surface Course

Elastic Modulus, $E_{AC}$ (psi), of Asphalt Concrete (at 68°F)
## Backcalculated HMA Moduli

### Table 5.2 Regression Analysis for HMA Stiffness – Temperature Relationship.

<table>
<thead>
<tr>
<th>Section</th>
<th>$\alpha_1$</th>
<th>$\alpha_2$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1*</td>
<td>11,696,542</td>
<td>-0.0457</td>
<td>0.985</td>
</tr>
<tr>
<td>N2*</td>
<td>14,308,573</td>
<td>-0.0414</td>
<td>0.952</td>
</tr>
<tr>
<td>N3</td>
<td>8,809,046</td>
<td>-0.0378</td>
<td>0.904</td>
</tr>
<tr>
<td>N4</td>
<td>8,030,572</td>
<td>-0.0351</td>
<td>0.915</td>
</tr>
<tr>
<td>N5</td>
<td>11,415,436</td>
<td>-0.0386</td>
<td>0.940</td>
</tr>
<tr>
<td>N6</td>
<td>8,482,965</td>
<td>-0.0302</td>
<td>0.962</td>
</tr>
<tr>
<td>N7</td>
<td>8,067,465</td>
<td>-0.0342</td>
<td>0.917</td>
</tr>
<tr>
<td>N8</td>
<td>6,918,499</td>
<td>-0.0321</td>
<td>0.989</td>
</tr>
<tr>
<td>All</td>
<td>8,187,876</td>
<td>-0.0340</td>
<td>0.850</td>
</tr>
<tr>
<td>Alvarez and Thompson</td>
<td>4,841,000</td>
<td>-0.048</td>
<td></td>
</tr>
</tbody>
</table>

* Limited FWD Data

### Equation

$$E = \alpha_1 e^{\alpha_2 \cdot T}$$
\[ a_1 = 0.171 \ln(\text{HMA Modulus}) - 1.784 \]

\[ R^2 = 0.998 \]
\[ a_1 = 0.171 \ln(\text{HMA Modulus}) - 1.784 \]

\[ R^2 = 0.998 \]

\[ a_1 = 0.54 \]

811,115 psi
Effect on Pavement Design

HMA Depth (in)

ESALs

18.5% Thinner

a1 = 0.44

a1 = 0.54
Minimum Thickness

• Not calibrated for thicknesses < 5”

• Need recommendation for thinner sections

• Lower volume recommendation
  – If new coefficient (0.54) results in thickness < 5”, use old coefficient (0.44)
    • If resulting thickness > 5”; use 5”

• ALDOT Implementation
  – No designs < 5”
Mr. D. J. McInnes
Director
Alabama Department of Transportation
Montgomery, Alabama

Dear Mr. McInnes:

Please refer to Larry Lockett’s letter dated August 11, 2009, regarding a proposed increase in the Flexible Pavement Structural Coefficient. We have reviewed the National Center for Asphalt Technology (NCAT) research study and concur with the use of a structural coefficient of 0.54 per inch of thickness for bituminous plant mix binder layers, and wearing layers.

The NCAT research study did not include OGFC layers. The existing structural coefficient should be used for OGFC layers.

Please contact Steve Mills at (334) 223-6360 or Kristy Harris at (334) 223-6360 if you have any questions.

Sincerely yours,

for: Mark D. Bartlett, P. E.
Division Administrator
Conclusions

• New advances in mix design technology warrants recalibrating structural coefficient of HMA

• Recalibration using NCAT Test Track data resulted in average $a_1 = 0.54$
  – Believed to be conservative estimate

• Using 0.54 instead of 0.44 yields 18.5% reduction in AC thickness
NCAT Report 09-03

RECALIBRATION OF THE ASPHALT LAYER COEFFICIENT

By
Kendra Peters-Davis
Dr. David H. Timm, P.E.

August 2009

Available at the NCAT Website
http://www.ncat.us/

NCAT Report 14-08

RECALIBRATION PROCEDURES FOR THE STRUCTURAL ASPHALT LAYER COEFFICIENT IN THE 1993 AASHTO PAVEMENT DESIGN GUIDE

By
Dr. David H. Timm, P.E.
Dr. Mary M. Robbins
Dr. Nam Tran, P.E.
Dr. Carolina Rodezno