Illinois DOT
From the AASHO Road Test
To
20 Years of Mechanistic Pavement Experience
......and Counting

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Transportation Research Board
87th Annual Meeting
January 13, 2008
Outline

- AASHO Road Test History
- Illinois Adoption of Mechanistic
- Current Updating Efforts

The AASHO Road Test

Mechanistic Pavement Design
Supplement to Section 7 of the Illinois Department of Transportation Design Manual

Cumulative ESALs, million

Probability of Failure, %

- 9-in CRCP without DC
- 9-in CRCP with DC
2 Years = 1.1 Million Axle Loads
Rigid Profile

MATERIAL

PCC

SANDY GRAVEL subbase

THICKNESS

$0 \quad 3 \quad 6 \quad 9 \quad 10'' \quad 20''$

$3\frac{1}{2} \quad 5 \quad 6\frac{1}{2} \quad 8 \quad 9\frac{1}{2} \quad 11 \quad 12\frac{1}{2}$
Flexible Profile

**MATERIAL**
- ASPHALT surface
- CRUSHED STONE base
- SANDY GRAVEL subbase

**THICKNESS**
- ASPHALT surface: 2 3 4 5 6
- CRUSHED STONE base: 0 3 6 9
- SANDY GRAVEL subbase: 0 4 8 12 1 6
Traffic

AASHO – Static Weights – Dynamic Loading

The AASHO Road Test
Pavement Performance

P.S.I. = 1.5
PSR = 0.0?
PSR = 0.0?
<table>
<thead>
<tr>
<th>Axle Load Pounds</th>
<th>Flex Single ESAL’s</th>
<th>Rigid Single ESAL’s</th>
<th>Flex Tandem ESAL’s</th>
<th>Rigid Tandem ESAL’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,000</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.0000</td>
<td>0.0001</td>
</tr>
<tr>
<td>6,000</td>
<td>0.010</td>
<td>0.01</td>
<td>0.001</td>
<td>0.002</td>
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<tr>
<td>12,000</td>
<td>0.189</td>
<td>0.176</td>
<td>0.014</td>
<td>0.026</td>
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<tr>
<td>18,000</td>
<td>1.00</td>
<td>1.00</td>
<td>0.077</td>
<td>0.133</td>
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<tr>
<td>24,000</td>
<td>3.03</td>
<td>3.36</td>
<td>0.260</td>
<td>0.444</td>
</tr>
<tr>
<td>30,000</td>
<td>7.00</td>
<td>8.28</td>
<td>0.658</td>
<td>1.14</td>
</tr>
<tr>
<td>36,000</td>
<td>13.9</td>
<td>17.1</td>
<td>1.38</td>
<td>2.43</td>
</tr>
<tr>
<td>42,000</td>
<td>25.6</td>
<td>32.2</td>
<td>2.51</td>
<td>4.55</td>
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</tbody>
</table>
Illinois Method of Calculating ESAL’s

- Collect static weight data from enforcement scales.
- Load spectrum by axle/vehicle type.
  - Single.
  - Tandem.
  - Triple.
- ESAL factor by FHWA vehicle class & road type.
  - Class I – Interstate and multi lane.
  - Class II – Two lane over 2000 ADT.
  - Class III - 750 to 2000 ADT.
  - Class IV – Under 750 ADT.
- Summarize into PV, SU and MU groups.
## PV, SU and MU

### Passenger Vehicles (PV)
- **Class 2**
  - Cars
- **Class 3**
  - Light Trucks

### Multiple Unit (MU)
- **Class 8 to 13**

### Single Unit (SU)
- **Class 4**
  - Buses
- **Class 5**
  - 2 Axle
- **Class 6**
  - 3 Axle
- **Class 7**
  - 4 Axle
Traffic Maps

Total ADT

Truck ADT

MU ADT

PV = Total ADT – Truck ADT
SU = Truck ADT – MU ADT
## Current ESAL Factors (Flex)

<table>
<thead>
<tr>
<th>Road Class</th>
<th>PV</th>
<th>SU</th>
<th>MU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>0.0004</td>
<td>0.394</td>
<td>1.908</td>
</tr>
<tr>
<td>Class II</td>
<td>0.0004</td>
<td>0.372</td>
<td>1.554</td>
</tr>
<tr>
<td>Class III</td>
<td>0.0004</td>
<td>0.355</td>
<td>1.541</td>
</tr>
<tr>
<td>Class IV</td>
<td>0.0004</td>
<td>0.350</td>
<td>1.523</td>
</tr>
</tbody>
</table>

Design Minimums:
- **Interstate** – 1,500 MU, 500 SU
- **Non Interstate** – 900 MU, 300 SU
Rigid Nomograph

SOIL

TRAFFIC

THICKNESS
Flexible Nomograph

TRAFFIC

SOIL

S.N.

4.75
AASHO Advances

• Equivalent $18^K$ Single Axle Loads (ESALs)
• Thickness Designs for both Flex & PCC
• “Equivalent” Pavements
• Cost Allocation
AASHO Limitations

• One Set of Materials.
• Two Years of Weathering.
• 1.1 Million Axles.
• Totally Empirical – need to extrapolate to 100’s of millions of axles.
Structural Number Concept

1958 Materials vs. Modern Materials
Why Illinois Pursued Mechanistic

- AASHTO design produced excessively thick pavements for high volume facilities.
- New materials very difficult to relate back to road test for layer coefficient.
- Modern facility traffic well beyond road test traffic.
- Valid procedure??
Mechanistic Design

Mechanistic -

“Concerning the Relationships Between Applied Forces and Material Responses.”

Basic Premise -

Low Deflections = Long Life
Mechanistic Engineering
IL-AAHSTO vs. Mechanistic

Traffic, ESAL's vs. HMA Thickness, Inches

- AASHTO
- Mech

Perpetual HMA Design
Illinois Mechanistic-Empirical Design

- Research completed in 1987.
- Load spectrum discussed – dismissed.
- Designs based upon 18K ESAL’s.
- Results very complex.
- Many designer inputs.
- Policy decisions needed to simplify.
Fatigue Theory

High Strain = Short Life
Low Strain = Long Life

18K
Fatigue Cracking

Repeated Bending

Leads to Fatigue Cracking
Fatigue Cracking

Repeated Bending

Leads to Fatigue Cracking
Illinois Mechanistic Loop

Pavement Model

Load Model

18,000 Pounds
80 PSI

Performance Calibration

Cumulative ESALs, million

Probability of Failure, %
Why Load Spectrum Not Used

• Data reliability.
  – Calibration.
  – Maintenance of equipment.

• Limited data collection ability.
  – Expense.
  – People – Head count limits.

• Data fit into performance calibration??

• Department understanding of ESAL’s.
Inputs – Full-Depth Asphalt

- Traffic.
- Soil Support (Eri).
- Location (temperature/modulus relations).
- Asphalt grade.
- Mix air voids and gradation.
- Crack initiation at bottom of HMA.
- Reliability.
Inputs – Jointed Concrete

- Traffic.
- Soil support (k).
- Joint spacing.
- Joint load transfer.
- Edge support.
- Drainage conditions.
- Concrete strength.
- Slab cracking.
- Reliability.
Decisions, Decisions, Decisions!

• Policy decisions:
  – To simplify design.
  – To limit sophisticated data collection or testing.
  – Insure design assumptions are built into pavement.

• Maintain “off-the-shelf” or current inputs.
  – 18K ESAL and related traffic data collection.
  – Current material test.
Example:

- Simplified correlation for soil inputs.
  - Not going to run subgrade resilient modulus (Eri) for every project.
  - Not going to determine “k” values.
  - Correlated to Corp of Engineers soil triangle (grain size analysis) to three common support levels.
Soil Input

45% Silt
27% Clay
28% Sand

“Poor”
## Impacts of Soil Inputs

<table>
<thead>
<tr>
<th>Soil Rating</th>
<th>Full-Depth HMA</th>
<th>Concrete</th>
</tr>
</thead>
</table>
| **Granular**  - 5%  
k = 200  
Eri = Stress Dependent | 13.75 | 9.25 |
| **Fair**  - 5%  
k = 100  
Eri = 5 ksi | 14.00 | 9.75 |
| **Poor**  - 90%  
k = 50  
Eri = 2 ksi | 14.25 | 10.25 |

For 2000 trucks/day in design lane – moderate volume Interstate
Pavement Performance

• Keys to long term performance:
  – Design.
    • Thickness.
    • Cross-section.
  – Materials.
  – Construction.
  – Maintenance.
“D” Cracked Concrete
ESAL Survival of Original Pavements – South IL

D-Cracking Comparisons

9-in CRCP without DC

9-in CRCP with DC

30% More Life

Cumulative ESALs, million

Probability of Failure, %
Keys to Pavement Performance
-Illinois

- Design (T)
- Design (D)
- Materials
- Maintenance
- Construction
Summary of Pavement Life (No DC) – Age

![Graph showing pavement life expectancy](image)

- 10-in JRCP
- 10-in CRCP
- 12 to 17-in HMAC

- Original
- 1st Thin OL
- 2nd Thin OL

Design 50 Percentile Age, years
Tentative
Summary of Pavement Life (No DC) – Cumulative ESALs

- 10-in JRCP
- 10-in CRCP
- 12 to 17-in HMAC

50 Percentile ESAL, million

Original
1st Thin OL
2nd Thin OL
Traffic Data
Search for New Portable Equipment

- Safety of the worker
- Quality and Quantity of data collected
- Cost to the Department
- Comply with new FHWA’s Traffic Monitoring Guide (TMG)
Nu-Metrics Hi-Star 97
PV, SU and MU

### Passenger Vehicles (PV)
- **Class 2**: Cars
- **Class 3**: Light Trucks

### Multiple Unit (MU)
- Class 8 to 13

### Single Unit (SU)
- **Class**: 4
  - **Buses**: 4 Axle
  - 3 Axle
  - 2 Axle

- **Class**: 5
- **Buses**: 4 Axle
- **Class**: 6
- **Buses**: 3 Axle
- **Class**: 7
- **Buses**: 2 Axle
Axle Classification vs. Length Classification
(data from permanent ATR locations)
Distribution of Vehicles by Length

Number of Vehicles

Vehicle Length (feet)

PV  SU  MU
Illinois Mechanistic Design

Minimum Designs:

Former procedure:

Minimum thickness by facility type

Same statewide

Industry issues
New Minimums

- Minimums by Facility Type
  - Interstates 2 Way ADT:
    - 500 SU  1500 MU
  - Other State
    - 300 SU  900 MU
  - Unmarked
    - Actual Traffic
Mechanistic Example

Given:  TF  =  4.27
        AC  =  PG 58 – XX
        Location = Springfield, IL
Soil Input

45% Silt
27% Clay
28% Sand

“Poor”
Note: The minimum design AC mixture temperature will be 76°F.

AC MIXTURE TEMPERATURE
(Mechanistic Design: Flexible Pavement)

Figure 54-9A
AC MIXTURE MODULUS ($E_{AC}$)
(Mechanistic Design: Flexible Pavement)

Figure 54-9B
DESIGN AC STRAIN
(Mechanistic Design: Flexible Pavement)

Figure 54-9C
AC THICKNESS DESIGN CHART
(Mechanistic Design: Flexible Pavement: SSR = Fair)

Figure 54-9D
Illinois 2008 Mechanistic Update

- HMA
  - New Fatigue Equation
  - PG Graded Materials for Modules
  - Limiting Strain (Max thickness)
- PCC
  - Relook at Joint Spacing
  - Mechanistic CRCP
- Both
  - New Minimum Traffic (Lower)
Implementation

- Research start 1980
  - 6 years
- Industry meetings
  - Design Procedures
  - Selection Process
  - Implementation
  - 2 years
- Issue Design 1989
Issues after Implementation

- Industry questions
- FHWA/IDOT review
- Revisions 1992
Summary/Suggestions

• Review design.
• Determine where performance gains needed in your state.
  – Durability (materials)
  – Design
  – Other
• Determine merits of each design input and worth of refinement.
• Involve industry
Challenges & Issues

Quality Data

Quantity Needed?

Simplified Inputs

Percent Clay

Percent Silt

Percent Gr

0 1 0 0

50

100

Gr

Poor

Fair
Questions?

Lincoln’s Home
Springfield, Illinois