Overlay Thickness Design Using NDT Methods

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Outlines

☑ Background
☑ Objective and Methodology
☑ Overlay Design Results
☑ Analyze and Propose NDT Overlay Procedure
☑ Cost/Benefit Analysis
☑ Summary and Recommendation
Background on Current DOTD Overlay Thickness Design

☑️ For intermediate and high traffic roads (usually ADT > 3000), use an empirical method provided in 1993 AASHTO Pavement Design Guide, where the overlay thickness is calculated

\[ h_{OL} = \frac{SN_f - SN_{eff}}{a_{OL}} \]

Where

- \( SN_f \) - the required future structural number
- \( SN_{eff} \) - the effective structural number of existing pavement
- \( a_{OL} \) - layer coefficient of the overlay AC layer, =0.44.
Background (contd..)

☑ Current DOTD Overlay Thickness Design

- \( SN_{eff} = a_1 \times h_1 + a_2 \times h_2 + a_3 \times h_3 \ldots \)
  - \( a_i \) – structural layer coefficient of existing layer \( i \); Not tested.
  - Determined by DOTD design layer coefficient table

- \( SN_f = F(Mr, ESALs, \Delta PSI, R, & So) \)

\[ h_{OL} = \frac{SN_f - SN_{eff}}{a_{OL}} \]

New AC Overlay: \( h_{OL} \)

Layer 1: \( a_1 \ h_1 \)

Layer 2: \( a_2 \ h_2 \)

....

Subgrade: \( Mr \)

→ AASHTO Flexible Pavement Design Equation

→ Mr - Not tested. Determined from DOTD Parish Map Mr-Table
Background on Current DOTD Overlay Thickness Design (Contd..)

☑️ For low traffic roads,

- sometimes no overlay thickness design was performed;
- Instead, a typical 2-inch coplaning plus a few inches new asphalt overlay are used as a typical overlay structure.

☑️ Due to no in-situ testing involved and its completely empirical nature,

- The current DOTD overlay design method usually provide *over* or *under* designed overlay thickness
Objective

To establish a *Structural Overlay Thickness Design Method* for Louisiana flexible pavements, based on,

- In-situ pavement conditions, and
- Utilizing *non-destructive test* (NDT) methods, i.e. Falling Weight Deflectometer (FWD) and/or Dynaflect.

Dynatest 8002 FWD

Dynaflect
NDT-Based Structural Overlay Thickness Design

- Effective Thickness Method, or ET Method
- Deflection-based Method
- Mechanistic-Empirical (M-E) Method
Effective Thickness (ET) Method

**Basic Assumption**

- The deterioration of a pavement structure can be viewed as if the overall pavement effective thickness becomes increasingly thinner as pavement ages.

**Thickness of Overlay = \( T_n - T_e \)**

- \( T_n \), the thickness required for a new full-depth pavement;
- \( T_e \) - the effective thickness of the existing pavement

\[
h_{OL} = \frac{SN_f - SN_{eff}}{a_{OL}}
\]
Deflection-Based Overlay Design Method

- A larger surface deflection
  - a weaker existing pavement structure
  - requires a thicker overlay;
- The overlay must be thick enough to reduce the deflection to a tolerable amount
  - Relationship (pavement deflection & allowable future traffic loads).
Mechanistic-Empirical (M-E) Method

- Models pavements as multi-layered elastic or visco-elastic structure
- Determine the critical stress, strain, or deflection by mechanistic methods using FWD backcalculated layer moduli
- Predict resulting damages by empirical failure criteria, e.g. fatigue cracking, rutting.
# NDT Overlay Design Survey

<table>
<thead>
<tr>
<th>State</th>
<th>Method</th>
<th>Software</th>
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<tbody>
<tr>
<td>Arkansas</td>
<td>Equivalent Thickness (ET)</td>
<td>ROADHOG</td>
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<tr>
<td>Alabama</td>
<td>ET (1993 AASHTO NDT)</td>
<td>Spreadsheet program</td>
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<td>California</td>
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<td>Design Manual</td>
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<td>Washington</td>
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Selected NDT-Based Overlay Design Procedures

☑ 1993 AASHTO NDT Method
☑ Arkansas ROADHOG
☑ Asphalt Institute MS-17
☑ Louisiana 1980 Deflection Method
☑ ELMOD5
☑ EVERPAVE

Equivalent Thickness
Deflection-based
M-E based
Research Approach

☑ (a) Perform overlay thickness design on selected test sections, using:
   ➞ (a) The current DOTD method, and
   ➞ (b) A suite of different NDT based procedures/software

☑ (b) Based on the overlay thickness analysis results, develop/recommend a structural overlay thickness design method for flexible pavements
   ➢ Using NDT tests, and
   ➢ based on Louisiana pavement conditions
Phase I Projects

☑️ Four in-service pavements
  ➔ I-12 (ESAL_d=24,400,000)
  ➔ LA28 (ESAL_d=1,513,000)
  ➔ LA74 (ESAL_d=700,590)
  ➔ LA44 (ESAL_d=353,256)
Discussion

☑ Mixed-bag overlay thickness results obtained from different methods

☑ One consensus result:
  ➔ DOTD method calls for 3.4” overlay on I-12
  ➔ However, all NDT-based design procedures call zero inch overlay

☑ This indicates that
  ➔ Overlay thickness design should be based on in situ pavement condition
Discussion (contd…) 

✅ Without further calibration and verification, none of those methods can be directly used in Louisiana: 

- ROADHOG Delta D vs. SNeff
- AI: $\delta_d = 1.0363 \times (\text{ESAL})^{-0.2438}$
- EVERPAVE & ELMOD5
  - Fatigue/rutting equations, transfer functions
Observations

✓ AASHTO NDT procedure tends to provide a high $SN_{eff}$ value for the existing pavements in Louisiana
Louisiana NDT-based Flexible Pavement Overlay Design Method

☑ Which design methodology needs to be chosen?
  ⇒ ET, Deflection-based, or M-E based?
  ⇒ The answer is ET method.

☑ How to determine the $SN_{eff}$ in the ET method based upon the Louisiana pavement condition?
  ⇒ Louisiana 1980 Pavement Evaluation Chart may be a good start
Louisiana Pavement Evaluation Chart

- Kinchen and Temple (1980)
- Using Dynaflect deflection, to determine
  - SN of existing pavements
  - Subgrade Modulus (Es)

- SN values used in the Chart development
  - Estimated by field cores including 26 failed pavements
  - Both Es and SN represent LA Pavement condition. Still routinely used in pavement research.
Comparison of SN Chart

![Graph showing comparison of SN Chart with data points and lines for different SN values.](image-url)
Summary

- The Louisiana Pavement Evaluation Chart is theoretical sound;
- Those shifting from theoretical results were based on local pavement conditions, e.g. using core determined SN values;
- Therefore, the Louisiana Pavement Evaluation Chart is a locally calibrated, theoretical SN chart
$\text{SN}_{\text{Dynaflect}} \text{ vs. } \text{SN}_{\text{FWD}}$

**SN Correlation**

\[ Y = 2.58 \ln(x) - 0.77 \]
\[ R^2 = 0.92 \]

*Note: Data from 13 projects and total 271 test points*
NDT-based Structural Overlay Design Procedure for Flexible Pavements in Louisiana

☑ Modified 1993 AASHTO NDT Method

☑ Perform FWD test @ 0.1 mile interval

☑ $SN_f$ determined at each test station using AASHTO design equation

  ⇒ With $Mr|_{\text{design}} = 0.4 \times Mr|_{\text{FWD}}$

☑ $SN_{\text{eff}}$ determined from FWD needs to be scaled down for Louisiana Condition

  ⇒ $SN_{\text{eff}} = 3.3 \times \ln(SN_{\text{FWD}}) - 1.5$

☑ Overlay thickness $= (SN_{\text{future}} - SN_{\text{eff}}) / a_{AC}$
**Phase II Project List**

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<thead>
<tr>
<th>M-E Project #</th>
<th>District</th>
<th>Parish</th>
<th>Project #</th>
<th>Route #</th>
<th>Length</th>
<th>ADT</th>
<th>Design</th>
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☑️ Except three widening projects - LA 143, US165 and LA1025, all other projects had a overlay thickness design.


Design Thickness Difference
(Current DOTD Method – Proposed Method)

“+” Over-design

“-” Under-design
✓ 1.0 inch over-design on I-12 will potentially cost $120,000/mile more in construction;

✓ 1.0 inch under-design on LA74 implies that
Cost/Benefit Analysis

☑️ For over-designed projects
  ➞ The average construction cost saving be $427,300 / project
  ➞ The average length of 6.9 mi ➞ Saving $62,000 /mile.

☑️ For under-designed projects
  ➞ The average predicted pavement life be 5.8 yr;
  ➞ Due to a faster deterioration
    ➢ Annual preventive maintenance/repair costs will be increased
    ➢ Need another overlay at the end of life
    ➢ Much greater costs to the property manager in the long run
  ➞ The average life-time cost saving be $230,600 / project
  ➞ The average length of 7.2 mi ➞ Saving $32,000 /mile.
Recommendations

- Recommend the proposed method to be used by DOTD before full implementation of the new M-E design guide.

- A computer program for the proposed overlay design procedure has been developed.
Thank you!