End of Life Considerations in Pavement Type Selection

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Auburn University
The National Center for Asphalt Technology

NCAT main office and lab
277 Technology Parkway
Auburn, AL
NCAT History

- Established in 1986 as a partnership between Auburn University and the National Asphalt Pavement Association Research & Education Foundation
- Best known for the “NCAT Textbook”, the ignition method, the Professor Training Course, the Asphalt Technology News newsletter, the NCAT Test Track, and applied research.
- The majority of funding for research comes from state Departments of Transportation.
2018 started our 7th research cycle

46 Test Sections, 200 ft. each

5 trucks each pulling 3 heavily loaded trailers make 400 laps/day

Test sections are evaluated continuously over 3 year cycles.
NCAT Lead Researchers

Dr. Nam Tran  Dr. Buzz Powell  Mr. Jim Musselman  Dr. Randy West  Dr. David Timm  Dr. Carolina Rodezno  Mr. Travis Walbeck  
Dr. Fabricio Leiva  Dr. Adriana Vargas  Dr. Fan Yin  Dr. Fan Gu  Dr. Raquel Moraes  Dr. Ben Bowers
NCAT's mission is to provide innovative, relevant and implementable research, technology development and education that advances safe, durable and sustainable asphalt pavements.
What is an LCCA and how is it used?

Life-Cycle Cost Analysis is a structured process for conducting an economic analysis of competing investment alternatives that takes into account all costs over the life of an investment.

Pavement related uses:
• Pavement Type Selection: asphalt versus concrete;
• Pavement Structural Design: Perpetual Pavement versus conventional design
Steps in an LCCA

1. Establish alternative strategies
2. Estimate timing of future activities
3. Estimate costs
   a. Initial construction
   b. Rehabilitation activities to maintain service of roadway
      i. Agency costs
      ii. User impact costs
   c. Salvage value
4. Compute the discounted total life-cycle costs
5. Analyze the results
6. Determine the best alternative

FHWA Primer, 2014
Some Challenges with LCCA

- Predicting future traffic
- Predicting timing of future maintenance
- Estimating future maintenance costs
- Estimating future user costs
- Dealing with end of pavement life uncertainties
- Changes in technology
LCCA Basics

\[ NPV = Initial\ Const.\ Cost + \sum_{k=1}^{N} Future\ Cost_k \left[ \frac{1}{(1+i)^{n_k}} \right] - Salvage\ Value \left[ \frac{1}{(1+i)^{n_e}} \right] \]
**LCCA Basics**

<table>
<thead>
<tr>
<th>Time</th>
<th>Cost</th>
<th>Salvage Value</th>
</tr>
</thead>
<tbody>
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</table>

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Initial Construction Cost Data

Initial costs for asphalt and concrete pavements are a function of:

• Pavement design thicknesses
• Price of raw materials (e.g. aggregates, binder, cement, recycled)
• Material quantities (scale of project)

Initial cost data used in LCCA should be based on recent bids for the region of the project.
Comparison of Bid Prices from Missouri, a State with a “Two Pavement System”

Annualized cost growth rate for both pavement types from 1992 to 2009 was the same.

Comparisons of prices were not made beyond 2009 since the volume of concrete dropped dramatically since then.
LCCA Basics

**NPV** = Initial Cost + \( \sum_{k=1}^{N} \text{Future Cost}_k \left[ \frac{1}{(1 + i)^{nk}} \right] - \text{Salvage Value} \left[ \frac{1}{(1 + i)^{ne}} \right] \)
Pavement Condition Thresholds

• Asphalt and concrete pavements have different performance metrics
• States use different condition (e.g. PCI) thresholds for different pavement types

• NCAT examined LTPP data for service lives:
  • Asphalt – avg. time to 1st rehab. **18** years; mean IRI = 112 in./mi.
  • Concrete – avg. time to 1st rehab. **24** years; mean IRI = 129 in./mi
Pavement Performance

Mean IRI (in./mi) for All Alabama Highways

Poor (>170 in./mi)

Good (<95 in./mi)

NCAT rec. rehab. threshold (120 in./mi)

Asphalt: 81

Concrete: 151
Rehabilitation in LCCA

asphalt pavement rehab.

Milling

Diamond grinding

Thin overlay

Joint sealing

concrete pavement rehab.
## Major Rehabilitation

### Concrete
- Asphalt Overlay: 71%
- Max. Restoration of PCC: 17%
- Slab Fracturing plus HMA: 5%
- Remove & Replace with PCC: 3%
- Remove & Replace with HMA: 3%
- PCC Overlay: 1%

### Asphalt
- Mill & Overlay: 56%
- Asphalt Overlay: 42%
- Full Reconstruction: 2%

*Avg. of data from 9 states*
Rehabilitation in LCCA

• Concrete requires rehabilitation sooner than most DOTs use in LCCA
• Rehabilitation costs have two parts to consider:
  1. agency costs
  2. user costs
• A key input in LCCA is the timing of rehab. activities.
Auburn University Work Zone Analysis

• Developed a comprehensive set of data-driven, nationally transferrable metrics that quantify the costs associated with asphalt and concrete pavement rehabilitation in terms of (a) road user costs, (b) crash mitigation costs, and (c) local business impact costs.

• Excel tool developed for engineers/project managers:
  • Input project variables
  • Output associated direct and indirect costs
  • Can do analysis of road rehabilitation scenarios requiring lane closers to determine the least impactful course of action.

A Auburn University Work Zone Analysis

• A generalized example shows that PCC work zones cost 55% more than asphalt work zones due to the additional time to reconstruct PCC.

• This example considers the costs and time associated with building and maintaining a typical 2 lane arterial highway in Alabama:
  • 20,000 ADT (and 15% freight)
  • Traffic speeds operating at 35mph from a 55mph posted speed.
  • Assumes asphalt rehab on 14 year intervals and reconstruction of the concrete pavement at year 42.
  • Examines the road user costs generated from the different times associated with curing the roadway materials. Times to install and remove work zone traffic control are incorporated in the example.
LCCA Basics

NPV = Initial Const. Cost + Σ_{k=1}^{N} Future Cost_k \left( \frac{1}{(1+i)^{n_k}} \right) - Salvage Value \left( \frac{1}{(1+i)^{n_e}} \right)
Salvage Value

• Often considered to have a negligible impact on LCCA
• However, that is typically due to the way salvage value is estimated.
• All of the asphalt has value, not just the last overlay.

See NCAT report 19.03 for further recommendations on salvage value
Composite Pavements...

• A term used for concrete pavements that have been overlayed with asphalt

• Only 15 DOTs keep up with their lane miles of composite pavements
  • All 15 have more lane miles of composite pavements than remaining concrete pavements
  • Missouri has 9,240 lane miles of composite pavement and 4,813 lane miles of concrete pavement.

• For the remaining 35 DOTs, Composite Pavements = Forgotten Mistakes
Reconstruction

• Concrete pavements often reach a point where ongoing rehab. is unwise and the PCC reaches the End of its Life.

• Dealing with that event is expensive!
Major Rehabilitation

Concrete

- Asphalt Overlay      71%
- Max. Restoration of PCC  17%
- Slab Fracturing plus HMA  5%
- Remove & Replace with PCC  3%
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- PCC Overlay         1%

Reconstruction

Avg. of data from 9 states
Reconstruction

- Demolition/removal of existing pavement
- Traffic delays/detours
- Crash costs
- Business impact costs
- Changes in final elevation
  - Adjusting bridges, drainage elements, guardrail, other structures in ROW
- All of those cost must be accounted for in the LCCA
Concrete Pavement Performance

• Many state DOTs have realized over the long term, concrete pavements are more costly to maintain when the actual cost of PCCP reconstruction is considered.

• Concrete pavements are often patched well beyond their performance lives because reconstruction is very expensive and disruptive to traffic. Consequently, many surviving concrete pavements exceed the FHWA limits for roughness.

• Twelve* state DOTs no longer design or build concrete pavements due to poor historical performance, traffic congestion to repair and reconstruct, and high initial costs.

*AK, DE, CT, HI, MA, MD, ME, MS, MT, NH, RI and VT
Crack & Seat and Break & Seat

Crack & Seat: used on plain (unreinforced) concrete pavements; crack spacing 1 to 5 ft.

Break & Seat: used on reinforced concrete pavements; crack spacing 0.5 to 2 ft.
Rubblization of Concrete

• 32 years old - the average age of rubblized concrete pavements in Alabama.

• 34 years old – the average age of concrete pavements rubblized in Louisiana

• 28 years old – the average age of concrete pavements rubblized in Florida

• Other states have similar data.
Summary

• The concrete paving industry continues to push for a political fix of market share.

• Real performance data do not support the claim of maintenance free concrete pavements for 40 years.

• Many states do not account for pavements that have to be reconstructed.

• Agency and User Costs of reconstructing concrete pavements must be considered in Life Cycle Cost Analyses.
Questions
Thank You

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Balanced Mix Design
An Overview

Randy West, Ph.D., P.E.
Director, National Center for Asphalt Technology
BMD – a definition

An asphalt mix design that uses practical performance tests on appropriately conditioned specimens to ensure resistance to common distresses and considers mix aging, traffic, climate and location within the pavement structure.
Why change?

Most asphalt technologists are not satisfied with the current long term performance of our pavements. There is a desire to significantly improve the life of asphalt pavements.
Why change?

- Volumetric properties do not tell us anything about the \textit{quality} of the binder, or about the interactions of different binder components and additives.
- $V_{be} = \text{the volume of effective asphalt} = \text{VMA} - V_a$
- $V_{be}$ is dependent on $G_{sb}$ which is not a reliable property
  - $G_{sb}$ of source materials are subject to change over time, but not often verified.
  - $G_{sb}$ has a low level of precision
  - $G_{sb}$ of RAP aggregate is questionable
With the current volumetric mix design system...

we have no way of knowing if these materials help or hurt
BMD Optimum Asphalt Content
BMD Performance Diagram

Performance "Sweet Zone"

- 6.5% AC
- 6.0% AC
- 5.5% AC

IDEAL CT Index vs. HWTT Rut Depth at 20k Passes (mm)
Numerous options to adjust mixes

Gradation

Asphalt Content

Modifiers

RAP Content

RAS Content

Rejuvenator
The BIG questions

1. What performance tests will be used in BMD for your state?
2. How will the performance tests be used? Where will they fit in the mix design process? (The Framework)
3. What criteria should be used in specifications?
4. What aging/conditioning protocols should be used for mixtures in BMD?
5. How will the performance tests be used in Quality Assurance?
Cracking Group Studies
Cracking Group Experiments

NCAT Test Track
Top-down cracking

MnROAD
Low-temperature cracking
NCAT Test Track

America’s asphalt pavement proving ground
NCAT Cracking Group Sponsors
Selected Top Down Cracking Tests

All tests have been conducted on:
1. lab prepared mix after short-term aging
2. lab prepared mix after short-term and critical aging
3. plant mix samples that were reheated
4. plant mix samples that were reheated and critically aged

critical aging for Auburn, AL = loose mix oven aging at 135C for 8 hours
## NCAT CG Field Performance

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Start of this Cycle</th>
<th>12/6/19</th>
<th>Crit. Aged CT Index</th>
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<tr>
<td>N1</td>
<td>20% RAP (Control)</td>
<td>10.3</td>
<td>10.6</td>
<td>8.1</td>
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<tr>
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<td>Control w/ High Density</td>
<td>6.9</td>
<td>7.5</td>
<td>5.1</td>
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<tr>
<td>N5</td>
<td>Low AC, Low Density</td>
<td>3.5</td>
<td>9.3</td>
<td>8.6</td>
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<tr>
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<td>20% RAP 5% RAS</td>
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<td>S5</td>
<td>35% RAP PG 58-28</td>
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<tr>
<td>S6</td>
<td>Control w HiMA</td>
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<td>0</td>
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<tr>
<td>S13</td>
<td>AZ Rubber Mix</td>
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<td>0</td>
<td>68.4</td>
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</tbody>
</table>
Selected Top Down Cracking Tests

Energy Ratio
SCB-LA
IFIT
OT-TX
OT-NCAT
IDEAL-CT

Not practical enough for routine mix design
Selected Top Down Cracking Tests

Unable to identify worst and best performing mixes
Selected Top Down Cracking Tests

IFIT

IDEAL-CT
MnROAD Cracking Group Test Sections

Test sections constructed August 2016
MnROAD Cracking Group Sponsors
# MnROAD Cracking Group

## Field Performance through April 2019

<table>
<thead>
<tr>
<th>Cell</th>
<th>Key Mix Factors</th>
<th>Transverse Cracking (ft.)</th>
<th>Load Related Cracking (% of lane area)</th>
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</thead>
<tbody>
<tr>
<td>16</td>
<td>Moderate RAP + RAS</td>
<td>58</td>
<td>1.5</td>
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<tr>
<td>17</td>
<td>Low RAP + RAS</td>
<td>70</td>
<td>6.3</td>
</tr>
<tr>
<td>18</td>
<td>Moderate RAP</td>
<td>35</td>
<td>3.8</td>
</tr>
<tr>
<td>19</td>
<td>Moderate RAP, extra AC</td>
<td>61</td>
<td>0.4</td>
</tr>
<tr>
<td>20</td>
<td>High RAP, softer binder</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>21</td>
<td>Moderate RAP, softer binder</td>
<td>28</td>
<td>1.1</td>
</tr>
<tr>
<td>22</td>
<td>Limestone agg. and 9.5 mm NMAS</td>
<td>50</td>
<td>4.4</td>
</tr>
<tr>
<td>23</td>
<td>Moderate RAP, Highly mod. binder</td>
<td>43</td>
<td>14.9</td>
</tr>
</tbody>
</table>
MnROAD Cracking Group Tests

Intermediate Temperature Tests

IFIT
Cantabro
OT-NCAT
IDEAL-CT

Low Temperature Tests

DCT
IDT Creep Compliance & Strength
Low Temp. SCB

other tests are being performed by other research organizations
BMD Implementation Status

California
- Bending Beam Fatigue
- Superpave Shear Test

Illinois
- Illinois Flexibility Index
- Hamburg Wheel Tracker

New Jersey
- Overlay Test
- Hamburg Wheel Tracker

Texas
- Overlay Tester
- Hamburg Wheel Tracker

Louisiana
- Semi-Circular Bend Test
- Hamburg Wheel Tracker
BMD Implementation Status

- **California**
  - Bending Beam Fatigue
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Getting all stakeholders to agree on a common BMD Approach will be like....
Work Ahead

- Selection of Tests
- Ruggedness and ILS studies
- Benchmarking current mixes
- Setting criteria
- Training
- Pilot Projects
95th AAPT Annual Meeting and Technical Sessions
The 2020 Annual Meeting will be held March 22-25, 2020
Westin San Diego Gaslamp Quarter, San Diego, California USA

Our 2020 venue
Westin San Diego Gaslamp Quarter

2020 Annual Meeting
The Annual Business Meeting and Technical Sessions of the Association of Asphalt Paving Technologists (AAPT) will be March 22-25, 2020 in San Diego, California at Westin San Diego Gaslamp Quarter. The annual meeting includes asphalt-related technical sessions comprised of peer-reviewed papers, and invited presentations on specific topics in the AAPT-ISAP International Forum, and Symposium as well as a Student Poster Session.

Visit http://asphalttechnology.org/annual-meeting.html for more details as they become available.

Important dates
December 2019 – Annual Meeting registration opens
March 22-25, 2020 - Annual Business Meeting and Technical Sessions

For the latest information please check our web site at: http://www.asphalttechnology.org

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THE VALUE OF AAPT MEMBERSHIP

The Association of Asphalt Paving Technologists is committed to providing members with resources and opportunities for communicating with fellow professionals and staying up-to-date on the latest developments in the asphalt paving industry.

INFORMATION
Expand your knowledge with access to the latest industry research, cutting-edge technologies and concepts.

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Become involved in an international community that represents all disciplines of the industry.

JOURNAL
Receive the AAPT Journal of technical papers, discussion and conference proceedings.

NETWORK
Connect with colleagues and build relationships through annual meetings and events.

Contact an AAPT member or visit asphalttechnology.org to learn more.
Questions
Thank You

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