Innovation
A practical international guide
– the California/USA Journey

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Content

• Review of historical pavement innovation in US
• Where we are now, and what will change?
• Where do we want get to?
• How do we get there?
• Conclusions and recommendations

• Intent is to stimulate thought and discussion
Incomplete review of historical innovation implementation in asphalt pavement in USA
### Changing priorities for innovation to respond to conditions

<table>
<thead>
<tr>
<th>Years</th>
<th>Infrastructure</th>
<th>Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980-2000</td>
<td>Management</td>
<td>Management systems, M &amp; R Scheduling, Preservation treatments, Condition Assessment</td>
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<tr>
<td>Years</td>
<td>Infrastructure</td>
<td>Innovation</td>
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<tr>
<td>1990-2025</td>
<td>Reconstruction</td>
<td>Reconstruction, Materials Optimization, Traffic Considerations, Longer design lives, Quality Assurance Mix design &amp; binder specs</td>
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<tr>
<td>2010-2050</td>
<td>Sustainability implementation underway</td>
<td>Materials Re-use, New materials Mechanistic design Noise</td>
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Continued expansion of the system boundaries in which pavement problems are defined.
Examples of recent innovation driven by reducing cost of performance per ton of asphalt

• Superpave Mix Design, better performance, same cost
  – PG binder specifications (fully implemented)
  – Volumetric mix design (nearly fully implemented)
  – Performance related mix testing (sporadic implementation)

• Polymers, better performance, increased cost
  – Extensively used in a number of states, particularly for surfaces

• Recycled asphalt (RA), reduced cost, same performance
  – US: about 90% of RA recycled in new plant mix; competition with concrete due to oil cost

NAPA, EAPA, AggBusiness, Caltrans
Examples of recent innovation driven by reducing cost of performance per ton of asphalt

• Warm Mix, reduced cost, same or better performance
  – US: driven by bonuses for quality (compaction) and cost of energy

• Rubberized asphalt, better performance, same cost
  – Overlays in California give superior performance with half thickness

• Putting more knowledge into the product
Barriers to implementation and signs of positive change

– Industry
  • Barriers: need consistent plans for government funding, ability to raise capital, costs of equipment, knowledge, low-bid environment, materials uncertainties
  • Positive: desire to innovate to stay competitive between industries, increase profit (or just survive)

– State/provincial Government
  • Barriers: low-bid environment, risk aversion incentives, low investment in design, lack of expertise
  • Positive: introduction of LCCA, ME design, QC initiatives at state level
Barriers to implementation and signs of positive change

– Local Government
  • Barriers: lack of expertise, low-bid environment, risk aversion incentives, no funding for research or adaption of research, low investment in design
  • Positive: high interest in some locations

– Academia
  • Barriers: ability to train enough students, ability to attract students to pavements, lack of support for pavement faculty positions, lack of incentives or ability to connect research to development and to real practice
  • Positive: improvement in quality of research, move away from empiricism
Where we are now, and what will change
Why do we need to innovate now?

• Goals changing
  – Network demographics: deployment, preservation, maintenance, rehabilitation
  – Traffic changes: numbers, tires, axle loads, suspensions
  – Public awareness of smoothness, noise, environment, cost

• Circumstances changing:
  – Funding levels and willingness of public to pay for roads
  – Bitumen properties
  – Relative costs of materials
  – Climate
  – Workforce

• Knowledge and tools betting better:
  – Mechanics, materials, management, statistical methods
  – Materials, construction and performance data
  – Lab testing capabilities, field testing capabilities
  – New materials, new construction machines and methods
Overall change in demand for asphalt innovation

• Change in customer demand for asphalt technology
  – “We have always had plenty of asphalt and built our roads in this kind of flexible pavement structure and always will”
  – “How can we get maximum pavement value per drop of bitumen and ton of asphalt, since we don’t have enough money to maintain our network?”

• Overall trend to remain competitive
  – Increase the knowledge content of the product
MAP-21 federal legislation and performance measures

- What has been the traditional measure of efficiency?
- The cornerstone of MAP-21’s highway program transformation is the transition to a performance and outcome-based program.

- Pavement Related Goals
  - Infrastructure
    - IRI, cracking, rutting
  - Environmental sustainability
    - Measures?

Request funding to meet goals

Do work, measure performance

Met goals?

YES

NO

Cut?

Audit, Change

http://www.fhwa.dot.gov/map21/summaryinfo.cfm
Master equation for environmental impacts

Environmental impact =

- Population
- GDP
- Impact

Population \times \text{GDP} \times \text{Person} \times \text{Impact}

Increase in wealth and economic activity, road networks

Technological efficiency

Ehrlich and Holdren (1971) Impact of population growth. e.g. via LCA
Science 171, 1211-1217
Slide adapted from R. Rosenbaum,
Pavement LCA 2014 keynote address
Pavement Life Cycle Assessment

Where can we improve technological efficiency?

- Design of materials and pavement
- Material extraction and production
- Equipment Use
  - Transport
  - Traffic delay
- Pavement performance
- Rolling resistance
- Safety
- Stormwater
- Noise
- Thermal
- Recycle
- Landfill

From: Kendall et al., 2010

R: Recycle
Markets for innovation: Who buys asphalt?

• Most of our research focuses on high volume routes
• Significant amount of spending by local government
• Special needs:
  • Less expertise
  • Lower quality assurance capability
  • Little or no research budget for asphalt
• Are we meeting their needs?
  – New materials, pavement designs, construction practices

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<thead>
<tr>
<th></th>
<th>STATE GOVERNMENT AMOUNT</th>
<th>LOCAL GOVERNMENT AMOUNT</th>
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</thead>
<tbody>
<tr>
<td>Transportation:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highways</td>
<td>97,508,989</td>
<td>61,053,150</td>
</tr>
</tbody>
</table>

US Census Bureau
Materials and pavement structures for local government low volume urban streets

- Ability to repair under-street utilities
- Easy to construct
- Low-impact development
  - Restoring natural water, thermal energy, nutrient flows in urban areas with different pavement structures
  - Low cost, low environmental impact, maintainable, restorable
Where do we want get to?
Vision Example:
California Pavement Research Program

• Written in 2000 with 10 to 15 year horizon
• Vision:
  – Processes and ingredients for continuously improving state-of-the-art pavement technology
• Goals
  – Continuous Improvement of the Efficiency of Caltrans Pavement Operations
  – Help Caltrans Improve Its Responsiveness to Its Internal and External Customers
• Approach: databases and tools
Vision Example

• Goals, cont’d
  – Improve the Sustainability of Pavement Structures
    • Cost
    • Environment
  – Maintain a Strong Research and Academic Instruction Program in Pavements in California
    • Must have paths to excellence or will not attract smart young people looking to achieve
  – Increase pace of change
    • Avoid “not invented here syndrome”
    • Training and access to technology

• Currently writing vision document to 2025
Database
- Design Input Database
- Construction Productivity Database
- Construction Quality Database
- Pavement Performance Database

Tool
- Design Tool
- Construction Productivity Tool
- Pavement Management & Information Tool
- Lab & Field Testing Tools

Field and Lab Tests of Pavement Condition
Rehabilitation, Reconstruction, New Pavement Design and Selection of Construction Strategy
Construction, Quality Control, Quality Assurance, Productivity Measurement
Performance Monitoring and Prediction
Program and Perform Maintenance to Optimize Network Condition

CalME
RealCost
CA4PRS
PaveM
CalBack, lab performance tests
2025 Vision for Implementation

• Quantitative sustainability assessment methods
• New materials, re-re-recycling
• Implement these advances into design
  – Aging evolution of mix properties
  – Thixotropy
  – Relationship of laboratory to in-place properties
  – Improved damage laws
  – Tire contact stress distribution, dynamic effects
  – Variability of all of above in the field and their effect on pavement reliability
  – Interaction of all of above and prediction of damage and distress throughout life
How we can get there
Pavement innovation process

• Conceptualization
  – Need driven or new idea driven
  – Often not completely new
• Research (20% of effort)
• Development (50% of effort)
• Piloting (30% of effort)
• Complete market penetration process after that
  – Further development and piloting in different places
• **Average time to complete this process is 10 years**
Critical ingredients for success

• Awareness of needs, and of developments around world
• Top level support
  – Sufficient understanding and willingness to take risk
• Strategic Plan
• Human technical + other resources to complete the innovation development and implementation process
• Incentives and mandates
  – Industry (financial incentives and mandates)
  – Government (mandates)
  – Academia (funding incentives)
• Intellectual rigor
  – Documentation of results
  – Outside critical review and benchmarking
Accelerated Pavement Testing tracks and fixed devices (months)

Laboratory Testing (weeks)

Computer Analysis (days)

Long-Term Monitoring (10-30 years)

Example Process

Reliability

Time & Cost
Example Process

Laboratory Testing
- Binder testing (grams)
- Fine aggregate mix testing (kg)
- Mix testing (tons)

Computer Analysis
- Mechanistic simulation to evaluate lab results
- Simulation of APT sections to validate and calibrate new models and results

Long-Term Monitoring (10-30 years)
Find ways to keep sophistication of testing and analysis, but make it faster and easier

- Make it
  - Smaller
  - Faster
  - Easier without becoming black box
- Start with full understanding of complexity, then simplify
Implementation and workforce capacity

• 40% of engineers are within five years of retirement in many pavement industry and government organizations.

• Need to recruit and rapidly promote many new people:
  – They need much greater skills to handle advanced pavement technology.
  – They have little patience with slow pace of innovation.
  – They will leave the industry if they don’t see innovation!!
Some ideas being put forward

• International development of advanced pavement curriculum requirements for universities

• US Professional licensure as Pavement Engineer, beyond general Professional Engineer
  – Requirement for pavement specific university or professional development courses
  – Examination for advanced knowledge and certification of experience with advanced practice
  – Like Geotechnical Engineer, Structural Engineer
Conclusions

• Innovation and its implementation are essential for survival
• Must develop plans and processes
  – Where you want to go
  – How you are going to get there
  – Who you need to get you there
    • Borrow, adapt, partner
  – Who will use it
  – All of the critical ingredients for success
• It takes a concerted, sustained effort

Image: sunnysidepost.com
Questions?