Approaches for Delivering More Sustainable and Multi-Functional Pavement

John Harvey
City and County Pavement Improvement Center
UC Davis

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Public Works Officers Institute
Monterey, CA
The future of local government pavements will be more sustainable and multi-functional

- Public expectations are for more sustainable and multi-functional pavements
  - State and local legislation
  - Public comments
- More sustainable:
  - Less greenhouse gas
  - Less air pollution
  - Less stormwater pollution
  - Less virgin material use
- Multi-functional:
  - Bicycles
  - Cool pavement
  - Permeable pavement

- To avoid unintended negative consequences, we must consider:
  - Full system
  - Full life cycle
Overview of How to Get More Sustainable and Multi-Functional Pavement

• Sustainability = making pavement last longer for less money and reducing pollution:
  • Better use of pavement management system to select and time treatments
  • Smoother pavement
  • Better asphalt compaction
  • Rubberized asphalt

• Making pavement multi-functional:
  • Pavement management of bike routes
  • Pavement for human thermal comfort
  • Consideration of permeable pavement
Impacts must consider **full life cycle** and **full system**

Which treatment has more environmental impacts?

- **Treatment A:**
  - Impact = 1,000 tons greenhouse gas per year across the preservation program from materials production, transportation, construction
  - Lasts 8 years

- **Treatment B:**
  - 20% less initial impact than Treatment A
  - Lasts 5 years

- **Impact comparison over 20 year analysis period:**
  - Treatment A: 20,000 tons of GHG
  - Treatment B: = 20,000 tons*(1-0.2)*8/5 = 25,600 tons of GHG

- **Conclusion:** Treatment A produces less impact over the life cycle
Action: Separate into segments with/without heavy vehicle (bus, truck) traffic
Focus on distresses that control pavement life in cracking-based decision trees

- Fatigue cracking and potholes caused by heavy loads:
  - Alligator cracking
  - Potholes
- Cracking caused by aging:
  - Longitudinal and transverse cracking
  - Joint reflections
  - Block cracking

- Other distresses
  - Low ride quality
  - Bleeding
  - Bumps and sags
  - Corrugations
  - Depressions
  - Edge cracking
  - Lane/shoulder drop-off
  - Patching and utility cut patching
  - Polished aggregate
  - Rutting
  - Shoving
  - Slippage cracking
  - Swelling
  - Weathering and raveling

Use these distresses rather than PCI
Alligator Cracking aka Fatigue Cracking aka Wheelpath Cracking
Treatment for load related fatigue cracking

- Fatigue cracking becomes alligator cracking, and eventually forms potholes
- Surface treatments will slow a little, but mostly helps with block cracking, not fatigue
- Will need to do periodic mill and fill with digouts of localized deep cracking
- Mill and fill may not be cost-effective once alligator cracking is extensive
  - Consider partial-depth or full-depth reclamation (FDR) cold in-place recycling depending on crack depth
- Do not let wheelpath cracking become extensive or must reconstruct

Extensive and likely deep alligator cracking, Starting to form potholes
Aging of the Asphalt

- Aging of the asphalt
  - Caused by oxidation, volatilization
  - Faster if high permeability and temperature
  - Permeability greatly reduced with better asphalt compaction

- Effects
  - Stiffening of mix with time
  - Won’t relax stresses from thermal contraction as well

Aging
mostly done by 5 years after placement

Stiffness increase from aging

2 to 5 times stiffer, much more elastic, less viscous

Construction

Years
Age Related Cracking

- Typically caused by long-term aging of asphalt concrete and daily temperature cycling (expansion/contraction)
- May also be reflective cracking from shrinkage cracks in underlying asphalt, cemented base, or concrete
- Poor asphalt construction compaction allows air to enter and age the asphalt faster, accelerates aging

Good compaction limits entry of air and slows oxidation
Age related cracking: transverse then block
Treatment for age-related cracking

- Keep the surface protected from aging
- Can potentially use fogs, slurries or microsurfacings and never have cracking if no heavy vehicles
- What frequency?
  - After aging has progressed but no cracks
    - About 7 to 12 years
  - Before cracking starts
    - Do not let cracking get extensive
  - Doing more frequently than needed can be a waste
Actionable **now**: Timely use of preservation for age related cracking
Example for urban street

- **Timely** use of preservation treatments can postpone AC mill and fills
  - Timely = when beginning to age, before cracking
  - Usually about 7 to 12 years

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Approximate Metric Tons GHG/lane mile</th>
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</thead>
<tbody>
<tr>
<td>Slurry Seal</td>
<td>4</td>
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<tr>
<td>2.0 inch HMA mill and fill</td>
<td>45</td>
</tr>
<tr>
<td>6.0 inch HMA remove and replace</td>
<td>161</td>
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</tbody>
</table>
LCCA and LCA results: Urban alternatives

- 50 year analysis, 2% discount rate
- Remove and replace:
  - 14% more cost
  - 60% more GHG
- Preservation:
  - 12% less cost
  - 27% less GHG

<table>
<thead>
<tr>
<th>Mill and Fill Scenario</th>
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<th>Year</th>
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<tbody>
<tr>
<td>HMA 2 inch mill and fill</td>
<td>38</td>
<td>0</td>
</tr>
<tr>
<td>HMA 2 inch mill and fill</td>
<td>38</td>
<td>20</td>
</tr>
<tr>
<td>HMA 2 inch mill and fill</td>
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<td>40</td>
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<table>
<thead>
<tr>
<th>Remove and Replace Scenario</th>
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<th>Year</th>
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<tr>
<td>HMA 2 inch mill and fill</td>
<td>52</td>
<td>0</td>
</tr>
<tr>
<td>Remove, replace 6 inches HMA</td>
<td>52</td>
<td>25</td>
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</table>

<table>
<thead>
<tr>
<th>Preservation Scenario</th>
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<th>Year</th>
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<tr>
<td>HMA 2 inch mill and fill</td>
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<td>0</td>
</tr>
<tr>
<td>Slurry seal</td>
<td>7</td>
<td>12</td>
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<tr>
<td>Slurry seal</td>
<td>7</td>
<td>19</td>
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<tr>
<td>Slurry seal</td>
<td>7</td>
<td>26</td>
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<tr>
<td>HMA 2 inch mill and fill</td>
<td>38</td>
<td>33</td>
</tr>
<tr>
<td>Slurry seal</td>
<td>7</td>
<td>45</td>
</tr>
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</table>

GHG adapted from A. Saboori doctoral thesis, 2020
Environmental Impacts over the Pavement Life Cycle
Actionable now: where to focus on smoother pavement

• Where to focus
  ▪ Lower traffic volume routes (<2500 veh/lane/day): bigger impacts are from materials, transportation, construction
  ▪ Higher traffic routes (>2500 vehicles/lane/day): bigger impacts from rolling resistance (roughness mostly)
Actionable now: Asphalt Compaction Quality Control
Effect of asphalt construction compaction on axle loads to cracking

General rule:
Load related cracking:
1% increase in constructed air-voids = 10% reduction in fatigue life under heavy loads

Age related cracking:
Similar effects on residential routes; more air voids = faster aging
How to Get Good Asphalt Compaction

- Include QC/QA construction air-void content specification in each contract
- Measure air voids as % of Theoretical Maximum Density
  - Not laboratory test maximum density
- Test strip, measure, communicate, enforce
- If using Caltrans or Greenbook method specification, likely getting 10 to 13% air voids = half of possible life from asphalt

Model specification on CCPIC web site!

Google: CCPIC
www.ucprc.ucdavis.edu/ccpic
Actionable **now**: use of thinner RHMA overlays

**Greenhouse Gases HMA vs RHMA**

- Same design for 10 year overlay on county road
- HMA strategy emits 26% more greenhouse gases than RHMA because of increased thickness

<table>
<thead>
<tr>
<th>Strategy for Overlays</th>
<th>Materials (MTons GHG)</th>
<th>Construction and Transport (MTons GHG)</th>
<th>Total (MTons GHG)</th>
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</thead>
<tbody>
<tr>
<td>2 inch mill + 3 inch HMA with 15% RAP</td>
<td>1,650</td>
<td>505</td>
<td>2,155</td>
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<tr>
<td>1.25 inch mill + 2.25 inch RHMA</td>
<td>1,310</td>
<td>396</td>
<td>1,706</td>
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<tr>
<td><strong>HMA/RHMA</strong></td>
<td><strong>1.26</strong></td>
<td><strong>1.28</strong></td>
<td><strong>1.26</strong></td>
</tr>
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Adapted from T. Wang doctoral thesis, 2013
Challenge for the Future: Multi-functionality

- Traditional goal:
  - Smooth pavement for vehicles at lowest cost
- Pavement dominates the urban landscape

Fractions of land area were measured above tree canopy

Sacramento

<table>
<thead>
<tr>
<th>Category</th>
<th>Fraction</th>
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</thead>
<tbody>
<tr>
<td>Pavements</td>
<td>39%</td>
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<tr>
<td>Vegetation</td>
<td>29%</td>
</tr>
<tr>
<td>Roofs</td>
<td>19%</td>
</tr>
<tr>
<td>Other</td>
<td>14%</td>
</tr>
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</table>
Challenge for the Future: Multi-functionality

• Actionable **now**:
  - Bicycles
    - Reconfigure to include bike lanes when restriping preservation treatments
    - Selection of treatments to improve bicycle ride quality
    - Minimize cracking and roughness through preservation
  - Cool pavement
    - Balance reflectivity to improve human thermal comfort
  - Stormwater
    - Consider permeable pavement
  - Quiet
    - Raveling and roughness increase noise
    - Manage through timely preservation
Consideration of Bicyclists When Choosing Preservation Treatments

• Caltrans sponsored study
• More than 100 riders surveyed state, county and city pavements
  ▪ HMA
  ▪ Slurry, microsurfacing
  ▪ Chip seals
• County and city roads
• Conclusions:
  ▪ Minimize cracking and roughness with preservation
  ▪ Do not select high texture seal coats
Cool and Reflective Pavement:
- Focus on human thermal comfort, not reduced electricity use
- Use cooler pavements with low GHG
- Reflective coatings have high GHG
- For thermal comfort must balance reflectivity
- Selection of street trees that are pavement-friendly

$M$ is the metabolic rate (W/m²). $W$ is the rate of mechanical work (W/m²). $S$ (W/m²) is the total storage heat flow in the body.
Conclusions

• Better pavement practices can improve financial and environmental sustainability at the same time

• There are strategies that you can be implementing now!
  ▪ Pavement management based on load and age related cracking
  ▪ Timely preservation
  ▪ Keep high traffic volume routes smooth
  ▪ Better asphalt compaction
  ▪ Rubberized asphalt

• Multi-functionality
  ▪ Use preservation treatments on bike routes; restripe as part of preservation
  ▪ Choose appropriate seal coats for bicycles
  ▪ Cool pavements: select low GHG treatments, balance reflectivity for comfort, pavement-friendly street trees
  ▪ Consider permeable pavement