Getting the Best Asphalt Pavement Performance:

The Importance of Compaction and Bonding of Layers

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San Diego & Imperial Counties Chapter APWA AMERICAN PUBLIC WORKS ASSOCIATION

ASCE SAN DIEGO SECTION

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Compaction and the Bonding of Layers

- Compaction and the bonding of layers are keys to the performance of AC/HMA pavements.
- Poor compaction:
  - Reduces cracking life about 15% for every 1% more air-voids (than 8%)
  - If the specification requirement is 8% air voids:
    - 11% = half the life
    - 5% = double the life
- Lack of bonding of layers:
  - Can halve cracking life
  - Increase risk of water damage at interface

AC/HMA Compaction

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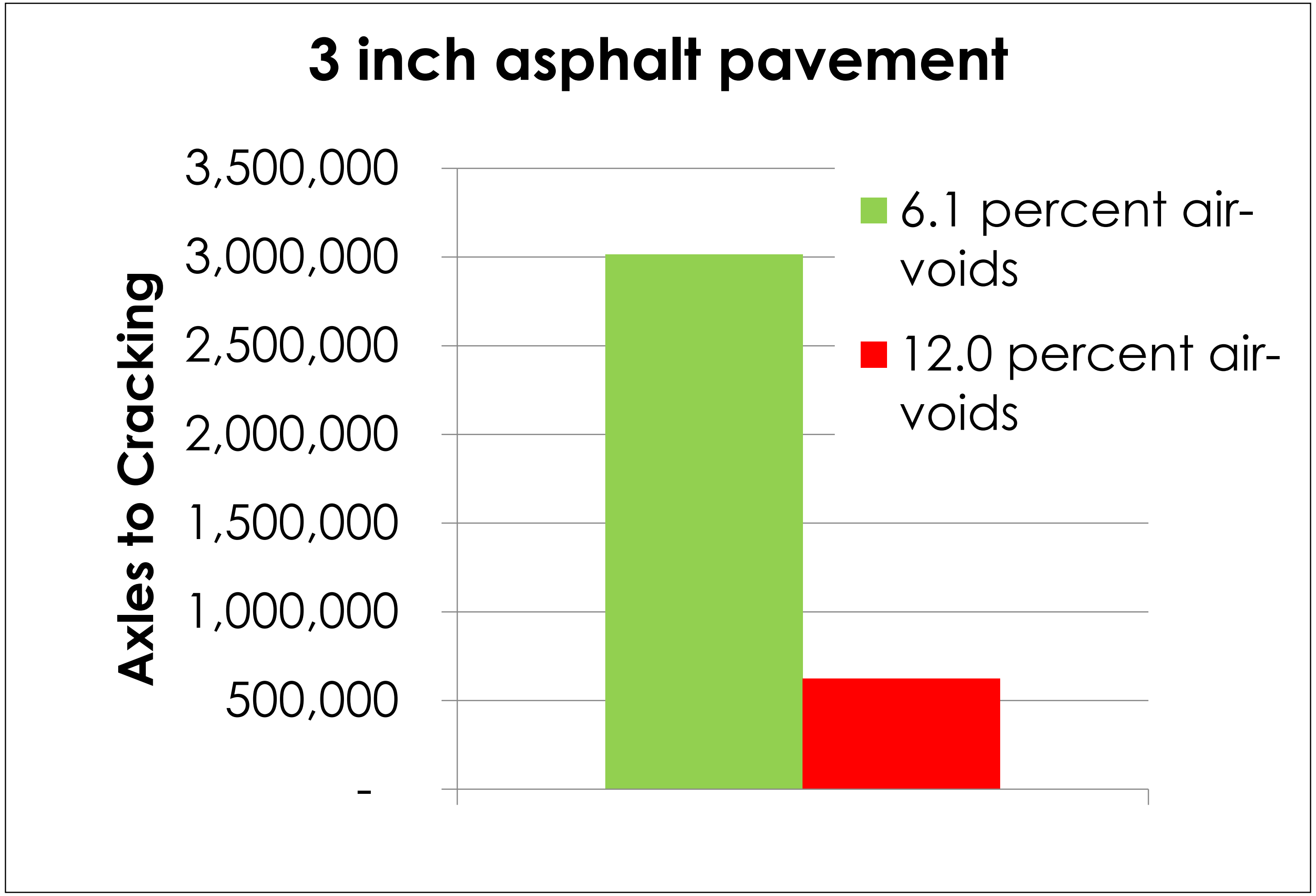
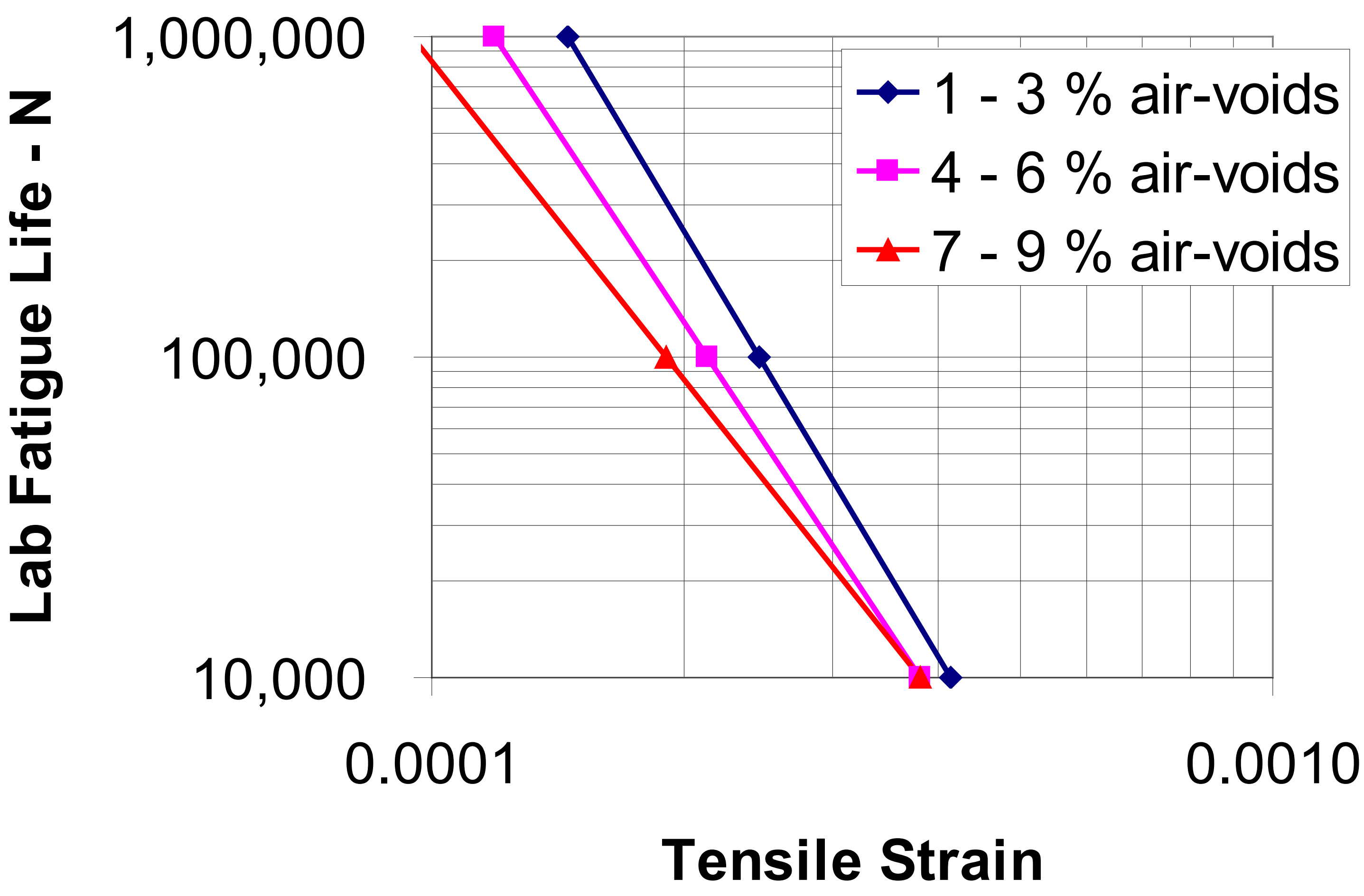
Effect of Asphalt Compaction on Axle Loads to Fatigue Cracking



Simulation based on FHWA Westrack project field results

Fatigue Life vs Asphalt Compaction



Effect of Compaction on Fatigue Life

General Rule: **1% increase** in constructed air-voids = **10% reduction** in fatigue life

Compaction/Density/Air Voids: Method Compaction

- ***Caltrans Standard Specifications***: 39-2.01C(2)(c), 39-2.01C(15)(b)
- Specifies equipment and no. of passes of each type of roller required.
- *In-place density is not tested/air voids not measured*.
- The ***Standard Specifications for Public Works Construction ("Greenbook")*** does not include a method compaction specification.

Compaction/Density/Air Voids: Method Compaction

- **How well does it work?**
  - See plot at right from Caltrans for statewide survey:
  - No = method specification
  - Yes = QC/QA measurement of air-voids and disincentives

Best Practices for Pavement

Is your asphalt only living half as long as it could?

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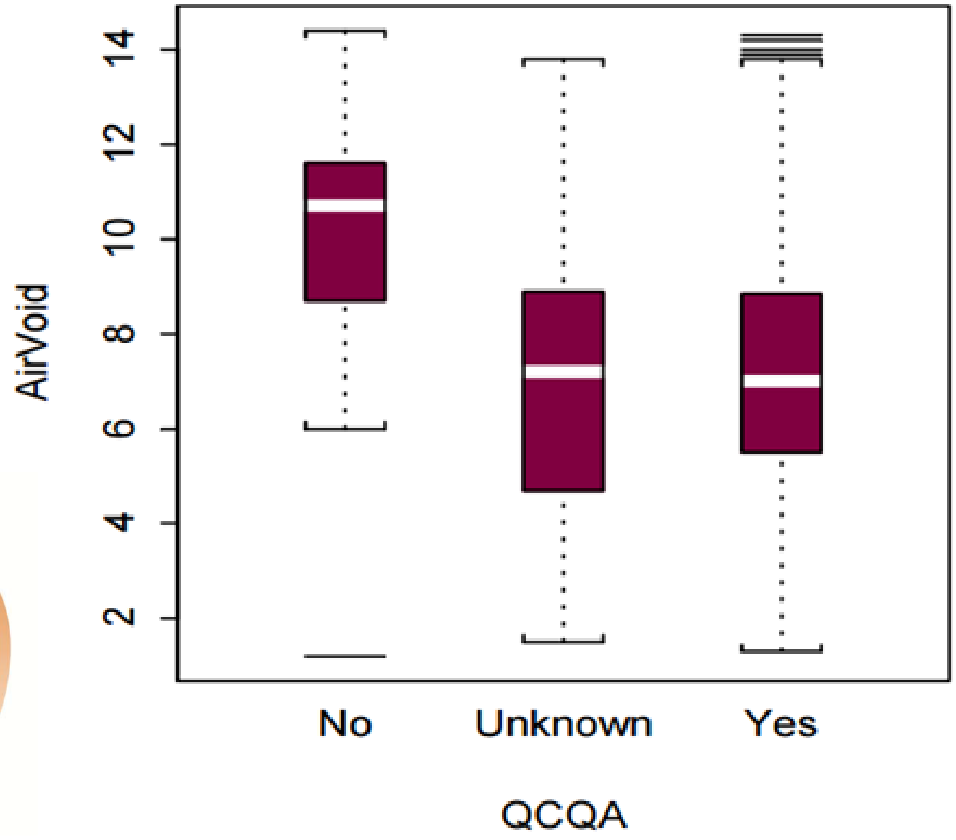
Writing and enforcing specifications for asphalt compaction

May 2017



Compaction/Density/Air Voids: Laboratory Bulk (Test Maximum) Density

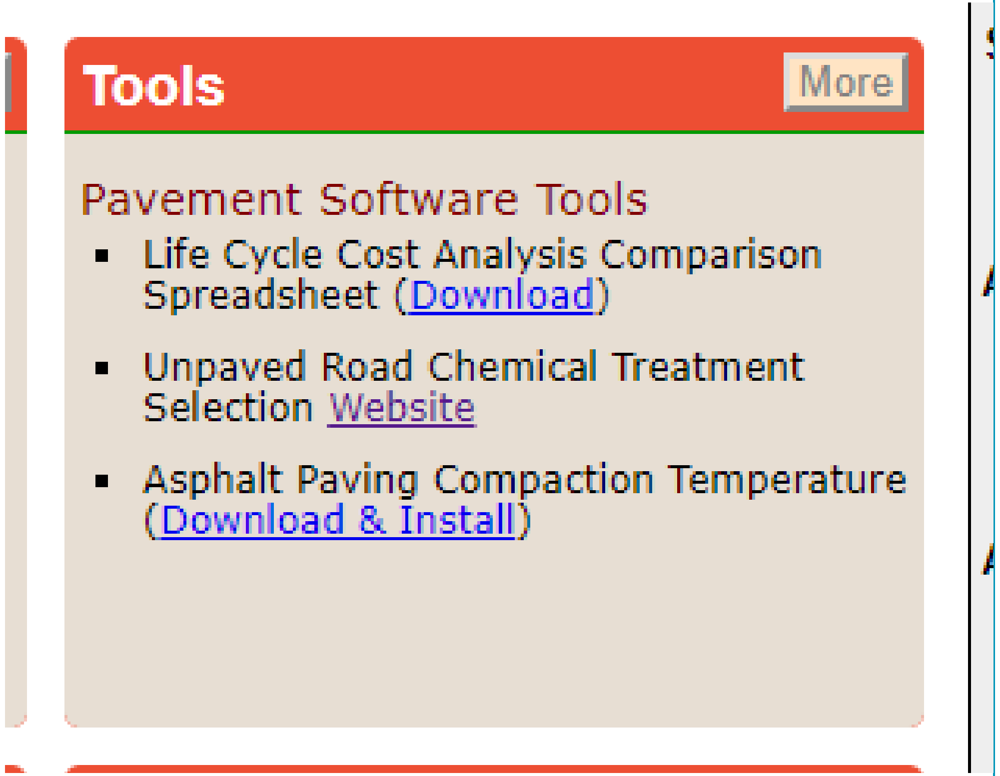
- California Tests 304 & 308
- ***Standard Specifications for Public Works Construction***: 302-5.6.2, 2021 and earlier editions
- % air voids correlates directly to pavement life
- No direct correlation to air voids
- SSPWC: 95% minimum = 8.8% air voids (for lab air voids of 4%)
- Refer to MS-22, Figure 10.9: 96% = 8% air voids

Compaction/Density/Air Voids: Theoretical Maximum (“Rice”) Density (TMD)

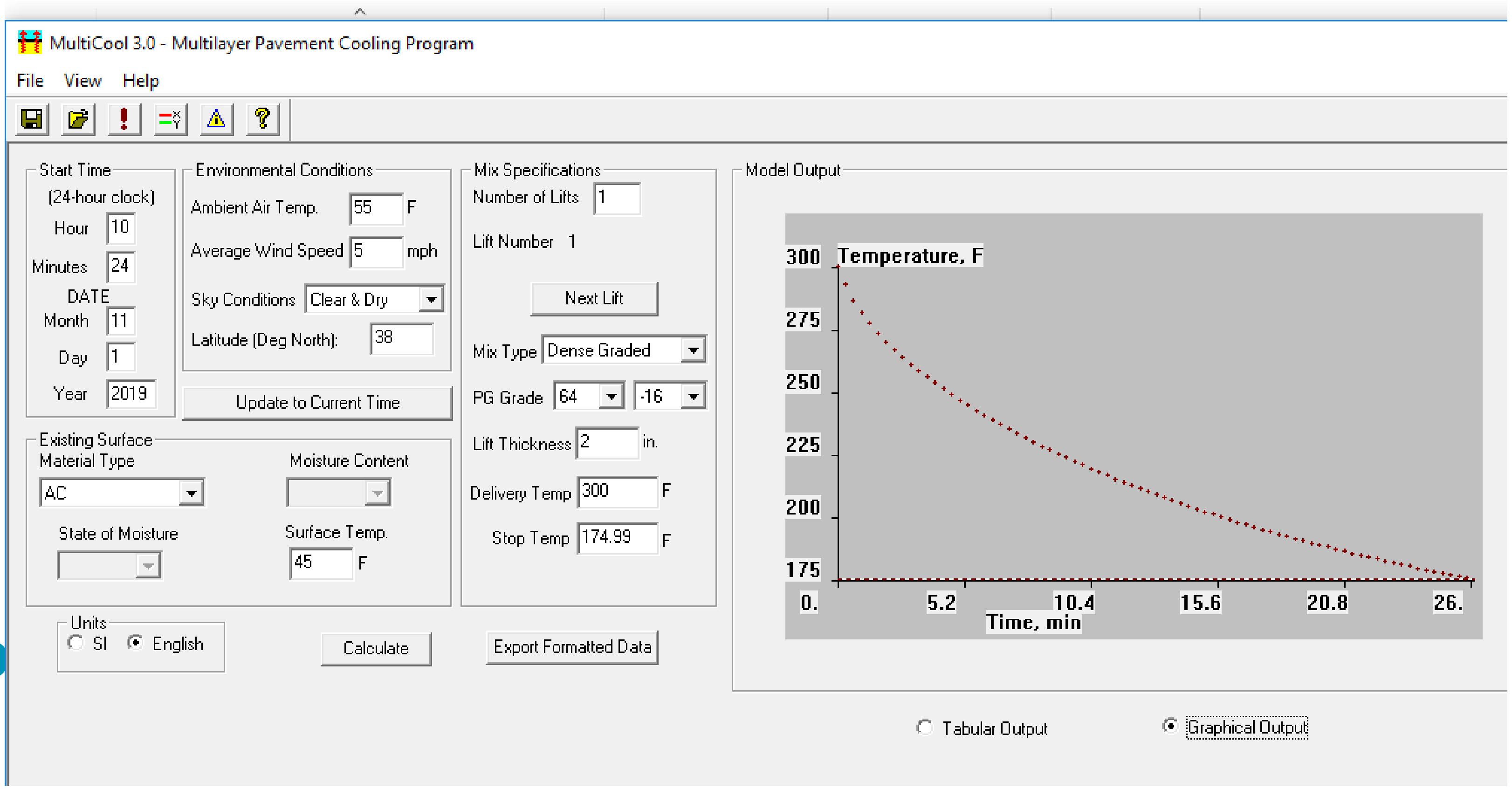
- California Test 309/AASHTO T 209, Method A/ASTM D2041
- ***Caltrans Standard Specifications***: 39-2.01A(4)(h)(vi), 39-2.01A(4)(i)(ii), 39-2.01C(15)
- ***Standard Specifications for Public Works Construction:*** 302-5.11, 2024 Edition.
- % air voids correlates directly to pavement life
- % TMD correlates directly to air voids, e.g. 96% = 4% air voids
- Caltrans Standard Specifications: 91% -97% (should be 92% minimum)

Temperature Control for AC/HMA Compaction

- **Asphalt compaction is about getting roller passes at correct mixture temperature**
  - Temperature, temperature, temperature
- **Multi-Cool software predicts available compaction time**
  - Free download on CCPIC website
  - Also available on National Asphalt Pavement Association website
- **Multi-Cool results have been validated by UCPRC/Caltrans research**



The Effect of Temperature:
Fall Sunny Paving Day – 2-inch overlay



- Comp … minutes

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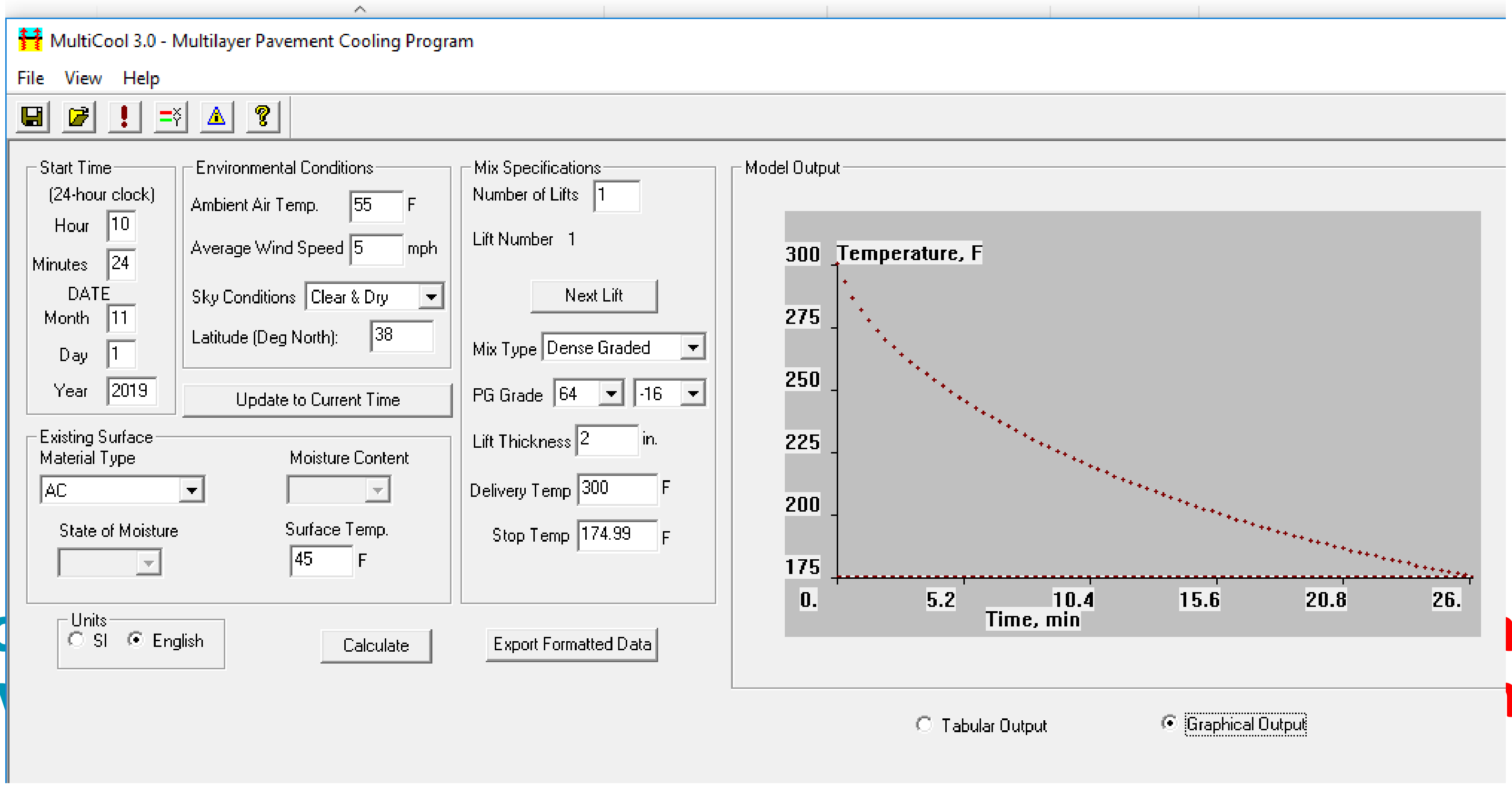
The Effect of Temperature:
Fall Sunny Paving Day – 1.5-inch overlay



- Compac ... minutes
- Same o ... minutes

Longitudinal Cracking due to Poor Joint Compaction

- Longitudinal cracks out of wheel path, or in wheel path but straight and often showing raveling and cracking
- Poor compaction major contributor
- Visible after rainfall
- Wedge joint construction helps with compaction
- Do not put longitudinal joints in wheel paths

Effect of Asphalt Compaction on Asphalt Surfaced Pavement Distresses

- **Distresses:**
  - Fatigue cracking
    - top down
    - bottom up
    - reflective
  - Rutting
  - Block cracking
  - Raveling
  - Low-temperature “thermal” cracking
  - Moisture damage
- ***Good compaction helps with ALL of these!***

Getting Good Asphalt Compaction

- **Maximum lift thickness**
  - 3 to 4 inches
- **Maximum size aggregate in gradation**
  - Not more than 1/3 lift thickness
- **Use pneumatic tired rollers for the passes between vibratory steel and later static steel *(not on ARHM/RHMA)***

- **Material Transfer Vehicles (MTV) remix the material before depositing in the paving machine. Remixing prevents segregation and results in a more uniform mixture temperature, both of which facilitate compaction when placing**

Getting Good Asphalt Compaction

- Correlating the Nuclear Gauge (California Test 375:
  - Caltrans Standard Specifications:
    - 39-2.01A(4)(h)(vi) Hot Mix Asphalt Density
  - Greenbook (2021 or earlier):
    - CCPIC Asphalt Compaction Model Specifications (modify and include as Special Provisions) (302-5.6.2)
  - Greenbook (2024):
    - Modified to make test strip optional ("If specified …")
    - Include Special Provisions to require test strip (302-5.11.2)

Getting Good Asphalt Compaction

- Use a ***quantitative*** (not method) ***specification*** to measure compaction.
- Specify in terms of ***in-place bulk density and theoretical maximum density*** (TMD), not laboratory test maximum density (LTMD).
- Use cores or nuclear gauges ***correlated*** for the specific mix/project (California Test 375/AASHTO T209) by construction of a test strip.
- Apply and enforce ***payment reductions*** if the specified density is not achieved. *(See CCPIC Asphalt Pavement Model Specifications, Table 1)*
- ***General Rule***: 1% increase in constructed air voids = 10% reduction in fatigue life.

Asphalt Compaction: Common Questions

- Won't this increase the bid cost for my asphalt?
- Isn't the cost of managing this specification high?
- Won't coring damage my new pavement?
- What can I do to help my contractors meet and exceed the specification and further increase the life of my overlays?

- Yes, but not significantly. The additional expense will be recovered by the lower life cycle cost.
- No.
- Cores are only needed from the test strip to correlate the nuclear gauge. If the compaction meets specifications, no further coring will be necessary.
- Require QC testing. Discuss at a pre-paving meeting.

Benefits of Good Compaction

- **Reduced/Retarded Pavement Distress/Aging:**
  - Longer cracking life (fatigue and age-related)
  - Less rutting in the pavement structural section
  - Less permeability, water damage
  - Slower aging, less raveling

- **Cost-Effectiveness:**
  - Little or no increase in construction cost
  - Reduced Life Cycle cost

Life Cycle Cost Analysis

Asphalt Compaction

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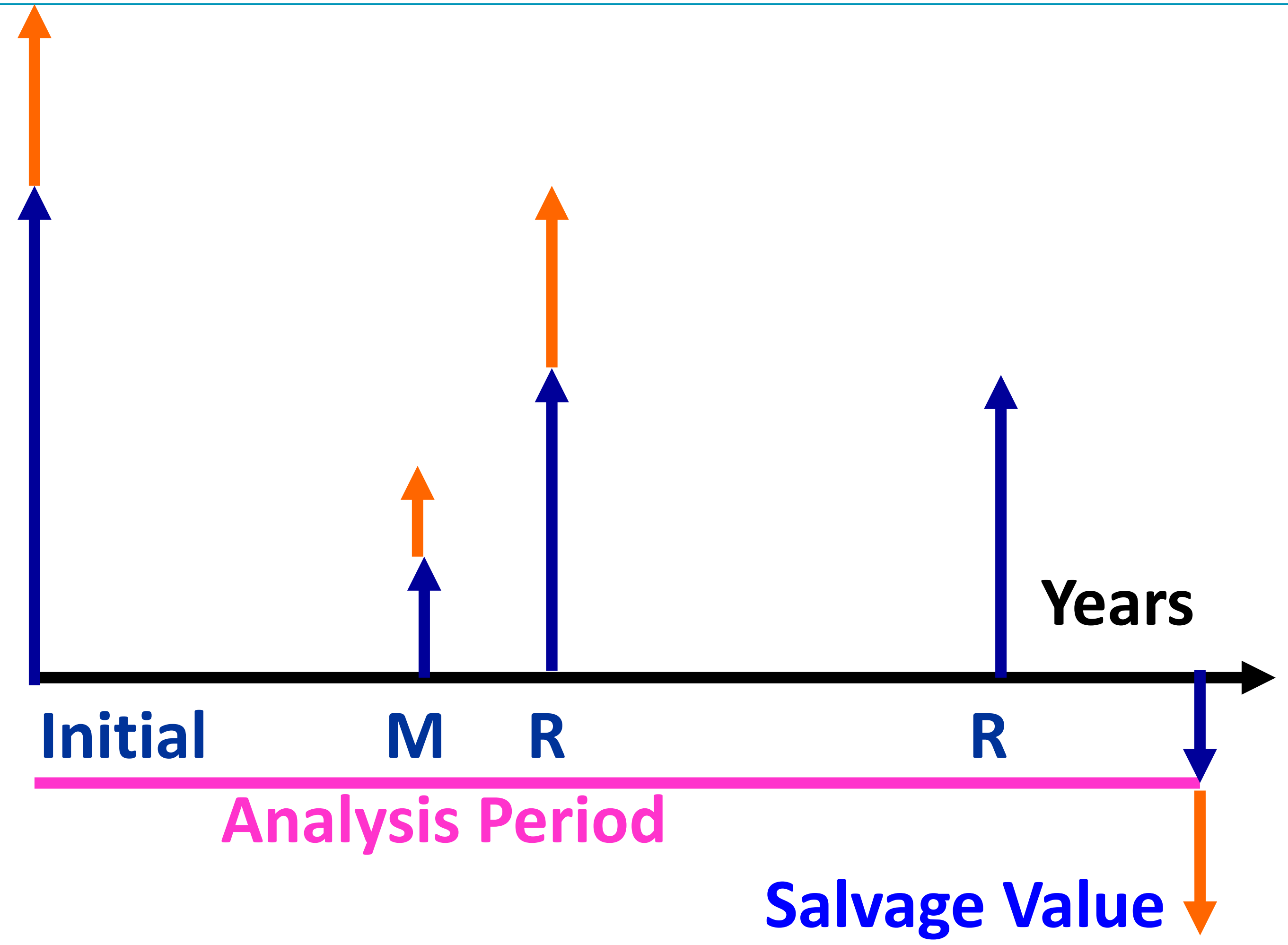
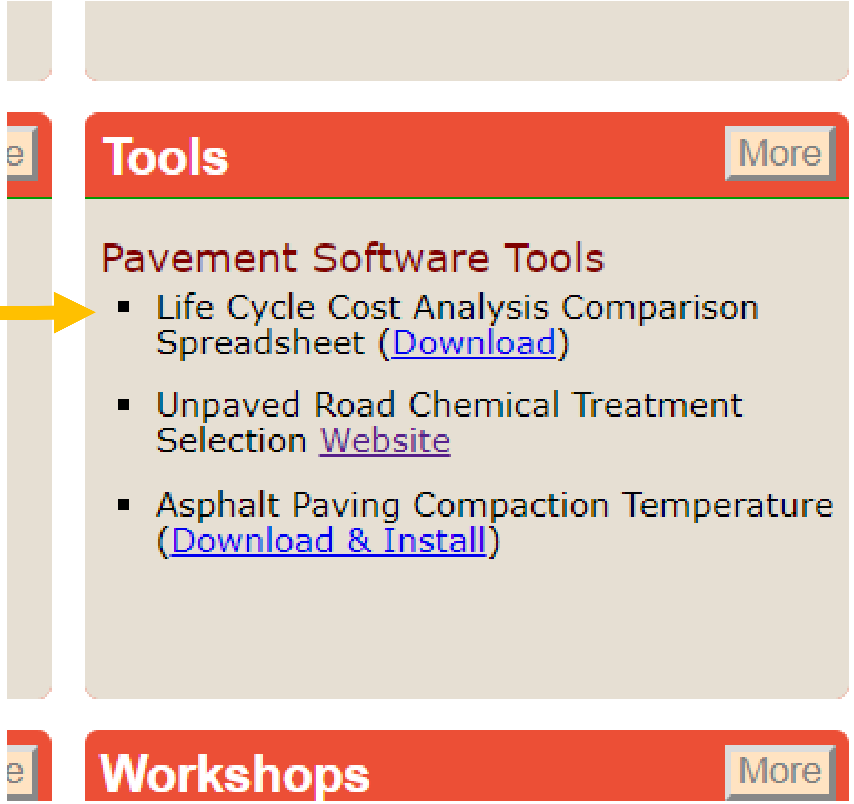
Life Cycle Cost Analysis (LCCA)

- Net Present Value = the total of costs over the analysis period, including discount rate.
- Equivalent Uniform Annual Cost = spread NPV over time, with discount.
- **$ (Agency Costs)**
- **$ (User Costs)**

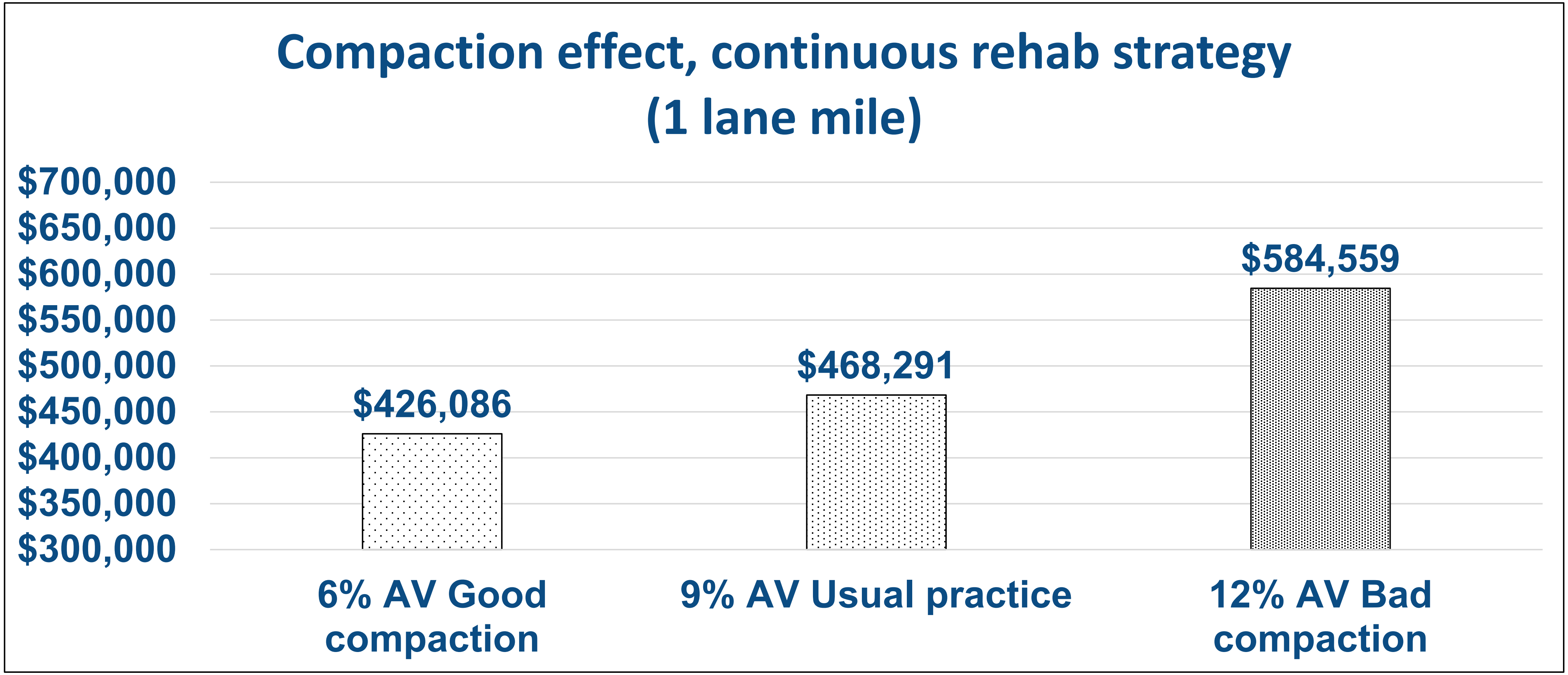


CCPIC LCCA Excel Tool

- Excel tool to calculate Net Present Value, Salvage Value and Equivalent Uniform Annual Cost
- Can compare 3 scenarios side by side
- Can choose and edit the list and sequence of treatments



LCCA: Effect of Asphalt Compaction



LCCA: The Bottom Line

LCCA and LCA example: 8% vs 12% air-voids

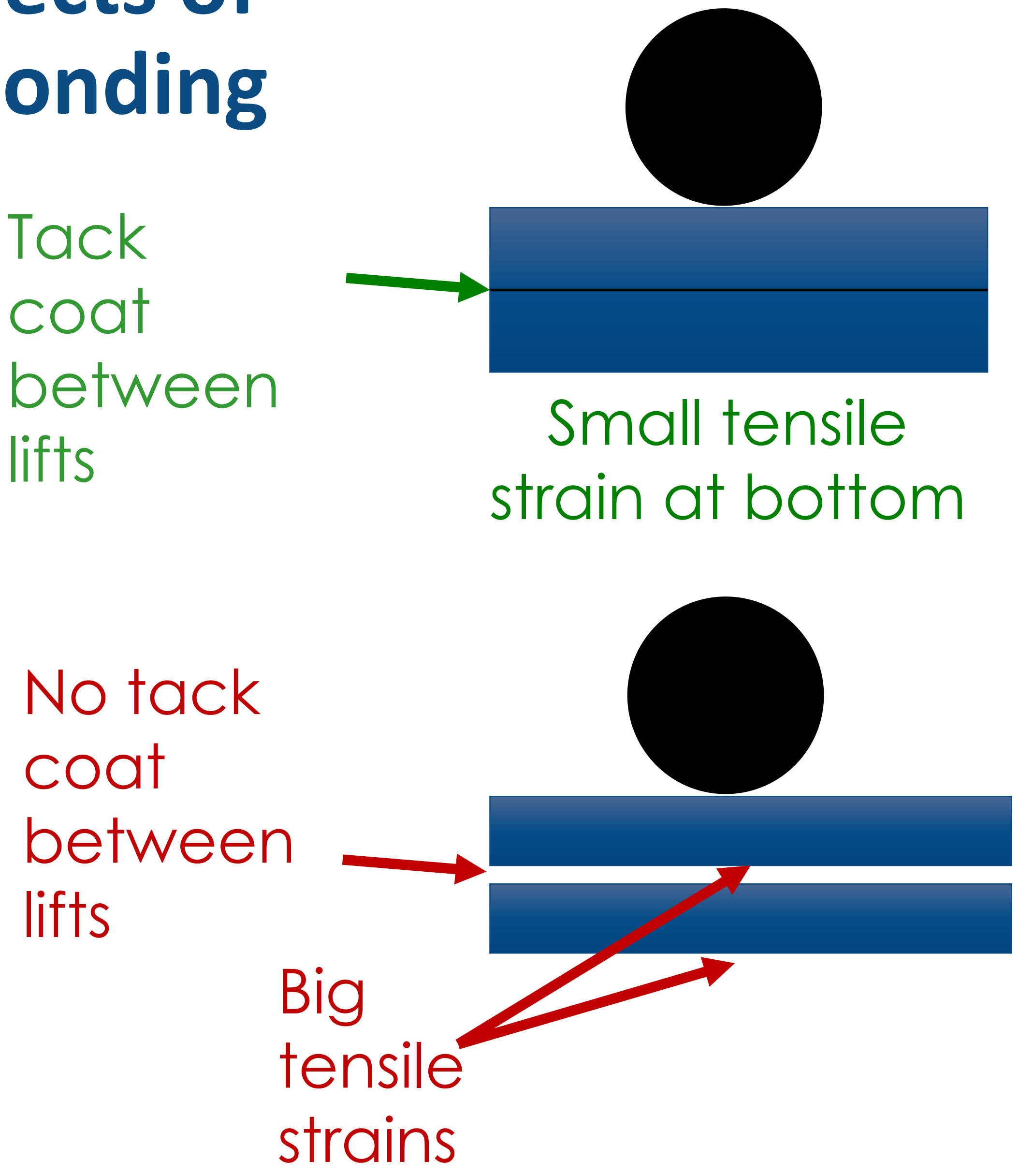
- Assumptions:
  - Rural county road pulverize HMA, compact, 4 in. HMA
  - $26/sy
  - 12% air-voids = 12 year life
  - 8% air-voids = 18 year life
- Net present cost* over 50 year period:
  - 12% air-voids = $4.36 million
  - 8% air-voids = $3.09 million = **29 % less cost**
- Greenhouse gas emissions are **34% less**

*2% discount rate

Bonding of Layers

Tack coats between asphalt layers: Effects of bonding and no bonding

- **Asphalt layers are well bonded:**
  - All layers resist bonding together
- **Asphalt layers not well bonded:**
  - Each layer bending by itself
- **Lack of bonding can cut fatigue life in half**



Delamination/Debonding Between Layers

- Lack of bonding reduces overlay fatigue life by about 50%, even if no shoving
- Due to insufficient tack coat
- application
- Surface must be dry, clean,
- free of dust and residual millings
- Place between lifts, even if
- underlying lift is still hot
- Specify by residual amount
- Track-resistant materials available
- Spray pavers available

Bonding of Layers: Tack Coat Application

- Proper tack coat application results in the pavement layers acting as a composite section
- Analogous to glue used in structural laminated beam
- Uniform application over the pavement surface, not streaked
- Ensure spray bar is pressurized and discharge cones overlap at least twice
- Encourage proper application by making a ***separate Bid Item (Caltrans Std. Specs. do, 2024 Greenbook will)***.

Resources

References and Links

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Summary of Technical Resources

CCPIC website: www.ucprc.ucdavis.edu/ccpic

Best Practices & Tech Briefs

Answers to common problems

- Writing and Enforcing Specs for Asphalt Compaction
- Writing Concrete Specs for Durability and Sustainability
- Unpaving to Create Affordable, Safe, Smooth Gravel Roads
- Pavement Condition Index (PCI)

Training Classes

Pavement Training

- About CCPIC subsidized training
- Currently offered training classes
- Subscribe to monthly training update emails
- Survey on your Agency's pavement training needs. Thanks.

Outreach - Presentations

For Viewing and Downloading

- Pavement Financial and Environmental Sustainability, Some Best Practices-Technical Advisory Committee , Transportation Agency for Monterey County, March 4, 2021.
- Pavement Financial and Environmental Sustainability, Some Best Practices, California Asphalt Pavement Association, October 7, 2020.

Sample Specifications

Model Specs

- Superpave HMA for Local Government Model Specification Language
- Asphalt Compaction Model Specification Language
- Concrete Pavement Model Specification Language
- Tack Coat Model Special Provisions

Guidance

Helpful Documents

- Chemical Dust Control and Stabilization Treatments on Unpaved Roads
- Stabilization of Subgrade Soils
- Guide for Partial-and Full-Depth Pavement Recycling in California
- Use of RAP in Gap-Graded Asphalt Rubber Mixes

Tools

Pavement Software Tools

- Life Cycle Cost Analysis Comparison Spreadsheet & ChangeLog (Download)
- Unpaved Road Chemical Treatment Selection Website
- Asphalt Paving Compaction Temperature (Download & Install)

References/Links

- **City and County Pavement Improvement Center (CCPIC)**
  - www.ucprc.ucdavis.edu/ccpic
- **CCPIC: *"Writing and Enforcing Specs for Asphalt Compaction"***
  - CCPIC_4-pgr_asph compact_final_May 2017.pdf (ucdavis.edu)
- **CCPIC: "*Asphalt Compaction Model Specification Language*"**
  - https://view.officeapps.live.com/op/view.aspx?src=http%3A%2F%2Fwww.ucprc.ucdavis.edu%2Fccpic%2Fpdf%2FCCPIC%2520Model%2520HMA%2520Compaction%2520Spec%2520(4-02-21)%2520for%2520posting.docx&wdOrigin=BROWSELIN

References/Links

- **CCPIC: *"Tack Coat Model Special Provisions"* (CCPIC):**
  - CCPIC_4-pgr_asph compact_final_May 2017.pdf (ucdavis.edu)
- **Caltrans: *"Tack Coat Guidelines"***
  - www.ucprc.ucdavis.edu/ccpic/pdf/Caltrans%20Tack%20Coat%20Guidelines.PDF

References

- ***Standard Specifications*, *2018,* Caltrans:**
  - https://dot.ca.gov/dot-media/programs/design/documents/f00203402018stdspecsa11y.pdf 1

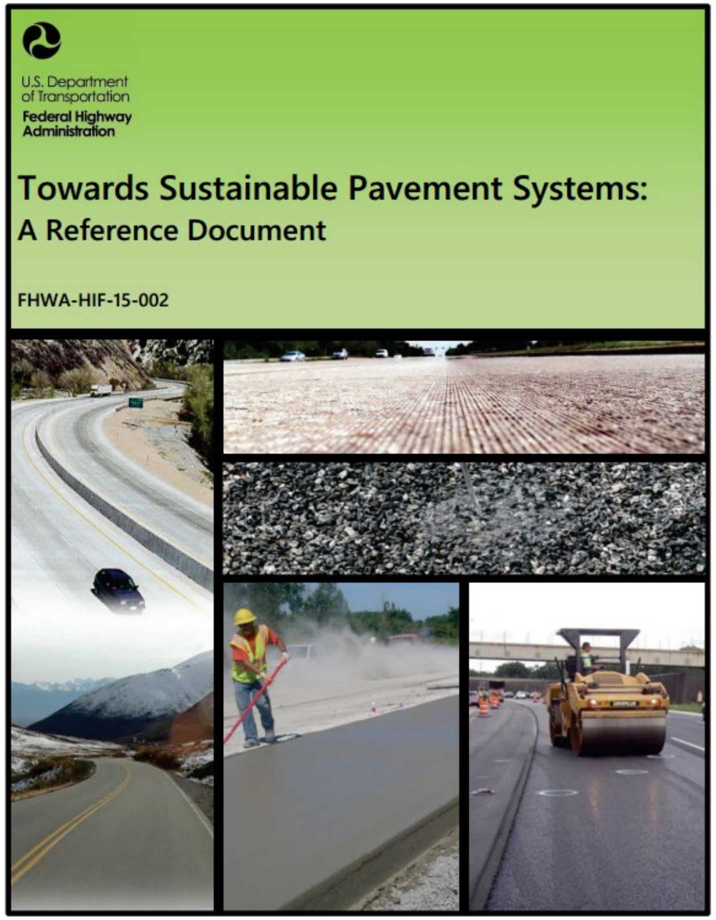
- ***Standard Specifications for Public Works Construction, 2021 Edition:***
  - https://www.bnibooks.com/collections/public-works/products/2021-greenbook-standard-specifications-for-public-works-construction

References

- ***Construction of Quality Asphalt Pavements, MS-22, Third Edition*, Asphalt Institute, ("MS-22")**
  - www.asphaltinstitute.org

Sustainable Pavements

- FHWA Sustainable Pavements Task Group
  - Sustainable pavement reference document (2015)
  - Covers everything about pavement and sustainability
    - Cost
    - Environment
    - (they usually go together)
  - Tech briefs and webinars



- http://www.fhwa.dot.gov/pavement/sustainability/ref_doc.cfm

Questions?

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