Getting the Best Asphalt Pavement Performance:

The Importance of Compaction and Bonding of Layers

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Representing CCPIC

Fall Asphalt Pavement Conference & Expo

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City and County
Pavement Improvement Center

CCPIC Mission and Vision

- **Mission**
  - CCPIC works with local governments to increase pavement technical capability through timely, relevant, and practical support, training, outreach and research
- **Vision**
  - Making local government-managed pavement last longer, cost less, and be more sustainable

City and County Pavement Improvement Center

- Sponsored by the League of California Cities, County Engineers Association of California, and the California State Association of Counties
- Chartered September 28, 2018

City and County Pavement Improvement Center

- **University of California Partners**
  - University of California Pavement Research Center (lead)
  - UC Berkeley ITS Tech Transfer
- **California State University Partners**
  - CSU-Chico, CSU-Long Beach, Cal Poly San Luis Obispo

CCPIC Organization

- **Governance**
  - Governance Board consisting of 6 city and 6 county transportation professionals

- **Current Funding**
  - Seed funding from SB1 through:
    - Institute of Transportation Studies at UC Davis, UC Berkeley, UC Los Angeles, UC Irvine
    - Mineta Transportation Institute at San Jose State University

CCPIC Scope

- **Technology Transfer:**
  - Training courses
  - Pavement engineering and management certificate program for working professionals through UC Berkeley ITS Tech Transfer
  - Outreach
- **Technical Resources:**
  - Technical briefs, guidance, sample specifications, tools, and other resources
- **Resource Center:**
  - Outreach, questions, pilot study documentation, and forensic investigations
- **Research and Development:**
  - For local government needs that are not covered by State and Federal efforts
  - Adapting work done for state government

Pavement Engineering & Management (PEM) Certificate Program

- **PEM Certificate Program Overview**
  - For engineers, asset managers, upper-level managers, technicians and construction inspectors
  - 88.5 hours of training
    - 56.5 hours in core classes, 32 hours in electives
    - Majority of classes to be offered online
  - In four categories:
    - Fundamentals
    - Management
    - Materials and Construction
    - Design

Pavement Engineering & Management Certificate: Curriculum

	Fundamentals	Hrs	Management	Hrs	Materials and Construction	Hrs	Design	Hrs
CORE 56.5 required	CCA-01 Introduction to Pavement Engineering and Management	10	CCB-01 Life Cycle Cost Analysis	4	CCC-01 Asphalt Concrete Materials and Mix Design	8		
	CCA-02 Pavement Sustainability	4	CCB-02 Pavement Management Systems and Preservation Strategies	10	CCC-02 Pavement Preservation Treatments, Materials, Construction, Quality Assurance	8		
					CCC-03 Pavement Construction Specifications and Quality Assurance	12.5		
56.5	**Fundamentals, CORE**	14	**Management, CORE**	14	**Materials and Construction, CORE**	28.5	**Design, CORE**	0
ELECTIVE 32 required 84 offered			CCB-21 Financing and Cash Flow for Pavement Networks	4	CCC-21 Concrete Materials & Mix Design	8	CCD-21 Asphalt Pavement Structural Section Design	8
			CCB-22 Integrated Asset Management for Multi-Functional Pavements	8	CCC-22 In-Place Recycling	8	CCD-22 Design, Construction, and Maintenance of Interlocking Concrete Pavers	6
					CCC-23 Gravel Roads Engineering, Construction, and Management	8	CCD-23 Concrete Pavement Design	8
					CCC-24 Roadway Construction Phasing, Scheduling, and Traffic Control	4		
					MISC Classes from Pavement Construction Inspection Certificate curriculum			
					CCC-26 Pavement Construction Management	8		
					CCC-27 Asphalt Pavement Maintenance Construction	6		
					TS-10 Work Zone Safety	8		
84	**Fundamentals, ELECTIVE**	0	**Management, ELECTIVE**	12	**Materials and Construction, ELECTIVE**	50	**Design, ELECTIVE**	22
Total for Certificate 88.5 hours	**Fundamentals**	14	**Management**	26	**Materials and Construction**	78.5	**Design**	22

Pavement Construction Inspection (PCI) Certificate Program

- **PCI Certificate Program Overview**
  - For engineers, material testing technicians and construction inspectors
  - 80.5 hours of training
    - 68.5 hours in core classes, 12 hours in electives
    - Majority of classes to be offered online

Pavement Construction Inspection Certificate: Curriculum

	Core		Hrs
CORE 68.5 required	PD-01	Construction Inspection	16
	CCI-01	Asphalt Pavement Construction Inspection	4
	CCI-02	Concrete Pavement Construction Inspection	4
	CCI-03	Concrete Street Improvements Construction Inspection	4
	CCI-04	Pavement Preservation Construction Inspection	4
	CCC-02	Pavement Preservation Treatments, Materials, Construction, Quality Assurance	8
	CCC-03	Pavement Construction Specifications and Quality Assurance	12.5
	CCC-26	Pavement Construction Management	8
	TS-10	Work Zone Safety	8
68.5	**Core**		**68.5**
	Electives (choose 12 hours from list below)		**Hrs**
ELECTIVE 12 required 26 offered	CCC-22	In-Place Recycling	8
	CCC-24	Roadway Construction Phasing, Scheduling, and Traffic Control	4
	CCI-06	Construction Inspection of Asphalt-Rubber Pavement Materials	2
	PD-02	Construction Inspection of Traffic Signals	8
	TS-18	Excavation and Trenching Safety	4
12	**Electives**		**26**
80.5	**Total required for certificate**		

CCPIC Training: Upcoming Classes

Code	Title	Date
CCB-01	Pavement Life Cycle Cost Analysis	December 13-14, 2022
CCA-02	Pavement Sustainability	February 13 & 15, 2023
CCC-01	Asphalt Concrete Materials & Mix Design	February 27-March 2, 2023

Overview

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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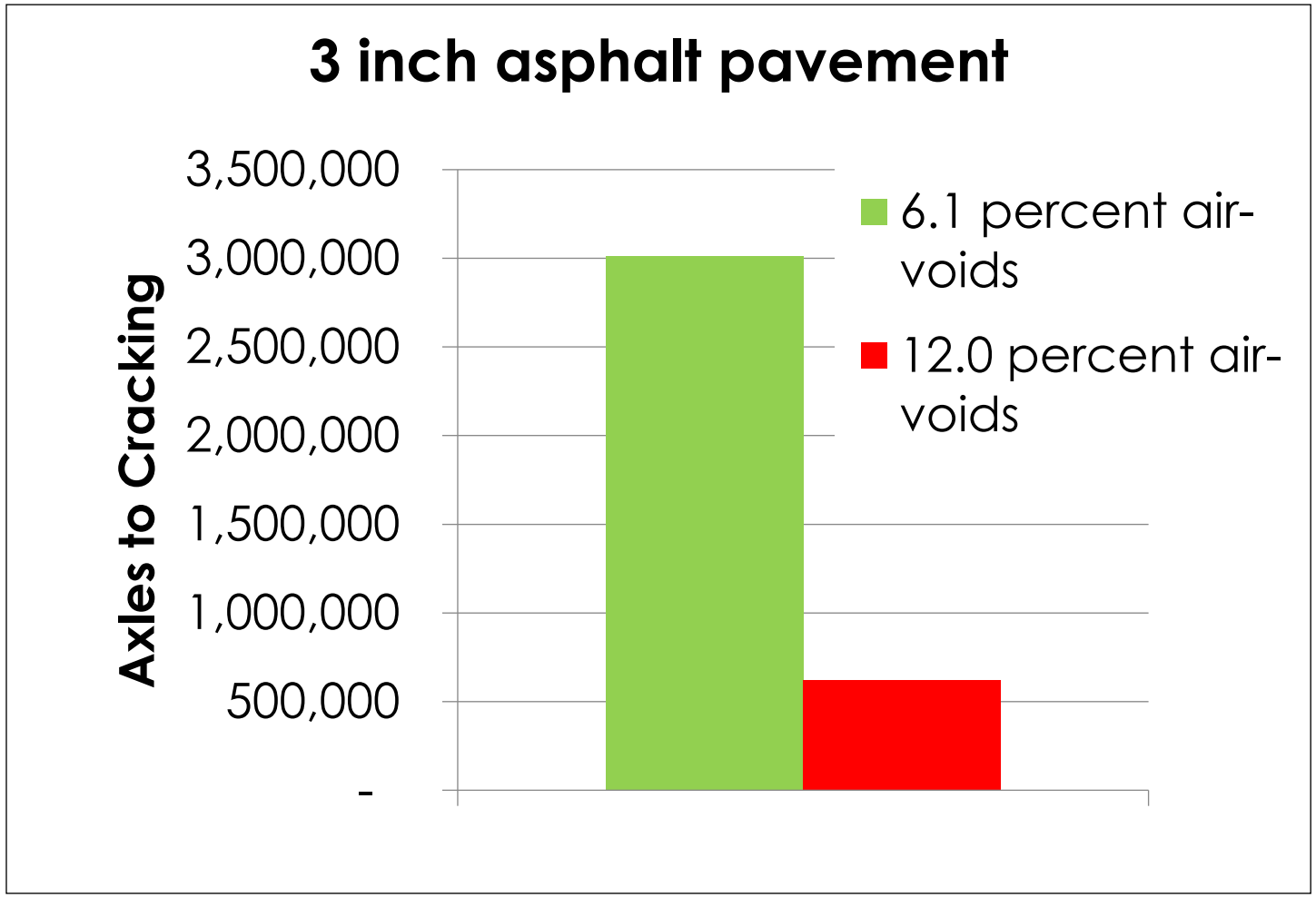
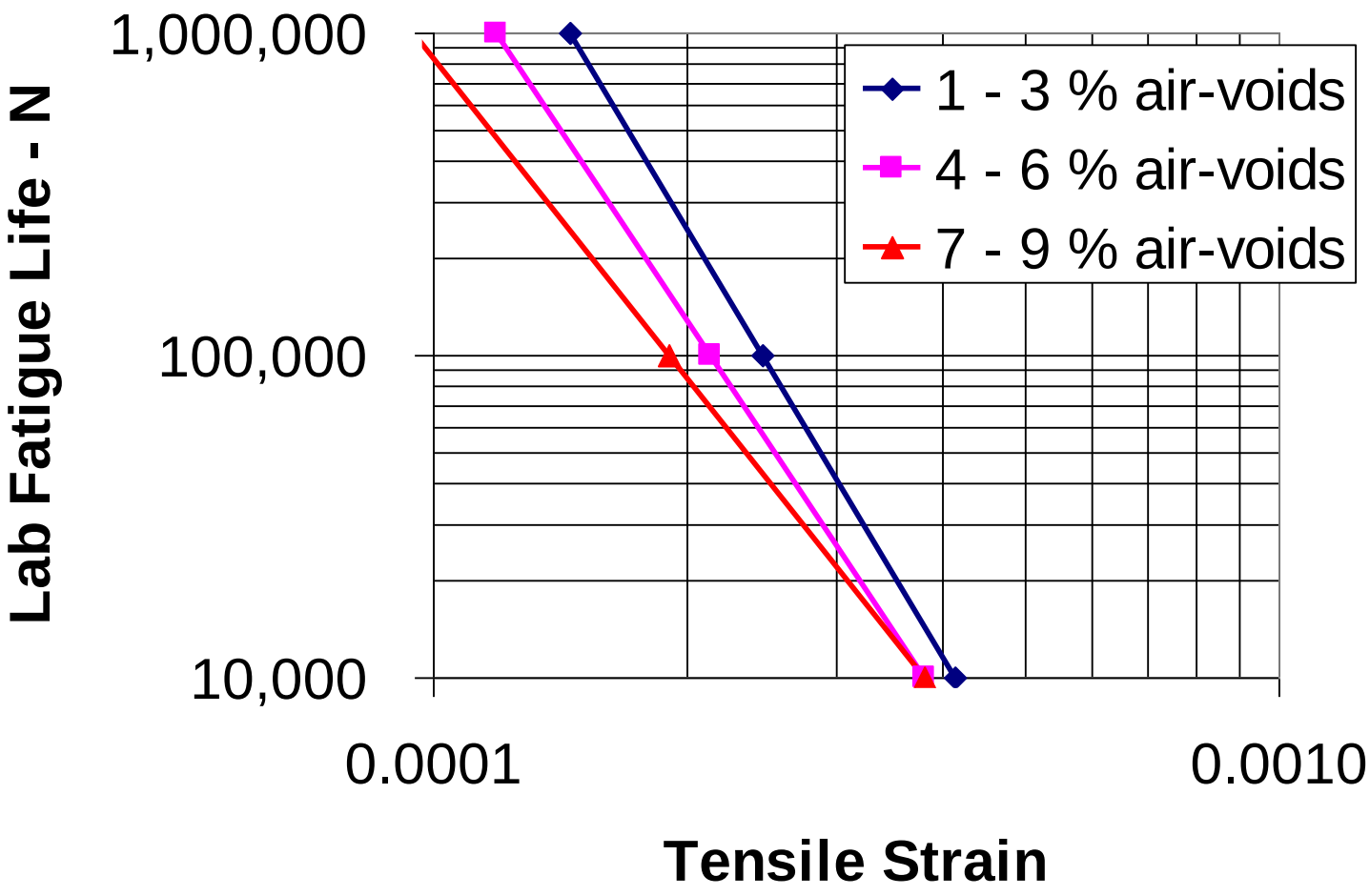
Effect of Asphalt Compaction on Axle Loads to Fatigue Cracking



Simulation based on FHWA Westrack project field results

Fatigue Life vs Asphalt Compaction



Effect of Compaction on Fatigue Life

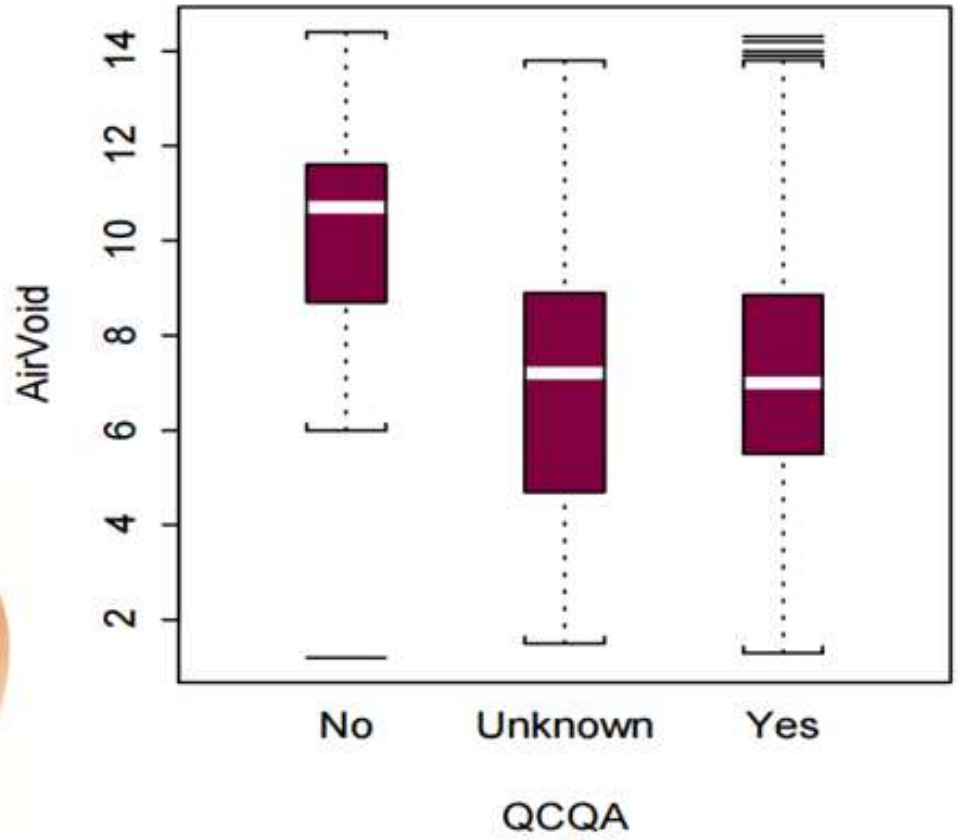
***General Rule*: 1% increase** in constructed air-voids = **10% reduction** in fatigue life

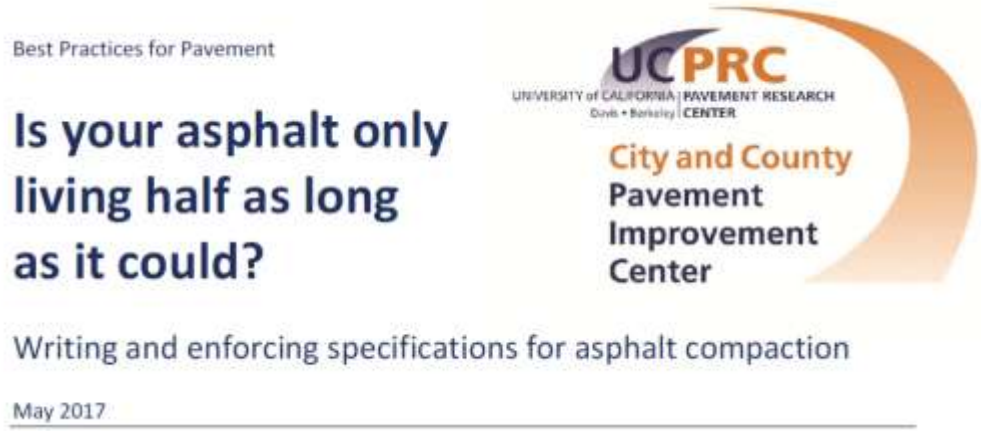
Compaction/Density/Air Voids: Method Compaction

- ***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*.

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





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

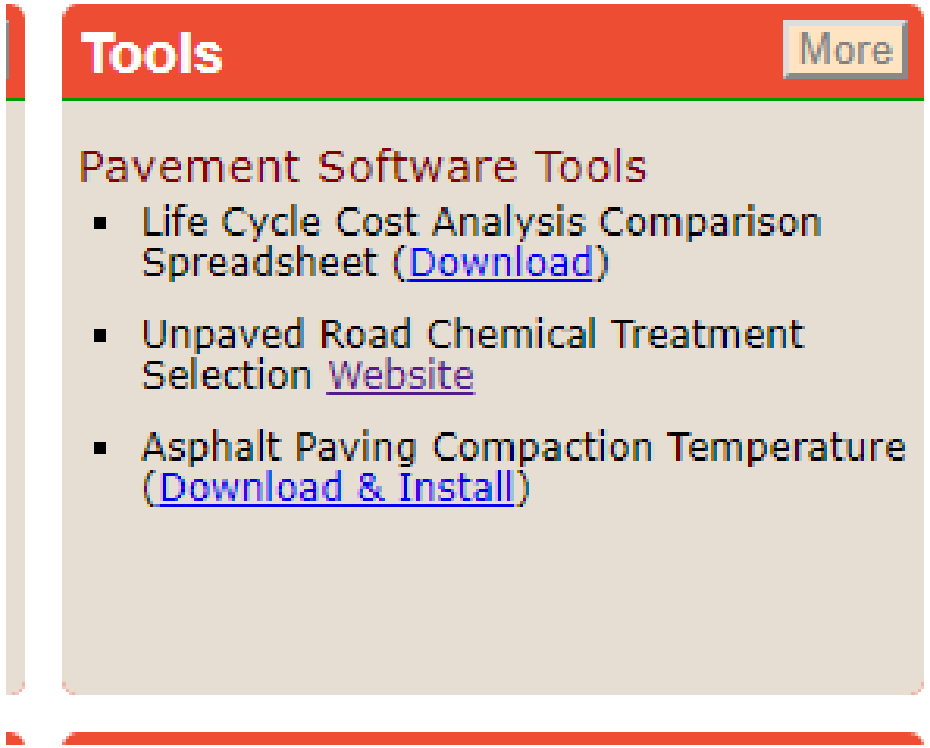
- California Tests 304 & 308
- ***Standard Specifications for Public Works Construction***: 302-5.6.2
- % air voids correlates directly to pavement life
- No direct correlation to air voids
- SSPWC: 95% minimum = 8.8% air voids (for lab air voids of 4%)
- Refer to MS-22, Figure 10.9: 96% = 8% air voids

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

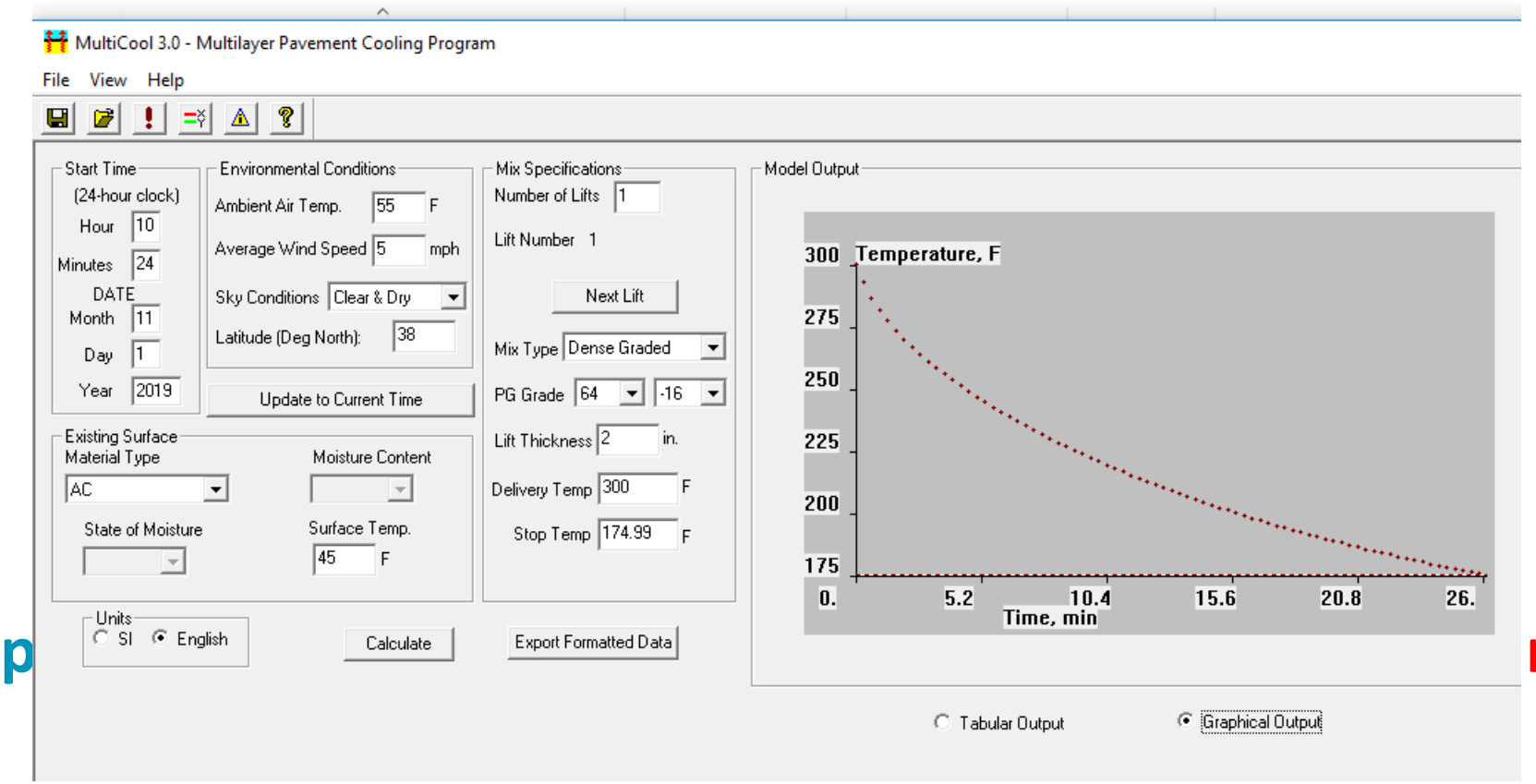
- California Test 309/AASHTO T 209, Method A/ASTM D2041
- ***Caltrans Standard Specifications***: 39-2.01A(4)(h)(vi), 39-2.01A(4)(i)(ii), 39-2.01C(15)
- ***Standard Specifications for Public Works Construction:*** Included in Change No. 301SM (2024 edition) currently in approval process
- % air voids 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

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

- Compaction time when ambient temperature is 55° F: **16 minutes**
- Same overlay on a sunny summer day (85° F): **32 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**
  - About 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**

- **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

- 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.
- ***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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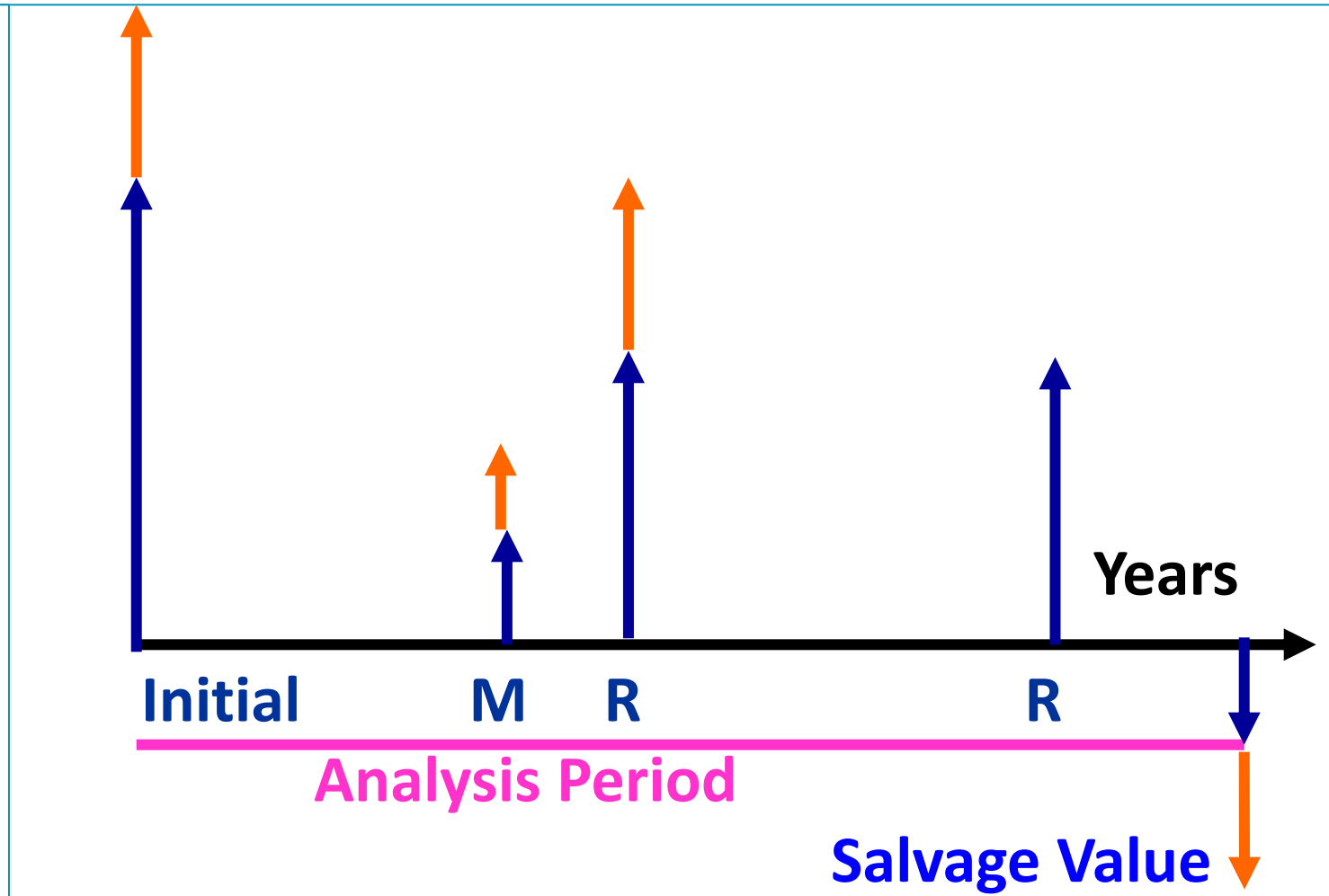
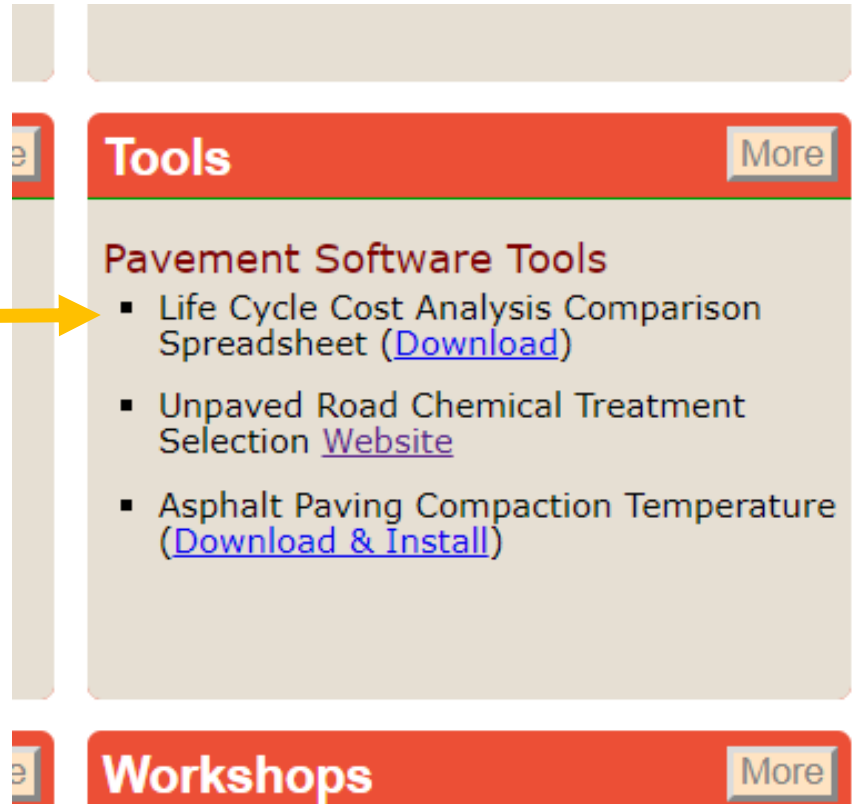
Life Cycle Cost Analysis (LCCA)

- 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)**

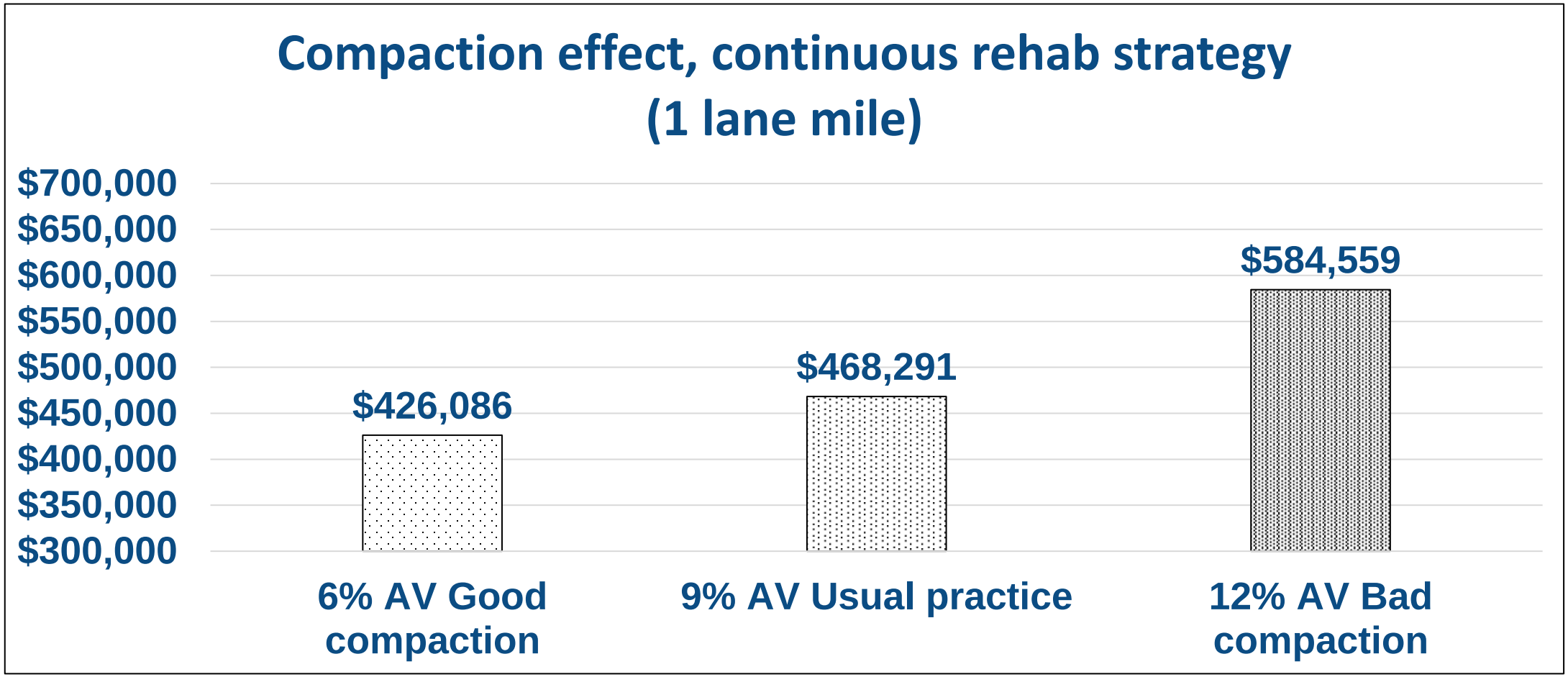


CCPIC LCCA Excel Tool

- 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

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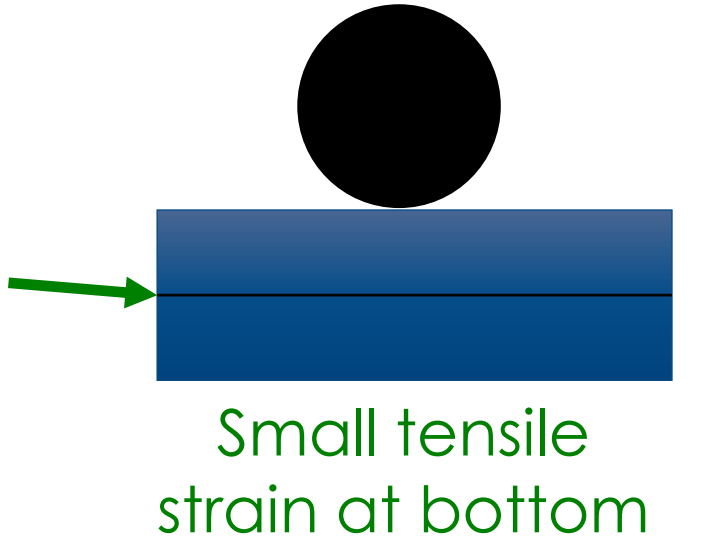
Tack coats between asphalt layers: Effects of bonding and no bonding

- **Asphalt layers are well bonded:**
  - All layers resist bonding together
- **Asphalt layers <u>not</u> 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

Delamination/Debonding: 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**

Resources

References and Links

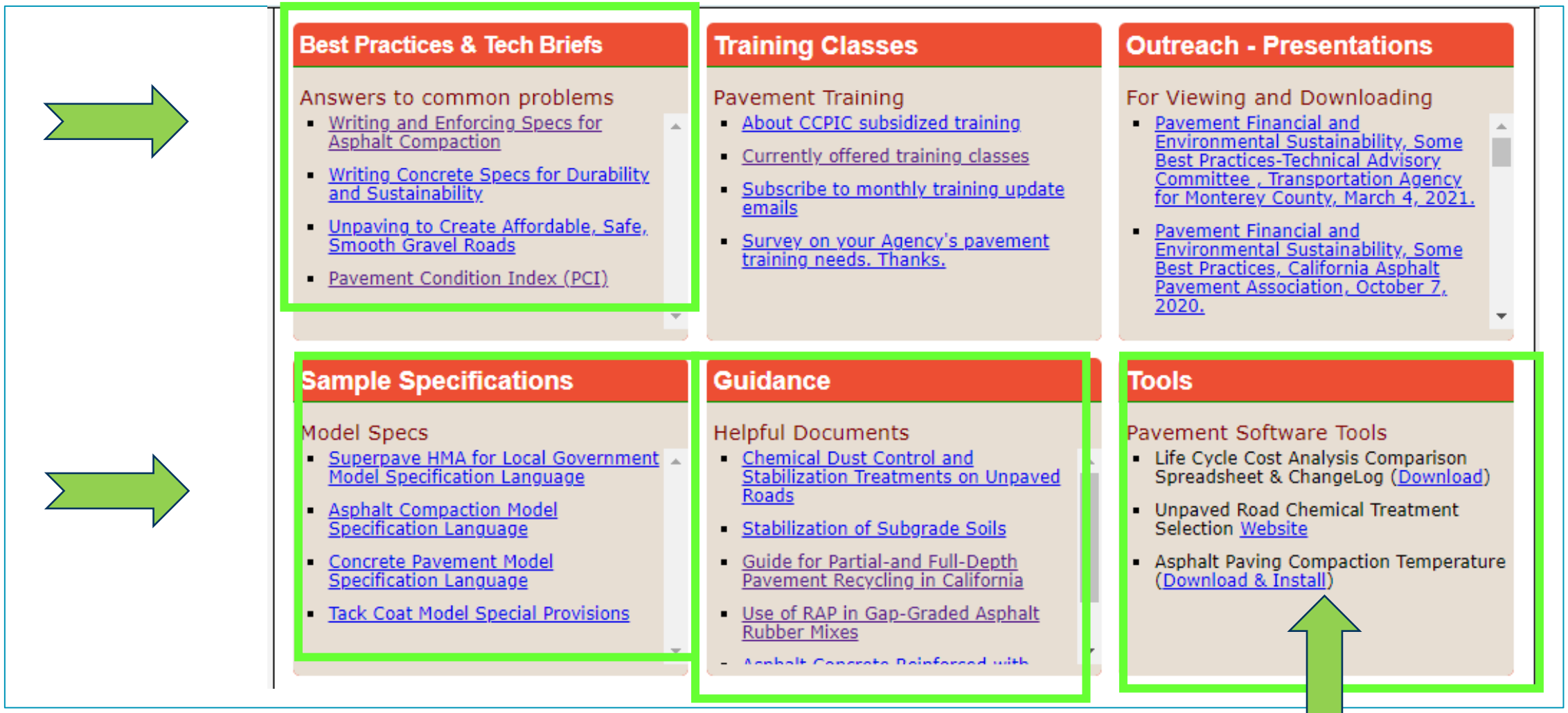
City and County
Pavement Improvement Center

References/Links

- **City and County Pavement Improvement Center (CCPIC):** www.ucprc.ucdavis.edu/ccpic
- **CCPIC: *"Writing and Enforcing Specs for Asphalt Compaction"*:** www.ucprc.ucdavis.edu/ccpic/pdf/CCPIC_4-pgr_asph compact_final_May 2017.pdf
- **CCPIC: "*Asphalt Concrete 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

Summary of Technical Resources

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



References

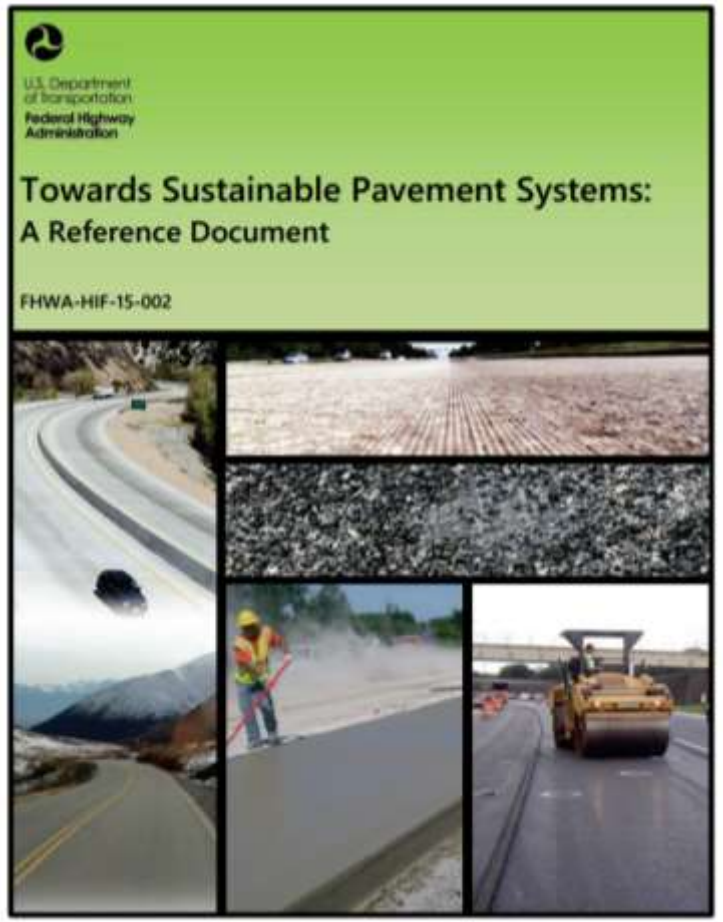
- ***Standard Specifications*, *2018*, Caltrans:**
  - https://dot.ca.gov/dot-media/programs/design/documents/f00203402018stdspecsa11y.pdf1
- ***Standard Specifications for Public Works Construction, 2021 Edition:***
  - https://www.bnibooks.com/collections/public-works/products/2021-greenbook-standard-specifications-for-public-works-construction

References

- ***Construction of Quality Asphalt Pavements, MS-22, Third Edition,* Asphalt Institute, ("MS-22")**
  - www.asphaltinstitute.org
- ***Tack Coat Guidelines,*** Caltrans:
  - www.ucprc.ucdavis.edu/ccpic/pdf/Caltrans%20Tack%20Coat%20Guidelines.PDF

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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