City and County Pavement Improvement Center

Pavement Condition Index (PCI): There's More *(and Less)* to the Score

John Harvey, PhD, P.E.
Erik Updyke, P.E.

Summer, 2022

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
CCC-02	Asphalt Pavement Preservation Treatments, Materials, Construction, and Quality Assurance	September 19-22, 2022
CCB-01	Pavement Life Cycle Cost Analysis	December 13-14, 2022

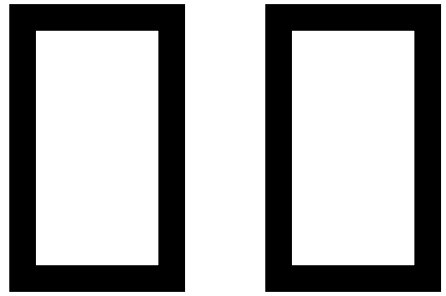
Pavement Distresses

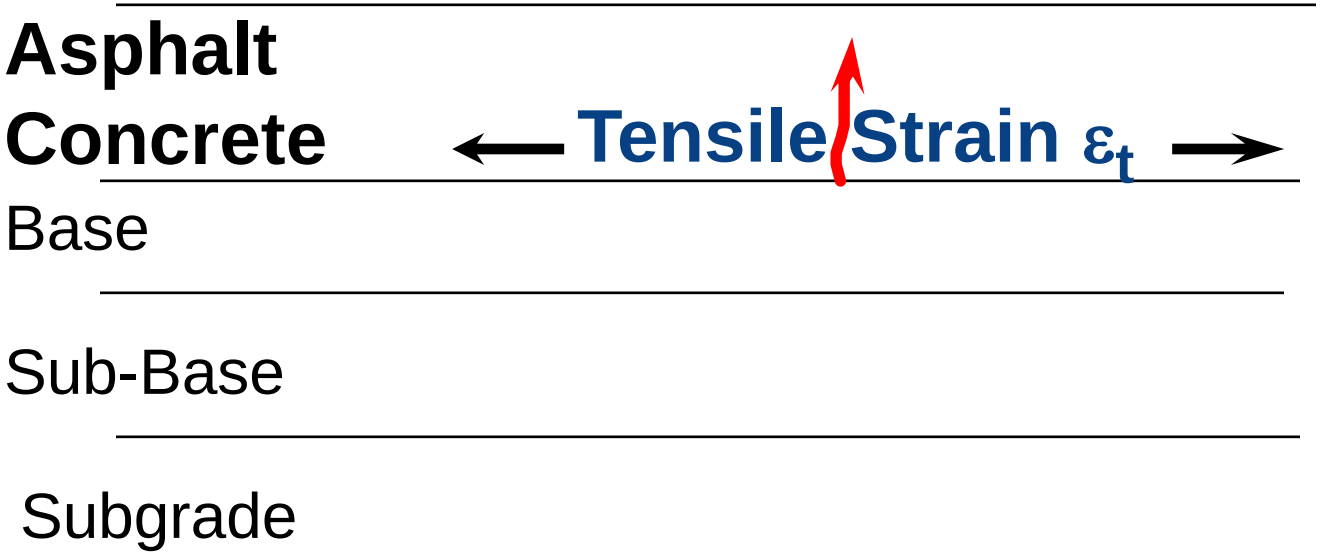
Identifying Types to Better Manage Asphalt Pavement

City and County
Pavement Improvement Center

Bottom Up Fatigue Cracking

At ***moderate*** temperatures, tensile strains under loading





Load-Related: Bottom-Up Fatigue Cracking

- **Interaction** of asphalt concrete layer, support of underlying structure, materials selection, construction compaction
- **Traffic loading:**
  - Only the truck loads count, cars are too light
  - Slower speeds = longer durations = bigger strains
- **Environment:**
  - Temperature
  - Water sensitivity
  - Aging

Initial Wheel Path Cracking

- May be transverse or Longititudinal
- Distress descriptions can be seen in the ***FHWA Distress Identification Manual***

Cracks Connect: Alligator Cracking

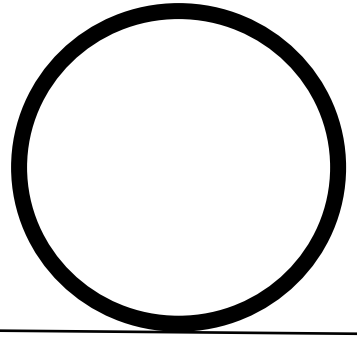
- Distress descriptions can be seen in the ***FHWA Distress Identification Manual***

Fatigue Cracking in Wheel Paths

- Distress descriptions can be seen in the ***FHWA Distress Identification Manual***

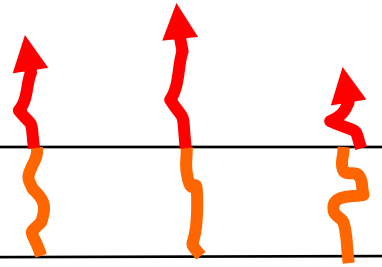
Reflective Fatigue Cracking

- Shear and tensile strains from loads passing over, tensile strains from thermal contraction
- Crack pattern resembles pattern before overlay



Asphalt Concrete

Cracked AC, PCC or CTB



Strains concentrated above cracks in layer below

Base

Sub-Base

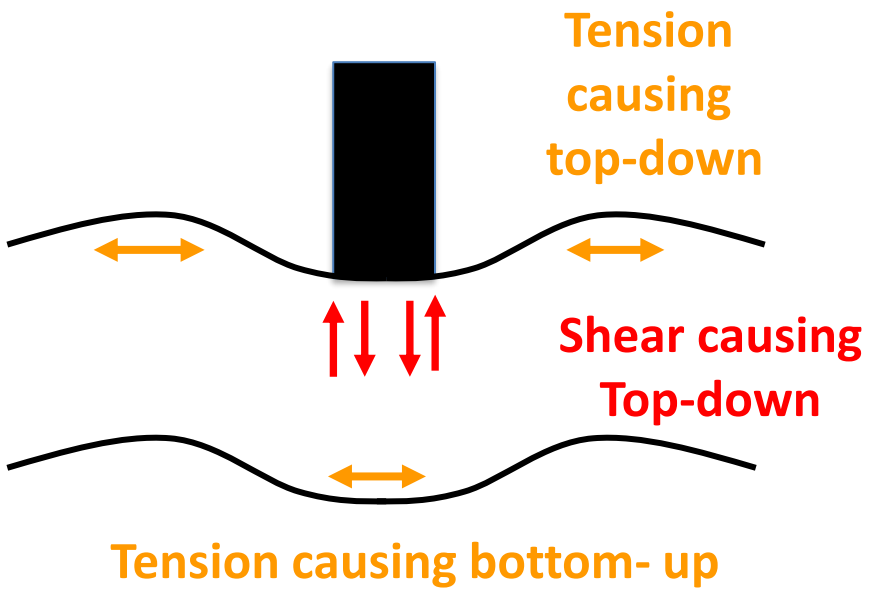
Subgrade

Reflective Cracking of Underlying Block Cracking and Longitudinal Joint, 7 Years Old

- Avoid putting longitudinal joints in the wheel paths!

Load-Related: Top-Down Fatigue Cracking

- Identified in the 1990s
- Cracking due to high tensile and shear stresses at the HMA surface near edges of truck tires



Top-Down Fatigue Cracking

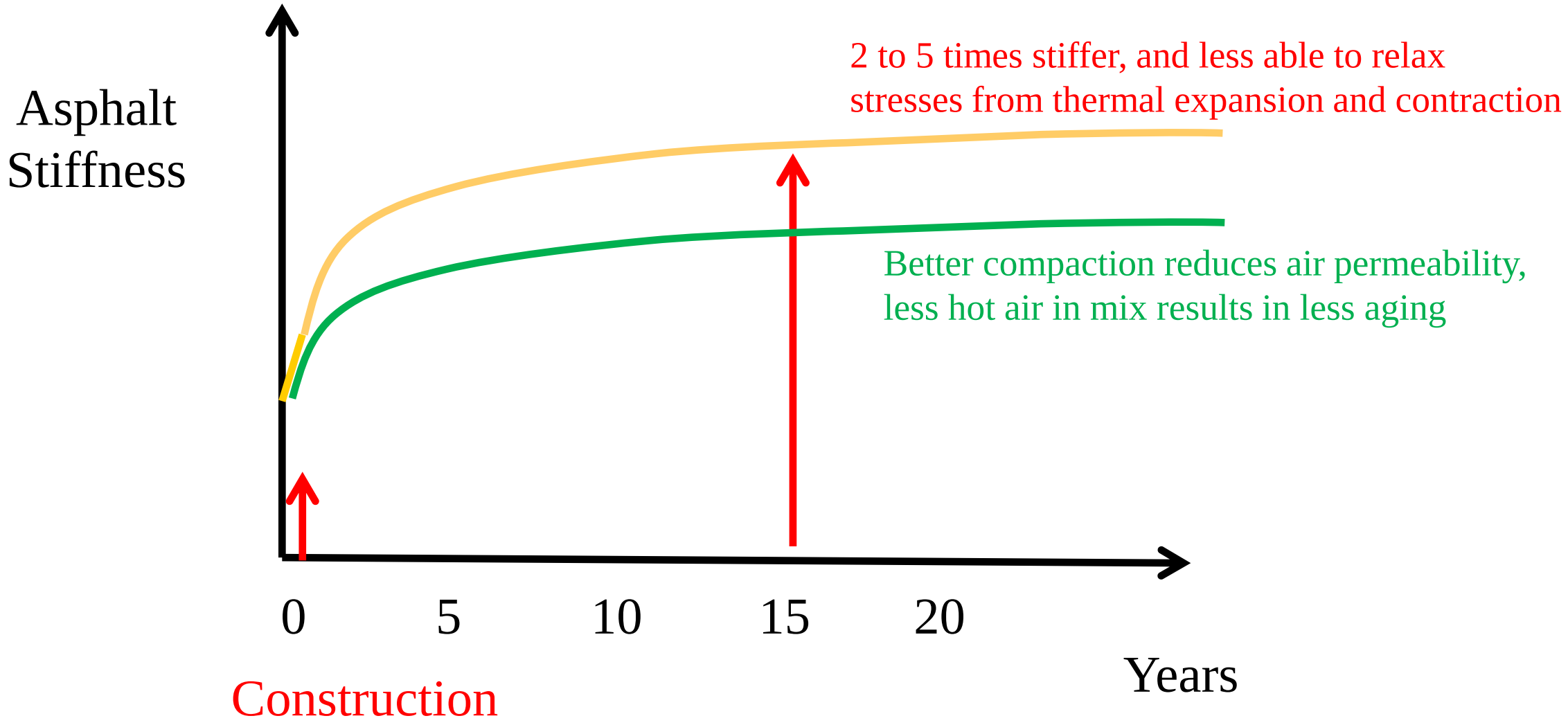
- Thin HMA (< 4”): Fatigue cracking generally starts at the bottom
- Thick HMA (≥ 4”): Fatigue cracking generally starts at the top
  Note, thickness of AC in photo on the previous slide is 20”
- Traffic loading: High truck tire pressures

Load-Related Fatigue Cracking: Strategies

- 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 (cold in-place recycling) or full-depth reclamation (FDR) depending on crack and rutting depth
- Do not let wheel path cracking become extensive or must reconstruct

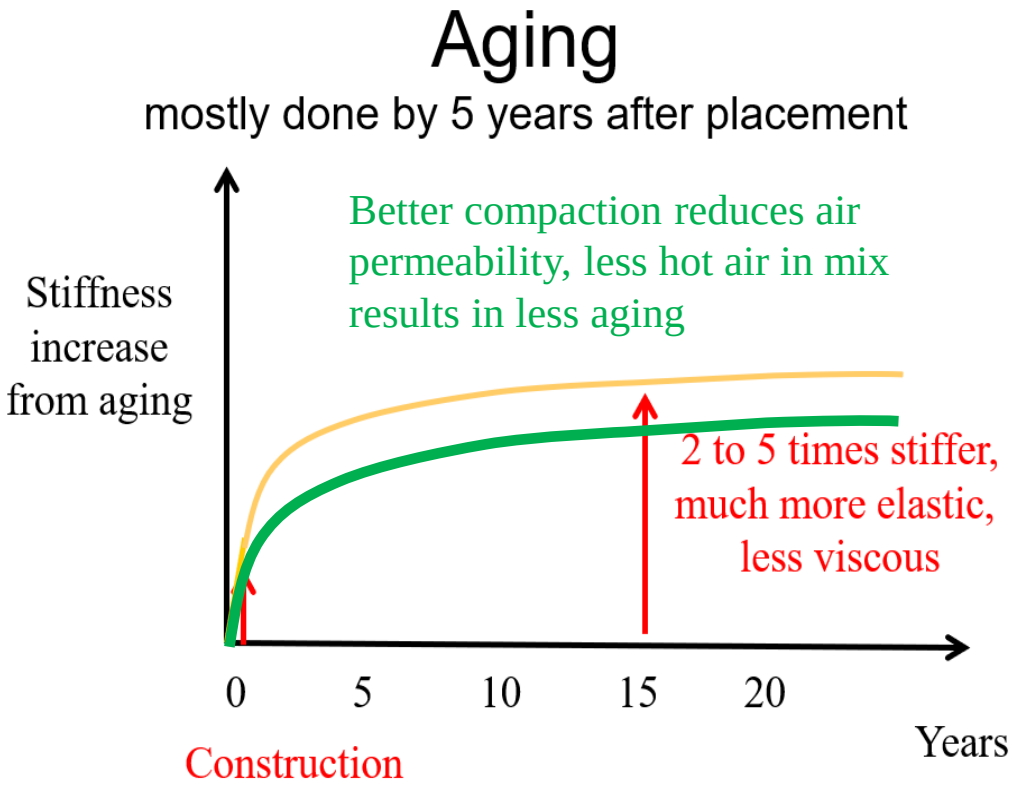
Aging

Amount of aging depends on asphalt chemistry, construction compaction, modifiers



Aging of the Asphalt Binder and its Effects

- **Aging:**
  - Caused by oxidation and volatilization
  - Faster if high permeability and Temperature (curve)
  - Permeability greatly reduced with better HMA/AC compaction (curve)
- **Effects:**
  - Stiffening of the mix over time
  - Won't relax stresses from thermal contraction as well



Age-Related: Block Cracking

- Typically caused by long-term aging of HMA/AC and daily temperature cycling (expansion/contraction)
- May also be reflection cracking from shrinkage cracks in cement treated base or underlying HMA/AC
- Poor HMA/AC compaction allows air to enter and age the asphalt faster

Good compaction limits entry of air and slows oxidation

Block Cracking

- Block cracking is top-down
- Distress descriptions can be seen in the ***FHWA Distress Identification Manual***

Age-Related Cracking: Strategies

- Keep the surface protected from aging
- Can potentially use perpetual fog seals, or slurry seal or micro surfacings
  - Slurry seal typically not applied to RHMA/ARHM
- What frequency?
  - After aging has progressed
    - About 7 to 12 years
  - Before cracking starts
    - Do not let cracking get extensive
  - Doing more frequently is not cost-effective

Moisture Damage

- Moisture damage is assessed by taking both dry and wet cores and measuring the in-situ pavement permeability.

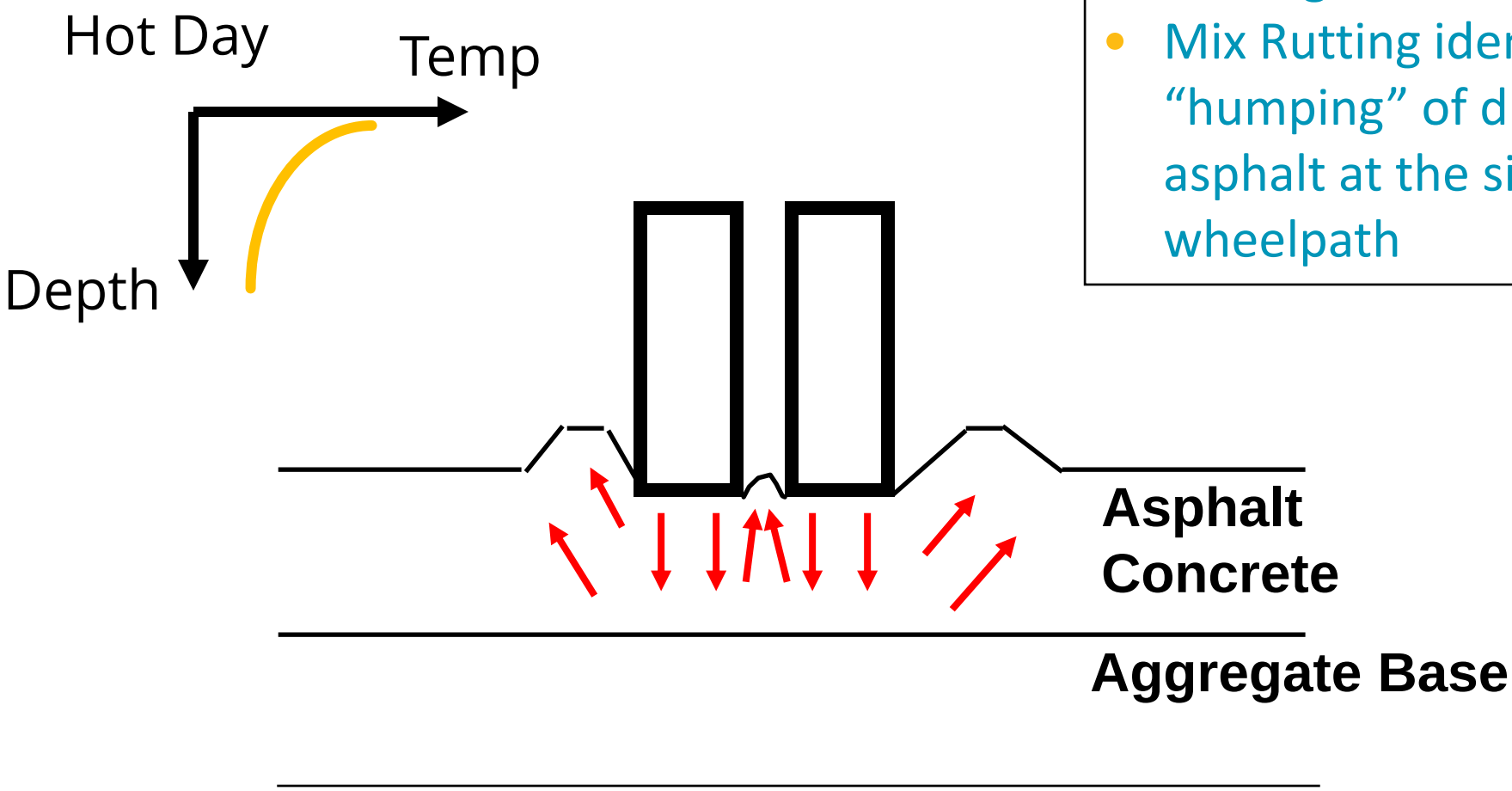
- The extent of moisture damage evaluated for each core.

Moisture Damage

- Layer 1 AV=13%
- Layer 2 AV=6.3%
- Water entered 1, trapped between layers

AC/HMA Mix Rutting

- High shear stresses at edges of tires
- Asphalt softer under slow moving traffic
- Mix Rutting identified by “humping” of displaced asphalt at the sides of wheelpath



AC/HMA Mix Rutting

- **Poor compaction makes rutting happen faster**
- **Much more shearing**
- **Some due to more compaction from traffic**
  - But only in wheel paths
  - Doesn’t help with aging and block cracking

Other Distresses: Delamination/Debonding

- 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**.

Pavement Condition Index (PCI)

The “More” and the “Less”

City and County
Pavement Improvement Center

Choosing Cost-Effective Strategies: Use of PMS Data and LCCA

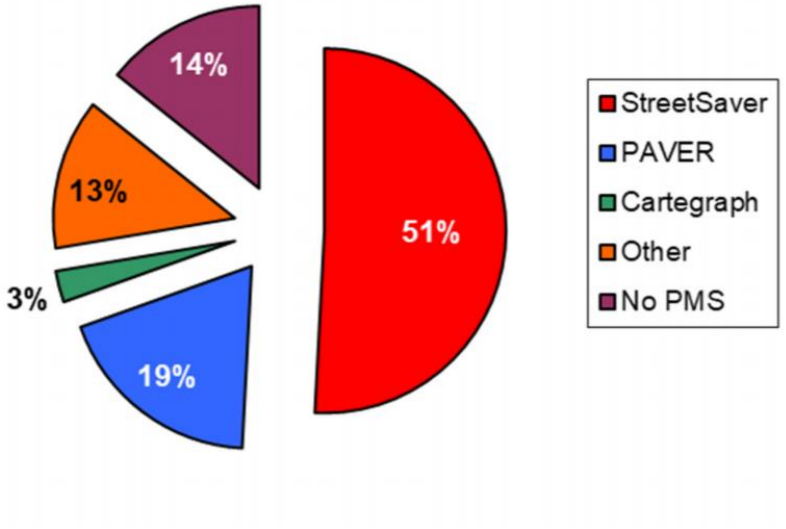


Figure B.4 PMS Software Used By Cities And Counties

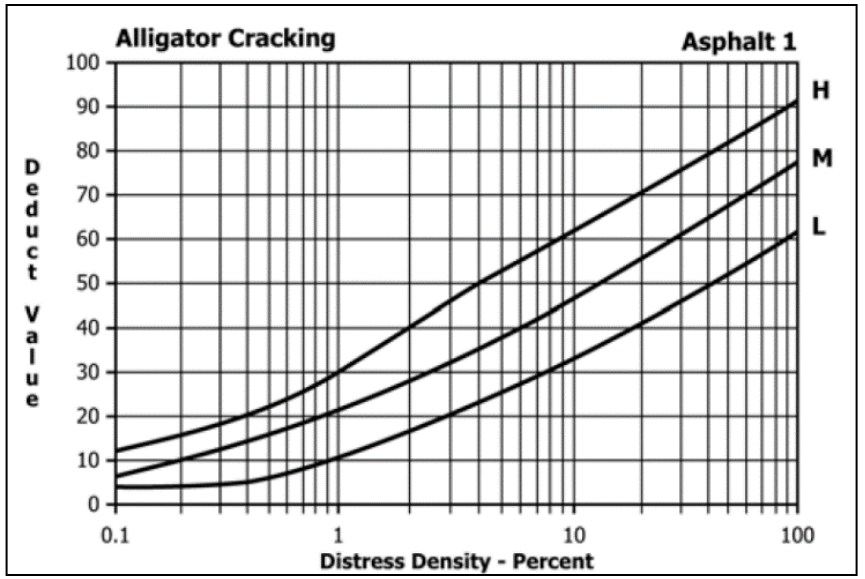
- Understanding the performance of your pavements is key to good pavement management and life cycle cost analysis (LCCA).
- ***Pavement condition*** is typically calculated and described in terms of pavement condition index (PCI).
- Agencies need to take one step back behind PCI to better understand ***pavement performance*** in order to better understand PMS data and make better strategy decisions.

Pavement Condition Index (PCI)

- **Definition/Standard:**
  - *"A numerical rating resulting from a pavement condition survey that represents the severity of surface distresses."* FHWA, *Practical Guide for Quality Management of Pavement Condition Data Collection*, page 87
  - ASTM D6433, *"Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys"*

Pavement Condition Index (PCI)

- **Calculation:**
  - *"An equation converts the severity and extent of each distress into a so-called "deduct value"; different deduct equations are used for the different distress types.*
  - *All the deduct values obtained across all the distress types are then added up and subtracted from 100.*
  - *The result is a PCI on a scale of 0 to 100."*



Variables in the PCI

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

Pavement Condition Index (PCI)

- **Problems and Limitations:**
  - *"… it has **limitations as an engineering tool** for local governments making pavement management decisions."*
  - *"Specifically, when a PCI is developed from condition survey data, **a lot of important engineering information is lost**, particularly data regarding cracking."*
  - *"A major deficiency in PCI is that roadway segments **can have the same or similar PCI [a tie score] but very different types of distress**."*

Same or Similar PCI:
Different Distresses = Different Strategies

CASE 1: TRAFFIC LOADING RELATED, PCI = 34			
DISTRESS	SEVERITY	QUANTITY	DV
Alligator Cracks	High	1x6	18
Alligator Cracks	Medium	1x4 1x5 1x7	17
Potholes	Medium	3	48
Potholes	Low	3	30
Rutting	Low	2x5 2x8	10
CASE 2: AGE, CONSTRUCTION, UTILITIES, OTHER FACTORS, PCI = 32			
Long/Trans Crack	High	15 20 8 6 12 18 6x7	43
Long/Trans Crack	Medium	25x2 18 13 9 10	20
Patching/Utility	High	25x4 25x2	40
Patching/Utility	Medium	12x6 4x7	20
Block Cracks	High	4x6 6x5	13

Pavement Condition Index (PCI)

- **The "Tiebreaker:"**
  - *"For these cases, **examining the distress types and extents of the distresses** and their effect on the pavement structure, **along with other available project-level data**, could serve as a tiebreaker to augment PCI making network-level and project scoping decisions."*

Summary: The "More" and the "Less"

- **What's "Less"?**
  - *"PCI is a simple, effective communication tool, but when used alone it is insufficient for choosing the right strategy at the right time to maximize the cost-effectiveness of pavement funding."*
  - PCI is not a measure of structure.
  - PCI alone is less information than is needed to select the appropriate strategy based on pavement distress

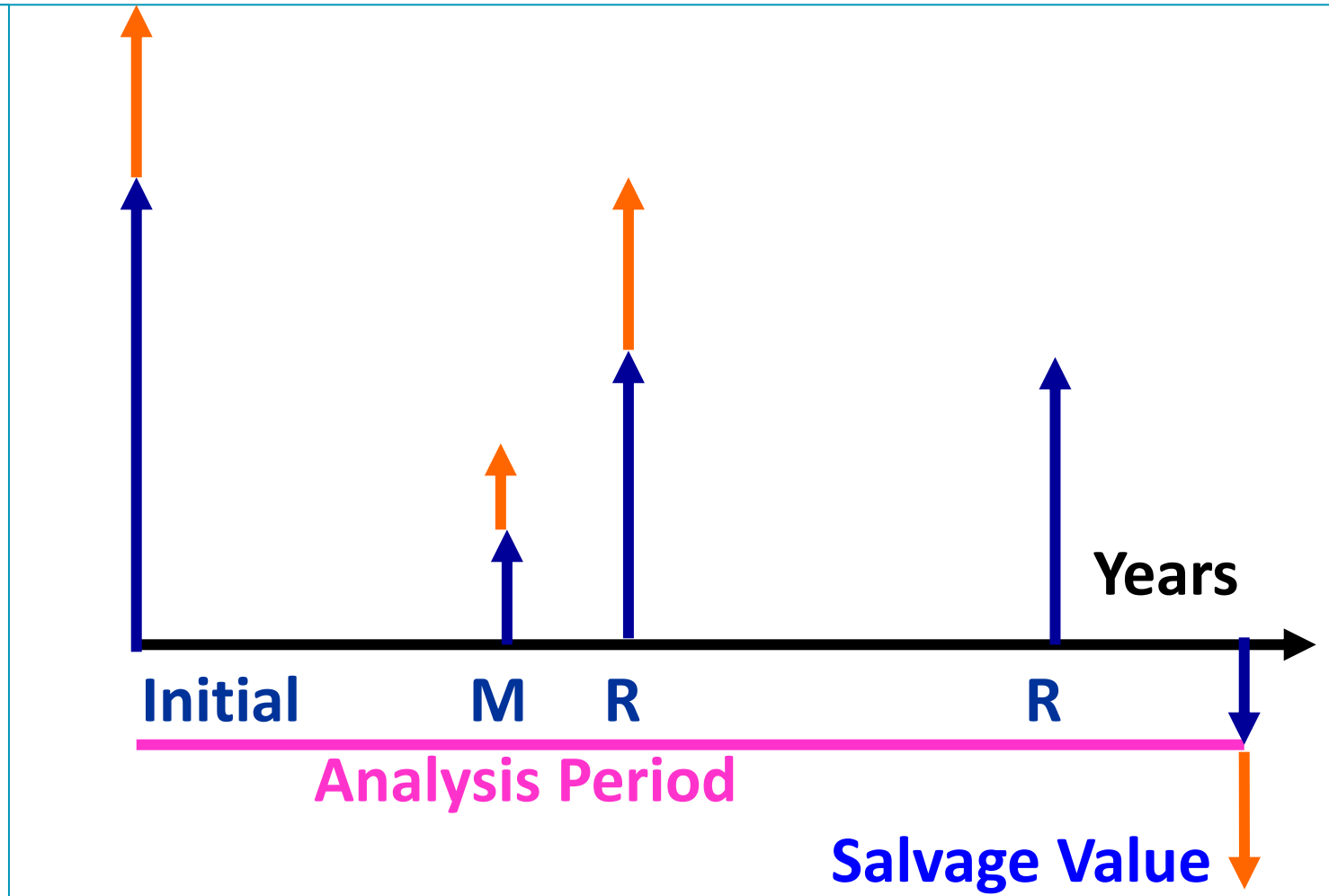
- **What's "More?"**
  - *"Managing pavement networks primarily based on identification of age- and load-related cracking will result in **more** informed and cost-effective treatment timing and selection."*
  - More project-level analysis and information is needed in order to select the appropriate strategy.

Life Cycle Cost Analysis

City and County
Pavement Improvement Center

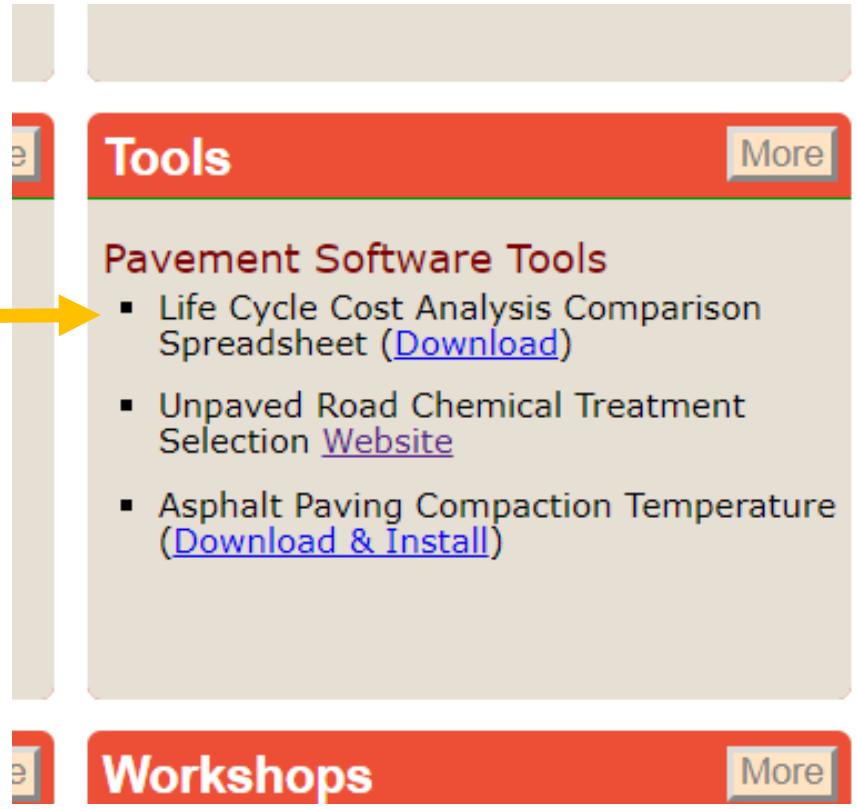
Life Cycle Cost Analysis (LCCA)

- 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



Strategy Selection

Considerations for Future Projects

City and County
Pavement Improvement Center

Questions to Ask

- Are the cracks due to fatigue in the wheel paths (traffic), or aging of entire surface (environment), or both?
- Is the network-level strategy in the PMS appropriate for the types of cracking?
- Did the last project on the same route perform as expected? If not:
  - What's changed?
  - Is the structural section adequate?
  - Was a thorough project-level investigation, associated testing, and calculations performed?
  - Was the appropriate strategy selected?
  - What binder was used? Should a modified binder (polymer, asphalt-rubber) be used in the next project (particularly useful if inlay/overlaying cracking)?

Pavement "MRI": Before Strategy Selection

- **M = Materials**:
  - What is the structural section composed of?
  - Subgrade, base material type and thickness, HMA/AC (gradation,
  - binder type, thickness).

- **R = Review:**
  - Completed projects at 3, 5, and 10-year milestones.
  - As-built plans,
  - Material testing records,
  - Traffic counts/traffic index calculations/projections,
  - Resident Engineer/Inspector records,
  - Change Orders.

Pavement “MRI”: Before Strategy Selection

- **I = Investigation:**
  - Was a project-level site investigation performed?
  - Borings
  - Cores
  - Dynamic Cone Penetrometer (DCP)
  - Falling Weight Deflectometer (FWD)
  - Subgrade Soil Classification Testing (SE, R-Value/CBR, PI)

Summary

Takeaways for thought and application

City and County
Pavement Improvement Center

Takeaways

- The ability to make good engineering decisions regarding the timing and type of strategy based only on PCI is limited; analyze the cracking.

- Life cycle cost analysis (LCCA) is a practical tool to determine the most cost-effective strategies:
  - Needs good performance estimates, agencies can use their own information
  - Focus on cracking, separated by:
    - Streets with heavy trucks/buses, wheel path fatigue cracking and age related cracking: will need rehabilitation eventually
    - Streets with no heavy vehicles, age related cracking only: can use only preservation treatments if timely

Resources

References and Links

City and County
Pavement Improvement Center

References/Links

- **City and County Pavement Improvement Center (CCPIC):**
  www.ucprc.ucdavis.edu/ccpic
- ***"Pavement Condition Index (PCI): There's More (and Less) to the Score"***
  www.ucprc.ucdavis.edu/ccpic/pdf/PCI 4-Pager final v2.pdf
- **University of California Pavement Research Center (UCPRC):**
  www.ucprc.ucdavis.edu
- **Maintenance Technical Advisory Guides (MTAG):**
  https://www.csuchico.edu/cp2c/library/caltrans-documents.shtml

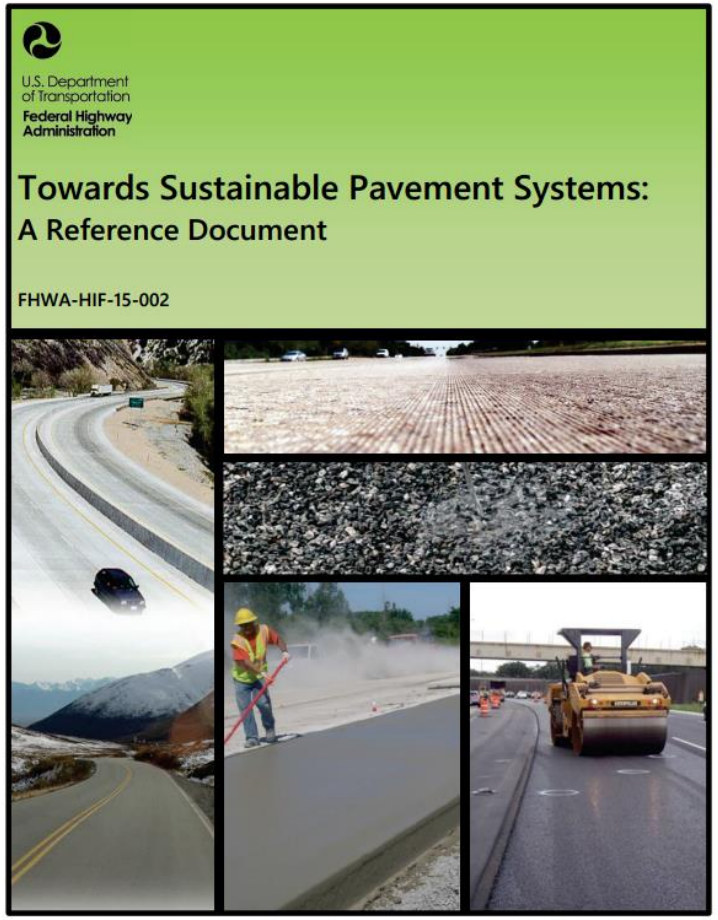
References/Links

- **FHWA *"Distress Identification Manual:"***
  https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/13092/13092.pdf

- **Caltrans *"Tack Coat Guidelines*:"**
  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?

- **John Harvey**: jtharvey@ucdavis.edu
- **Erik Updyke:** eupdyke@ucdavis.edu
- **Shadi Saadeh:** Shadi.Saadeh@csulb.edu
- **Ashraf Rahim:** arahim@calpoly.edu