NCHRP Project 9-57

Laboratory Tests to Assess Cracking Resistance of Asphalt Mixtures

Sponsored by
National Cooperative Highway Research Program

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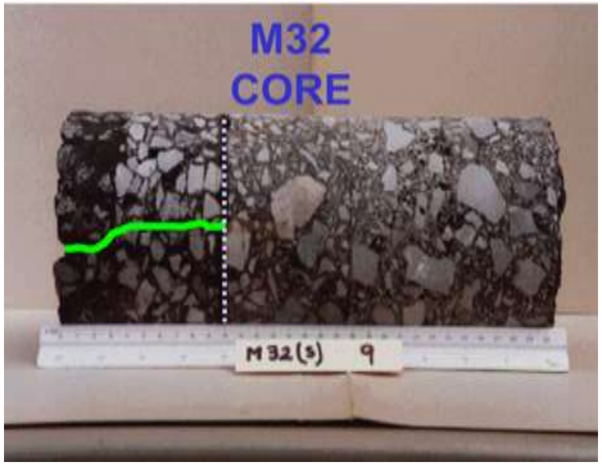
The Need

- Volumetric Mix Design – Does it make sense when our materials have changed so much?
- Balanced Mix Design
  - Max. set by AC for 98% density
  - Max. AC set by rutting test (must be less than 98% density)
  - Min. AC set by cracking test
  - Optimum is between max. AC and min. AC

Types of Cracking

Thermal

Reflection



Top-Down Fatigue

Bottom-Up Fatigue

Outline

- Project Objectives/Tasks
- Workshop and Products
- Workshop Outcomes
- Experimental Designs
  - Ruggedness
  - Interlaboratory Study
- Validation Experimental Designs/Potential Sections
  - Thermal
  - Reflection
  - Top-Down
  - Bottom-Up
- Summary

Cracking Tests Workshop

- Goals
  - Select cracking tests for 4 cracking types
  - Identify potential field/APT test sections
- What we prepared for the workshop:
  - Interim report
  - Cracking test webinars
  - Cracking test booklet
  - 9 cracking test videos

Workshop Outcomes

Items	Thermal Cracking	Reflection Cracking	Bottom-up Fatigue Cracking	Top-down Fatigue Cracking
Selected cracking tests	1. DCT 2. SCB-IL 3. SCB at low temp.	1. OT 2. SCB at intermediate temp. 3. BBF	1. BBF 2. SCB at intermediate temp.	1. SCB at intermediate temp. 2. IDT-UF
Key factors for designing field experimental test sections	1. Climate (temperature, moisture, solar radiation); 2. Traffic; 3. Pavement structure and subgrade; 4. Asphalt mixtures; 5. Existing pavement conditions for reflection cracking.			
Potential field test sections	1. LTPP; 2. SPS10; 3. MnRoad; 4. NCAT Test Track; 5. Test sections under NCHRP 9-55, 9-58, and 9-59.			

Selected Cracking Tests

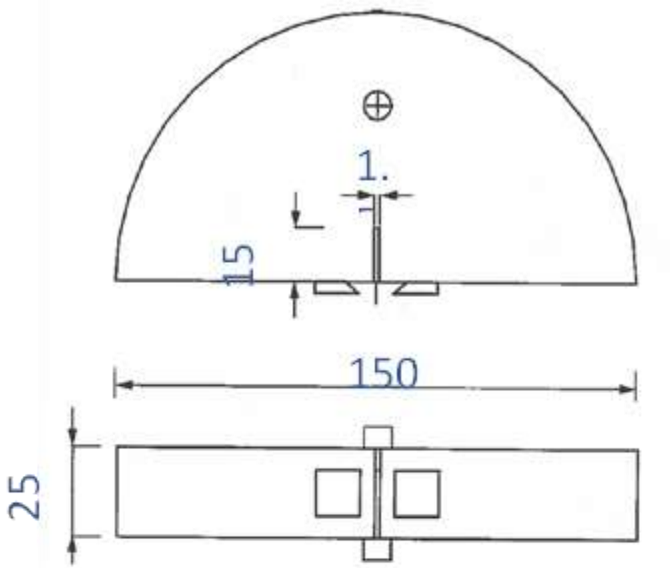
- Disc Compact Tension (DCT)
- Semi-Circular Bending (SCB)
  - University of Minnesota – Low Temperature
  - Louisiana Transp. Research Center – Intermed. Temp
  - University of Illinois – Intermed. Temp
- Overlay Tester (OT)
- Indirect Tension Test (IDT)
- Bending Beam Fatigue (BBF)

Laboratory Evaluation

- Review Existing Information and Studies
  - SCB ILS - ASTM
  - Asphalt Institute
  - NCAT
  - MnDOT
- Available Test Equipment
- Ruggedness Testing
- Precision and Bias

Ruggedness Testing

- Purpose: Identify factors that influence test results and determine how closely they must be controlled.
- Sensitivity test on variables instead of materials.
- Example: SCB
  - Specimen thickness
  - Loading rate
  - Test temperature
  - Notch depth
  - Air voids



Interlaboratory Study

- Purpose: Determine repeatability and reproducibility of test method.
  - Repeatability – single operator
  - Reproducibility – multiple laboratories
- Test familiarization is important
- Test specimens from one laboratory
  - Virgin DGA with 19 mm NMAS
  - Virgin DGA with 9.5 mm NMAS
  - DGA with high binder replacement

Field Validation Experimental Design

- Objective:
  - Validate Cracking Tests
  - Not Study Cracking Mechanisms
- Want to make sure cracking test differentiates mixes that will crack from those that will not.
- D-optimal Design
  - Full or even partial factorials not practical
  - D-opt: computer generated design that selects the best subset of factor-level combinations
  - Considers important effects with smaller number of observations

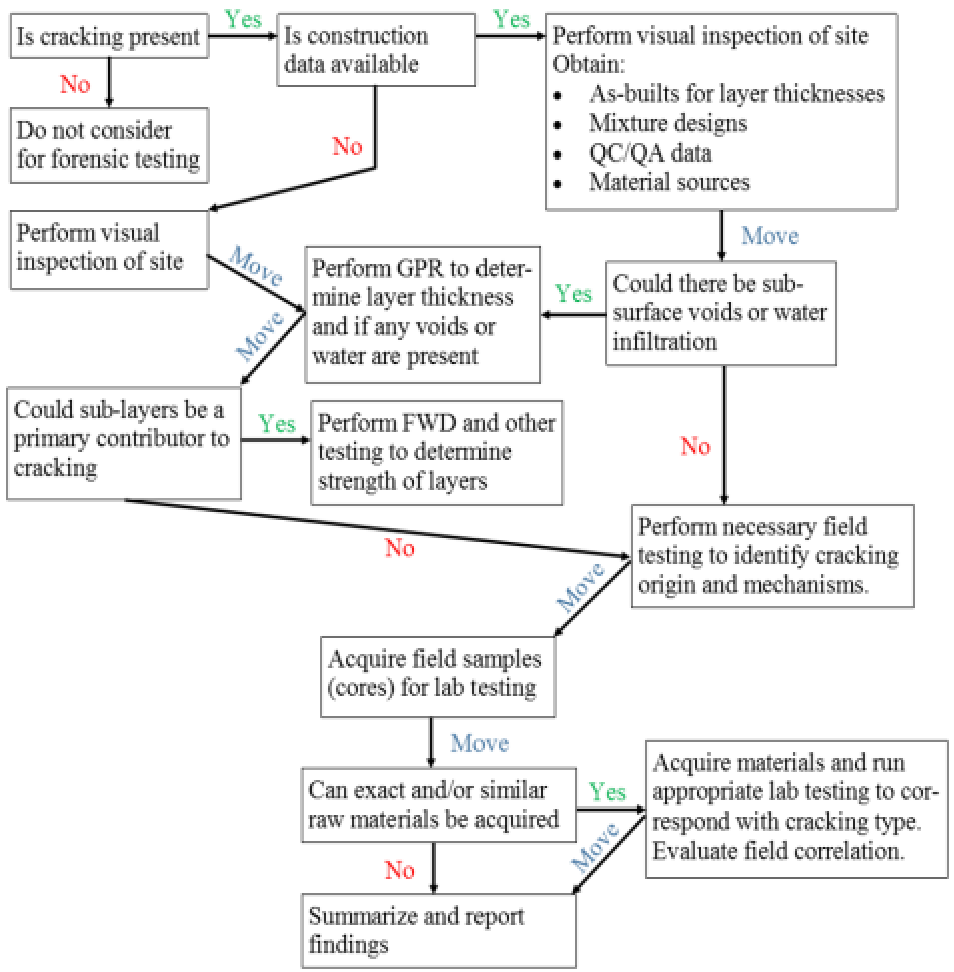
Field Validation Experimental Design

- Consider Factors
  - Pavement Structure
  - Climate
  - Traffic
  - Mix Types
  - Binders
- Existing Facilities vs. New Sections

Field Validation

- Present Schedule
- Cost Estimate
- Material Quantities
- Provide Forensic Plan

Forensic Plan



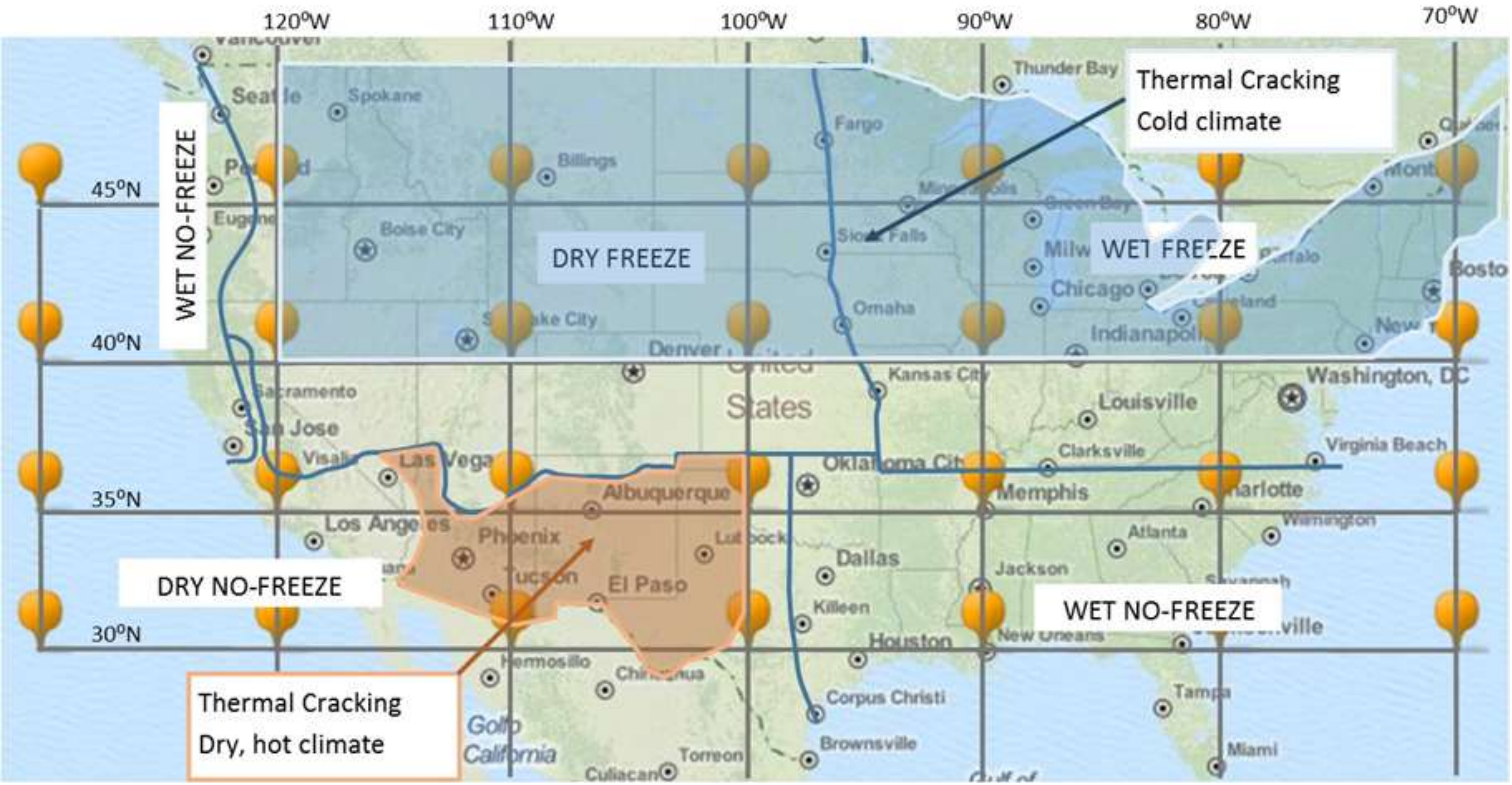
Thermal Cracking

- Climate
  - Cold, few F-T cycles
  - Diurnal cycling
- Mix Types
  - DGA with spec binder
  - DGA Low PG-1 grade
  - SMA
- Pavement Structure
  - Thick: > 6 inches
  - Thin: ≤ 6 inches
- Traffic
  - High: > 300k ESAL/yr
  - Low: < 300k ESAL/yr

Thermal Cracking D-opt.

Test section	Climate	Mixture	Structure	Traffic
1	Cold	DGA_Regular PG	Thick AC	High
2	Cold	SMA	Thin AC	High
3	Cold	DGA_PG-Lower	Thin AC	Low
4	Diurnal cycling regions	DGA_PG-Lower	Thick AC	High
5	Diurnal cycling regions	SMA	Thick AC	Low
6	Diurnal cycling regions	DGA_Regular PG	Thin AC	Low

Thermal Cracking



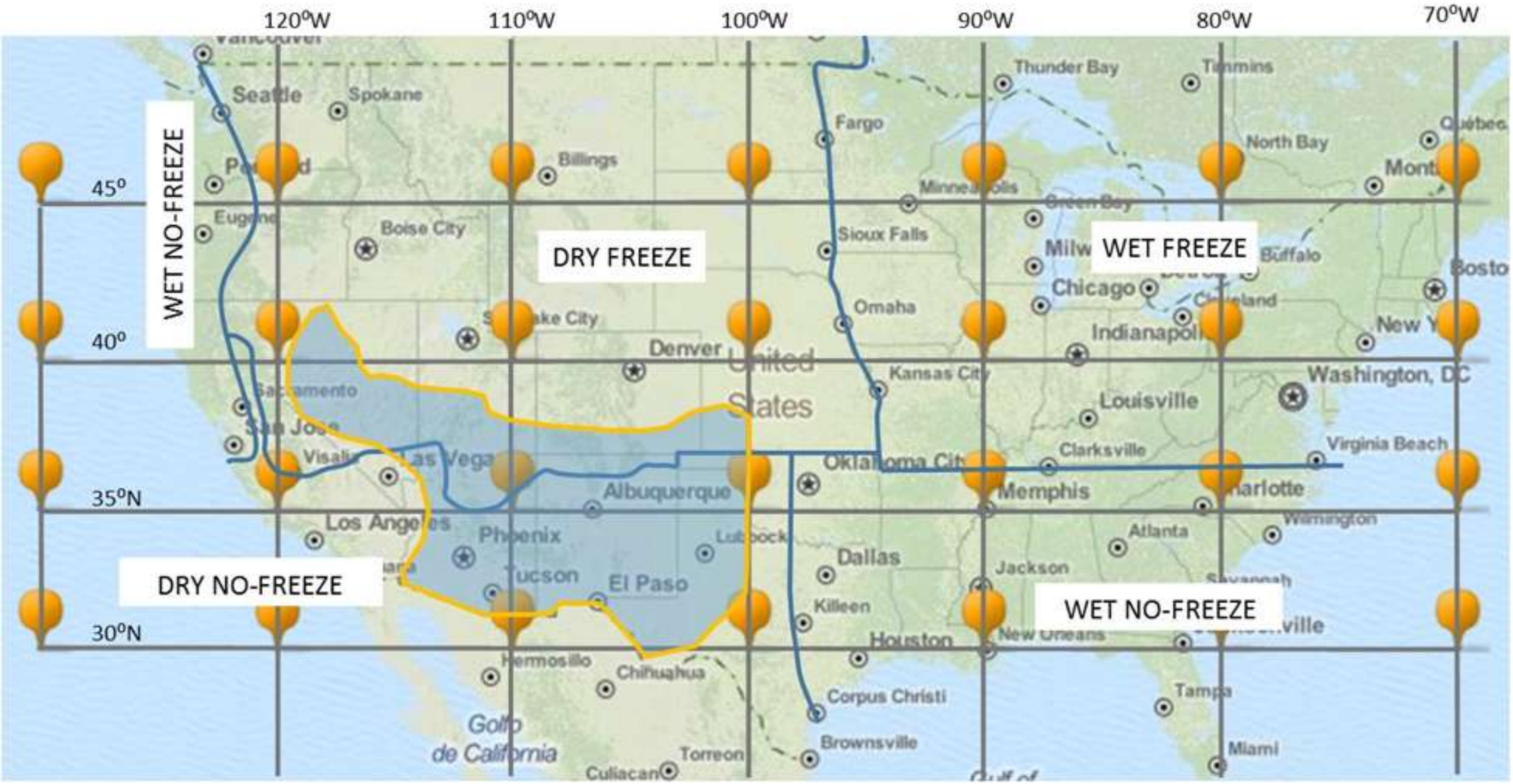
Reflection Cracking

- Climate
  - Steady state warm
  - Diurnal temp cycling
- Existing Structure
  - Cracked AC/Gran Base
  - Cracked AC/CTB
  - JPCP with poor LTE
  - JPCP with good LTE
- Mix Type
  - DGA
  - Performance Mix (SMA, A-R, etc.)
  - Crack resistant (Strata, Texas CAM, etc.)
- Overlay Thickness
  - Thin: <2 in.
  - Thick: 2-6 in.
- Traffic: High (>300k ESAL/yr)

Reflection Cracking D-opt.

Test section	Climate	Existing pavement type	Mixture	Overlay thickness	Traffic
1	Steady state	Cracked AC/Granular base	DGA	≤ 50 mm (2 inches)	> 300,000 ESAL/year
2	Steady state	Cracked AC/CTB base	Special crack resistant mix	≤ 50 mm (2 inches)	
3	Steady state	JPCP with low LTE	Performance mix	≤ 50 mm (2 inches)	
4	Steady state	JPCP with high LTE	Special crack resistant mix	50–150 mm (2–6 inches)	
5	Temperature cycling	Cracked AC/Granular base	Special crack resistant mix	≤ 50 mm (2 inches)	
6	Temperature cycling	Cracked AC/CTB base	Performance mix	50–150 mm (2–6 inches)	
7	Temperature cycling	JPCP with low LTE	DGA	50–150 mm (2–6 inches)	

Temperature Cycling for Refl. Cracking



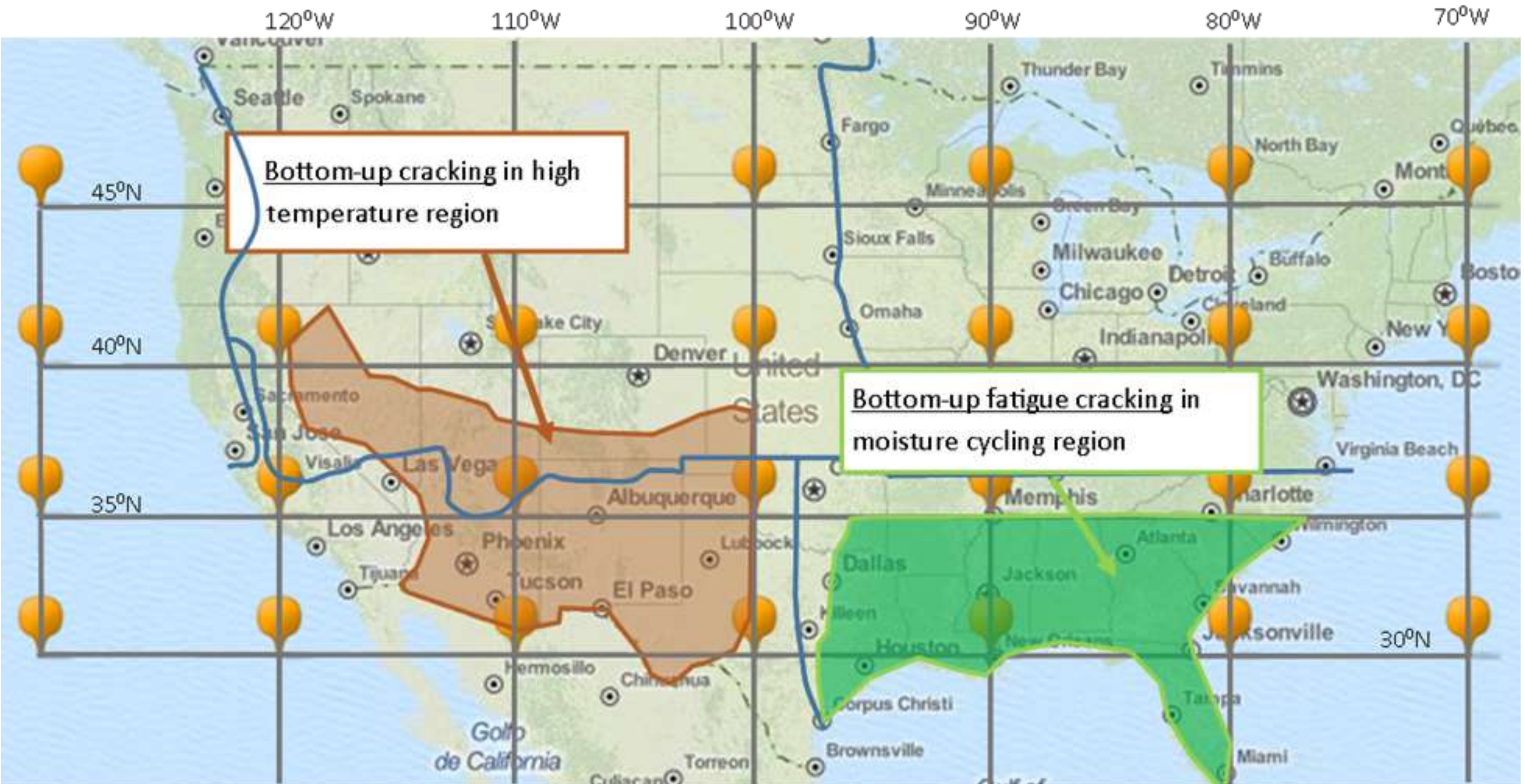
Bottom-up Fatigue

- Climate
  - High temp/moist cycling
  - All other
- Traffic
  - High: >300k ESAL
  - Low: ≤300k ESAL
- Mix Type
  - V. good resistance
  - Good resistance
  - Medium resistance
  - Poor resistance
- Pavement Structure (AC < 6 in)
  - AC/gran
  - AC/CTB
- Subgrade
  - Good
  - Poor

Bottom-up Fatigue

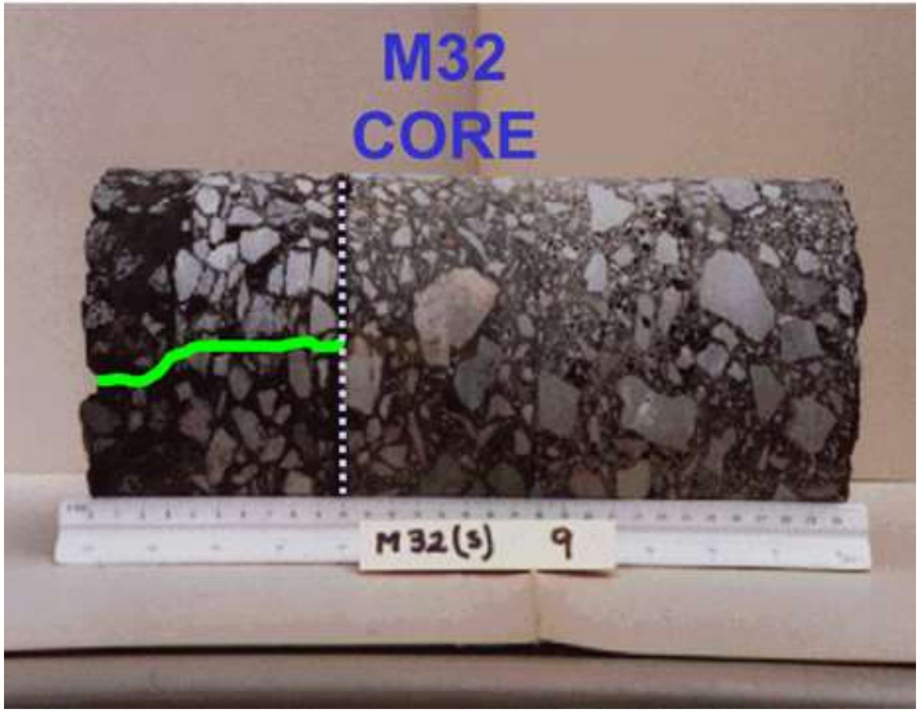
Test section	Climate	Traffic	Mixture	Pavement structure	Subgrade
1	All others	High	Very good cracking resistance mix	AC/CTB base	Poor
2	High temperature/ moisture cycling regions	High	Good cracking resistance mix	AC/granular base	Poor
3	All others	High	Medium cracking resistance mix	AC/granular base	Good
4	High temperature/ moisture cycling regions	High	Poor cracking resistance mix	AC/CTB base	Good
5		Low	Very good cracking resistance mix	AC/granular base	Good
6	All others	Low	Good cracking resistant mix	AC/CTB base	Good
7	High temperature/ moisture cycling regions	Low	Medium cracking resistance mix	AC/CTB base	Poor
8	All others	Low	Poor cracking resistance mix	AC/granular base	Poor

Bottom-up Fatigue



Top-down Cracking

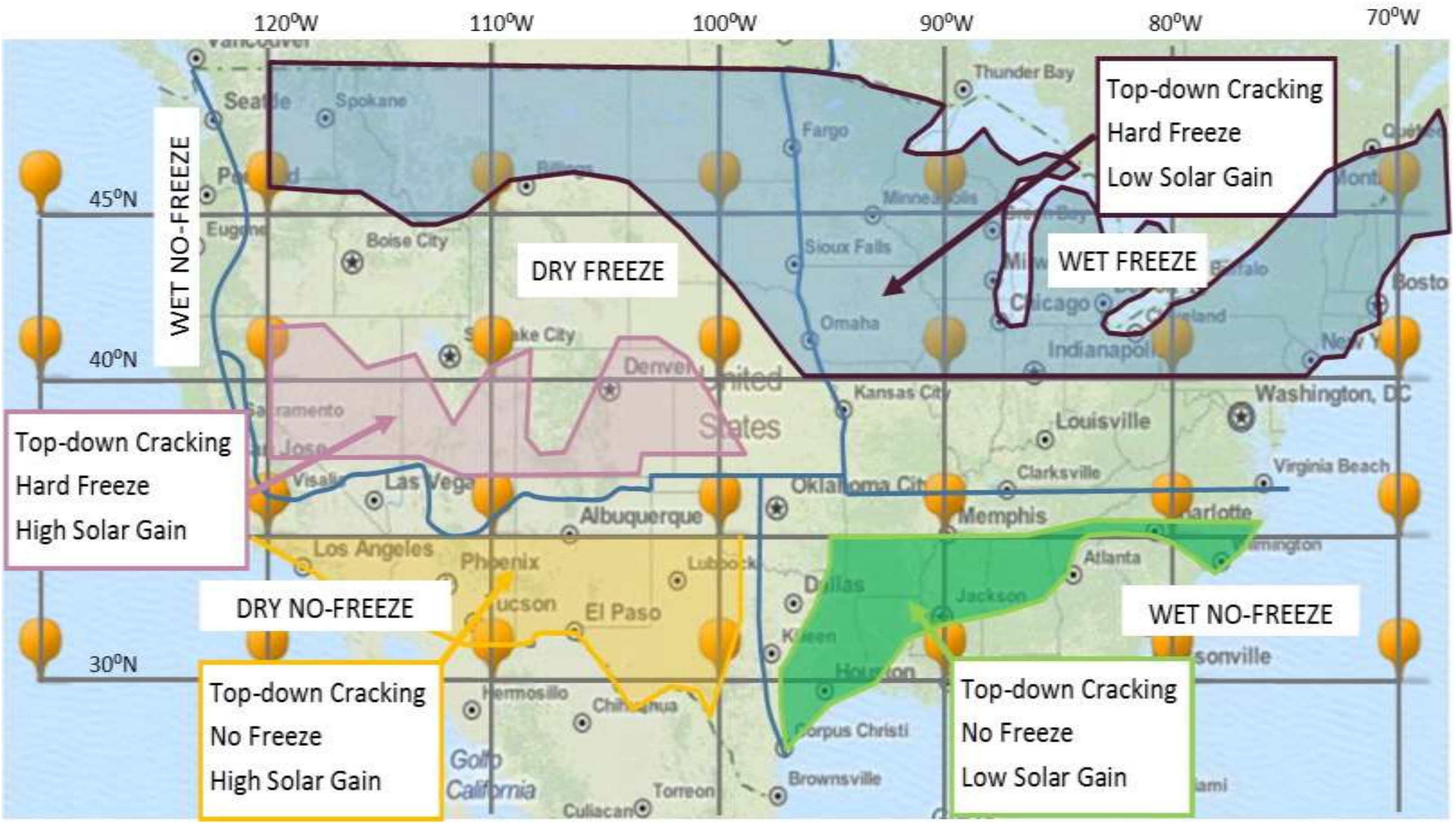
- Climate
  - Hard freeze, low solar
  - Hard freeze, high solar
  - No freeze, low solar
  - No freeze, high solar
- Mix Type
  - DGA coarse, high AV
  - DGA coarse, low AV
  - DGA fine, high AV
  - DGA fine, low AV
- Traffic
  - High (>300k ESAL/yr) fast
  - Low (<u><</u>300k ESAL/yr) slow
  - High (>300k ESAL/yr) slow
- Pavement: <u>></u>6 in.



Top-down Cracking D-opt

Test section	Climate	Traffic	Mixture
1	Hard Freeze, High Solar	Low volume, low speed	DGA fine, high AV
2	Hard Freeze, High Solar	High volume, low speed	DGA coarse, high AV
3	Hard Freeze, Low Solar	High volume, high speed	DGA fine, low AV
4	Hard Freeze, Low Solar	High volume, low speed	DGA fine, high AV
5	No Freeze, High Solar	High volume, high speed	DGA coarse, low AV
6	No Freeze, High Solar	Low volume, low speed	DGA coarse, high AV
7	No Freeze, High Solar	High volume, low speed	DGA fine, low AV
8	No Freeze, Low Solar	High volume, high speed	DGA fine, high AV
9	No Freeze, Low Solar	Low volume, low speed	DGA coarse, low AV

Top-down Cracking



Available Facilities and Characteristics

Items	APT	Full-scale test tracks	Full-scale Test Roads	In-service Pavements
Examples	FHWA-ALF, Louisiana-LAF, CalTrans-HVS, Florida-HVS, Illinois-ATLAS, TxDOT-APT	WesTrack NCAT test track	MnRoad	LTPP-GPS/SPS sections and state DOT sections NCHRP Sections
Traffic load	Known traffic; well controlled traffic; often overloaded	Known traffic; WesTrack: 4 units of tractor/ trailer –triple combinations NCAT Track: four fully loaded trucks	Known traffic; Real traffic	Unknown traffic (most of time); Real traffic; many SPS sections equipped with WIMs
Traffic speed	Slow; around 5-12 mph	Around 40-45 mph	Real traffic and real speed (around 60 mph)	Real traffic and real speed (around 60 mph)
Test period	Several months	one-three years	4 years	Several years to more than 15 years
Environment	Temperature is often controlled	Natural weather	Natural weather	Natural weather
Aging effect	Artificial aging can be considered, but not natural aging	Impact of short-term aging on performance is considered.	Impact of short/medium-term aging is considered	Impact of long-term aging is addressed

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