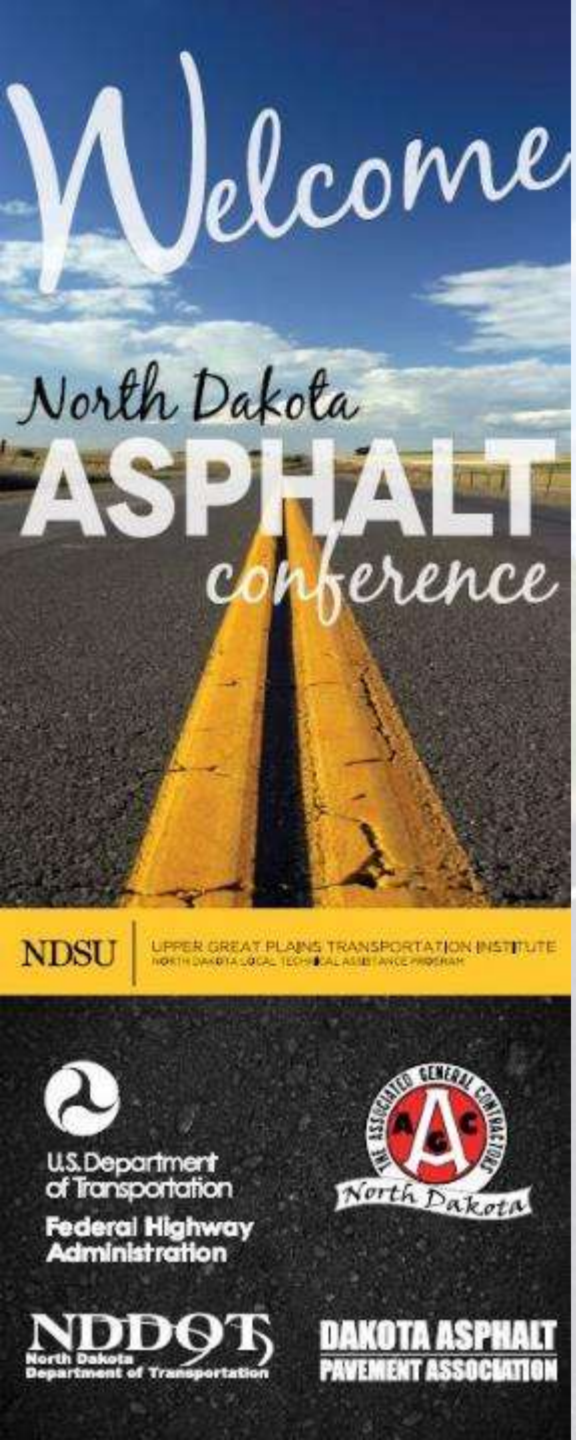


Long Life Pavement Fundamentals

Dr. David Timm, PE

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

North Dakota Asphalt Conference

Bismarck, ND - April 10-11-2018

Global Roadway Infrastructure

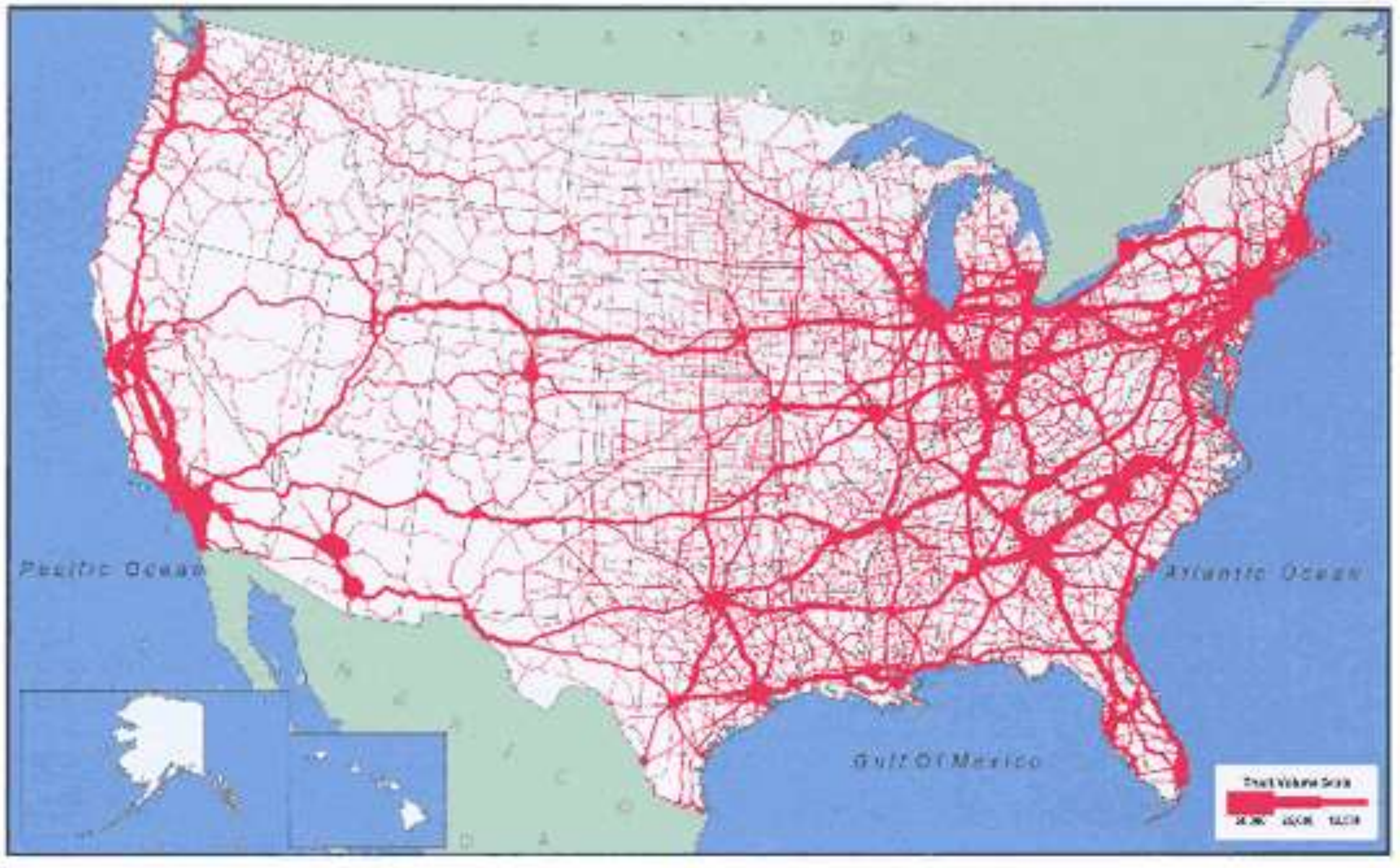
- Nearly 40 million miles of roads on Earth (2013)
  - Enough roads to circle Earth 1,600 times

https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=0ahUKEwiOmdmw3PbQAhUDVyYKHbNADMsQjRwIBw&url=http%3A%2F%2Fwww.telegraph.co.uk%2Fnews%2Fscience%2Fpicture-galleries%2F8838796%2FSatellite-images-of-Earth-show-roads-air-traffic-cities-at-night-and-internet-cables.html%3Fimage%3D10&bvm=bv.141536425,d.eWE&psig=AFQjCNE7rZhGP-7foDHDKcY2V66xH19SGw&ust=1481909260361755

Global Roadway Mileage – Top 5 Countries

U.S. Roadway Infrastructure

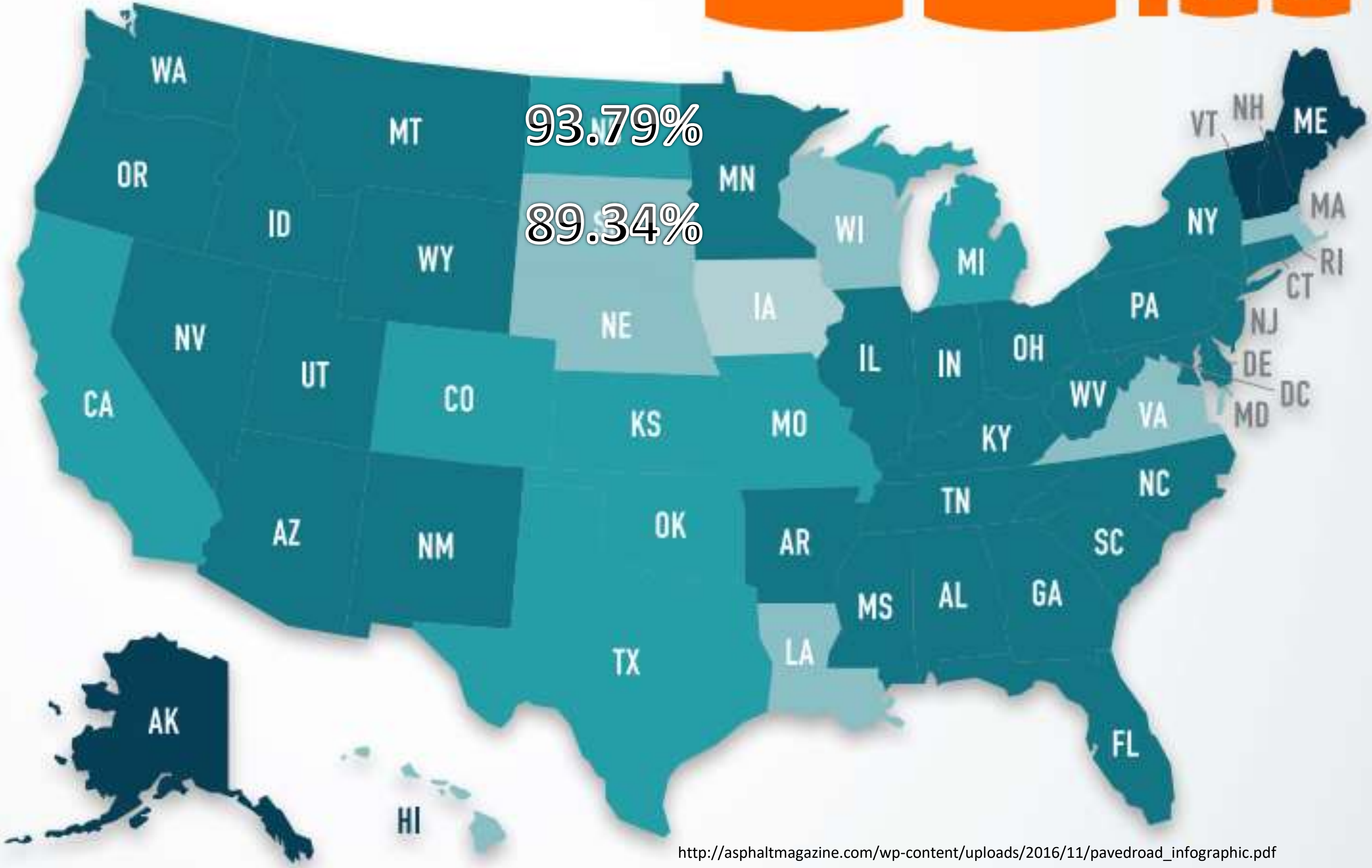
- 2,674,821 miles paved
- 1,417,901 miles unpaved



http://www.fhwa.dot.gov/policy/otps/bottlenecks/images/fig28.gif

HOW MANY OF OUR U.S. ROADS ARE PAVED WITH ASPHALT?

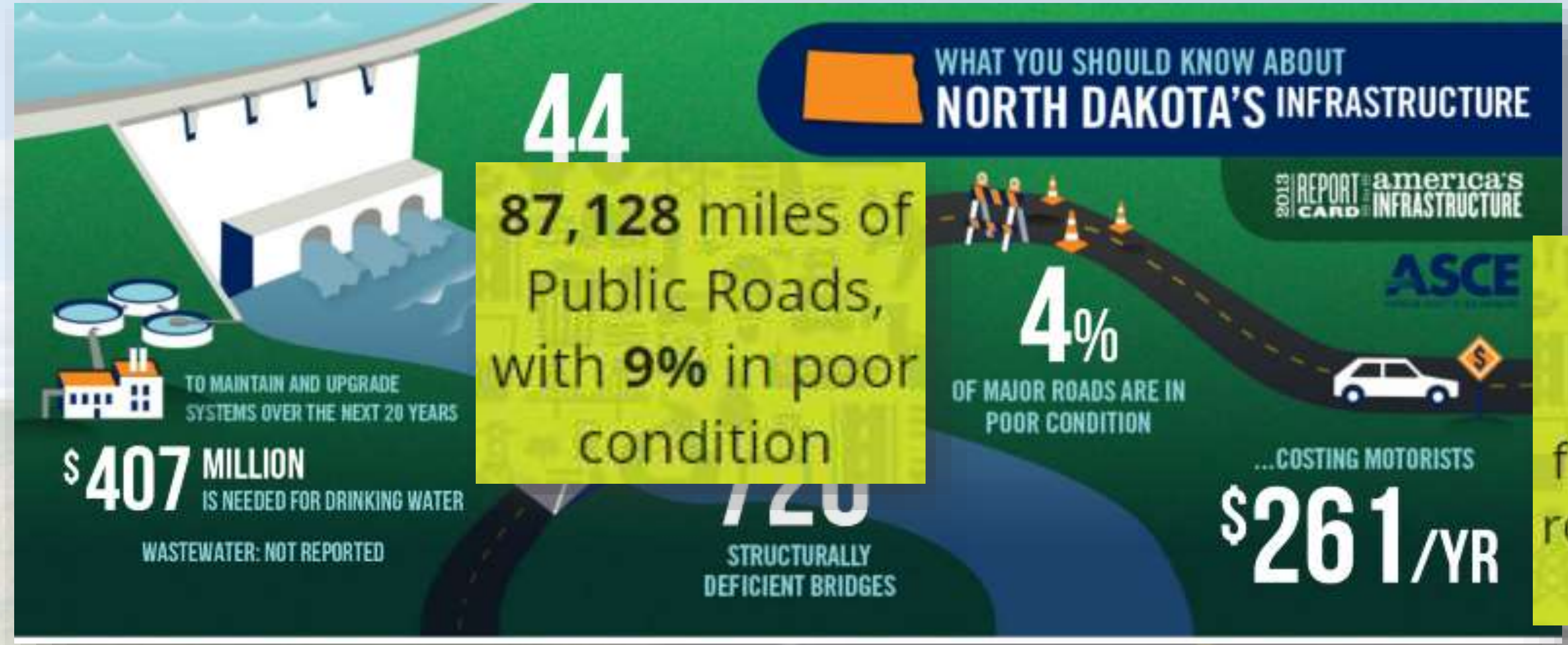
93.99%



http://asphaltmagazine.com/wp-content/uploads/2016/11/pavedroad_infographic.pdf

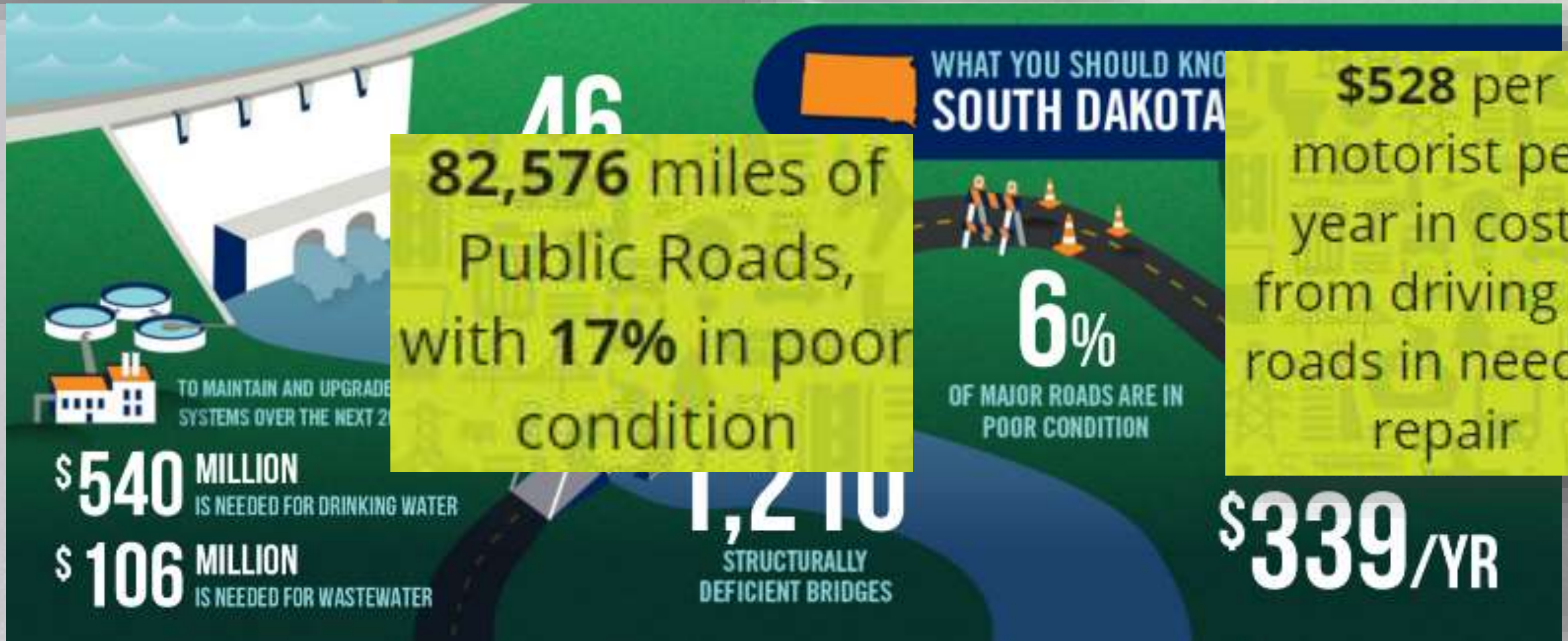
U.S. Road Report Card (2013)

Dakota Report Cards (2013)



87,128 miles of Public Roads, with **9%** in poor condition

$400 per motorist per year in costs from driving on roads in need of repair



82,576 miles of Public Roads, with **17%** in poor condition

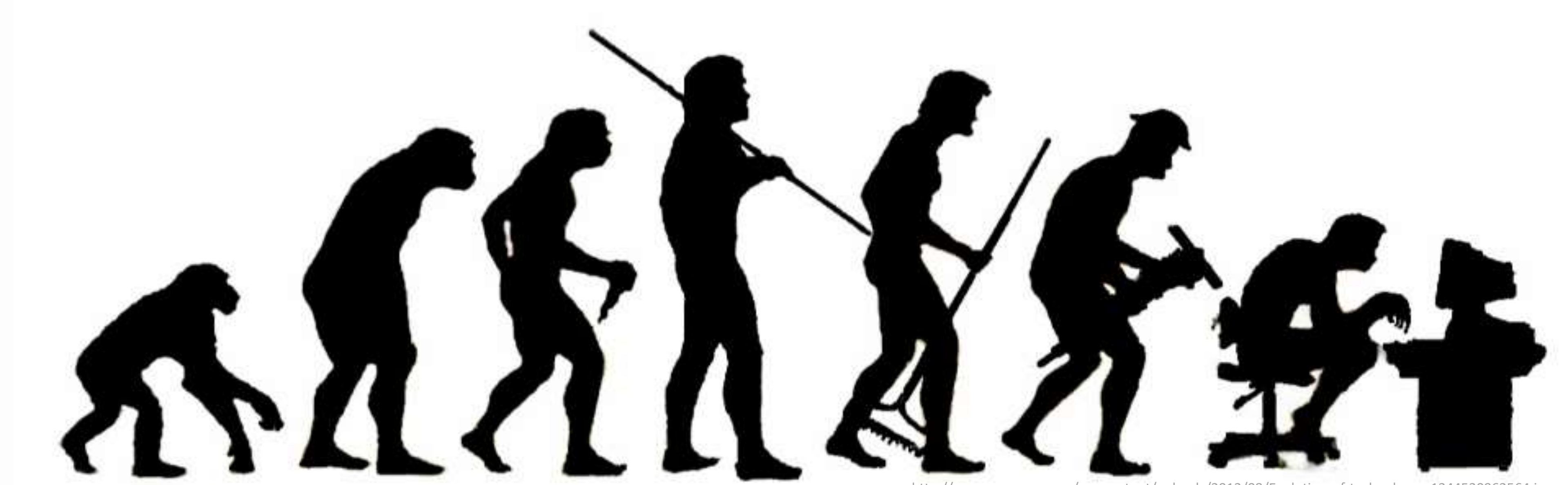
$528 per motorist per year in costs from driving on roads in need of repair

Road Construction Economics

- Estimates according to ARTBA
  - Construct new 2-lane undivided road
    - $2-$3 million per mile in rural areas
    - $3-$5 million in urban areas
  - Construct a new 4-lane highway
    - $4-$6 million per mile in rural and suburban areas
    - $8-$10 million per mile in urban areas
  - Construct a new 6-lane Interstate highway
    - $7 million per mile in rural areas
    - $11 million or more per mile in urban areas
  - Expand an Interstate Highway from 4 lanes to 6 lanes – about $4 million per mile
  - Mill and resurface a 4-lane road – about $1.25 million per mile

http://www.artba.org/about/transportation-faqs/

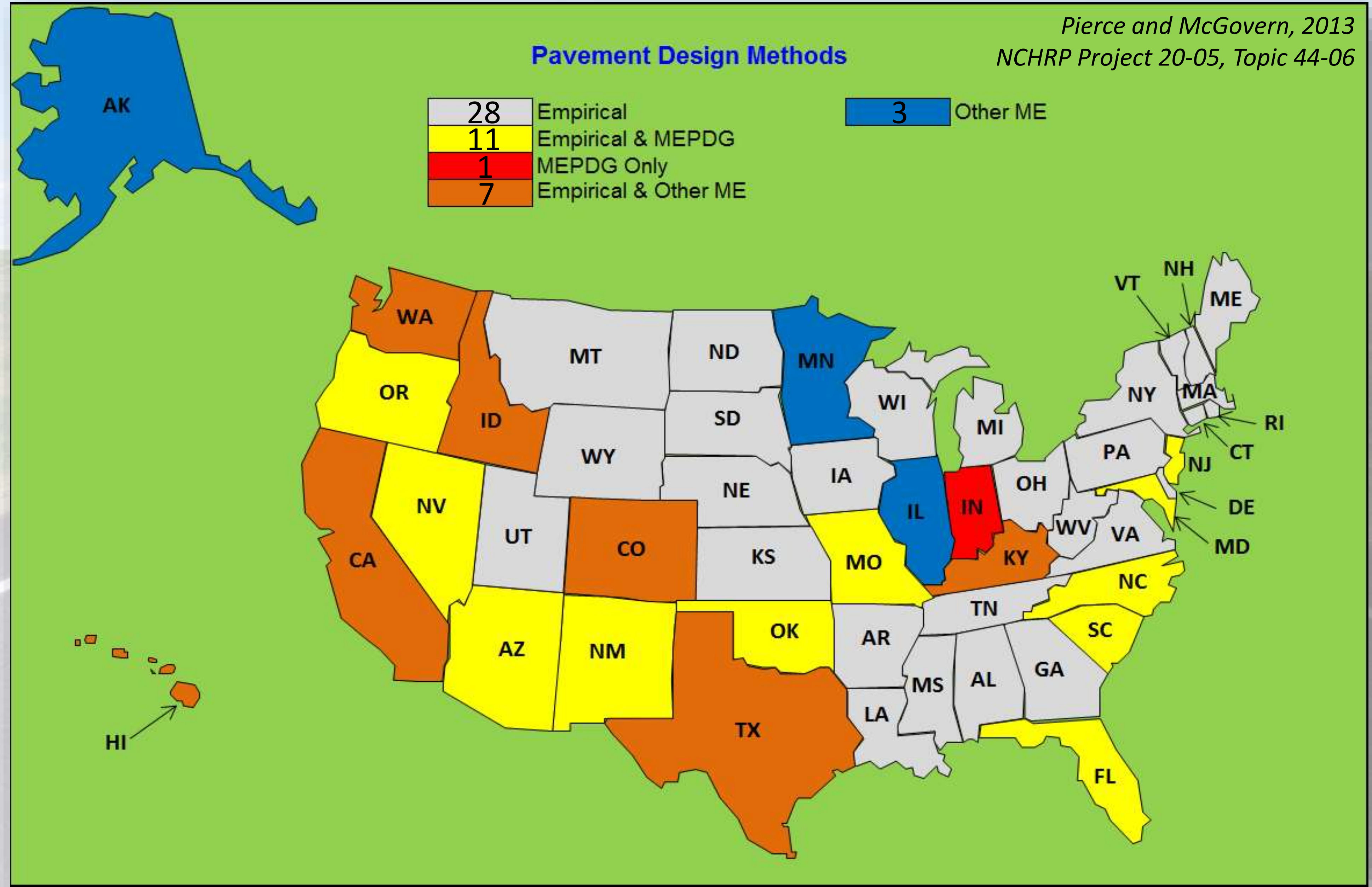
Evolution of Pavement Thickness Design



http://www.pcgerms.com/wp-content/uploads/2012/08/Evolution-of-technology-e1344530962564.jpg

Pre 1950's	1960's	1980's	1990's	2000's
Experience	Development of Empirical Methods	Initial Mechanistic-Empirical Methods	NCRHP 1-37A M-E Design	Implementation of M-E Methods

Flexible Pavement Design in the U.S. - State of the Practice



AASHTO Empirical Flexible Pavement Design Method

$$\log W_{18} = Z_R S_0 + 9.36 \log(SN+1) - 0.20 + \frac{\log\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.4 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \log M_R - 8.07$$

Empirical Method Based on AASHO Road Test

Figure 1. Looking east, Loops 5 and 2 in foreground.

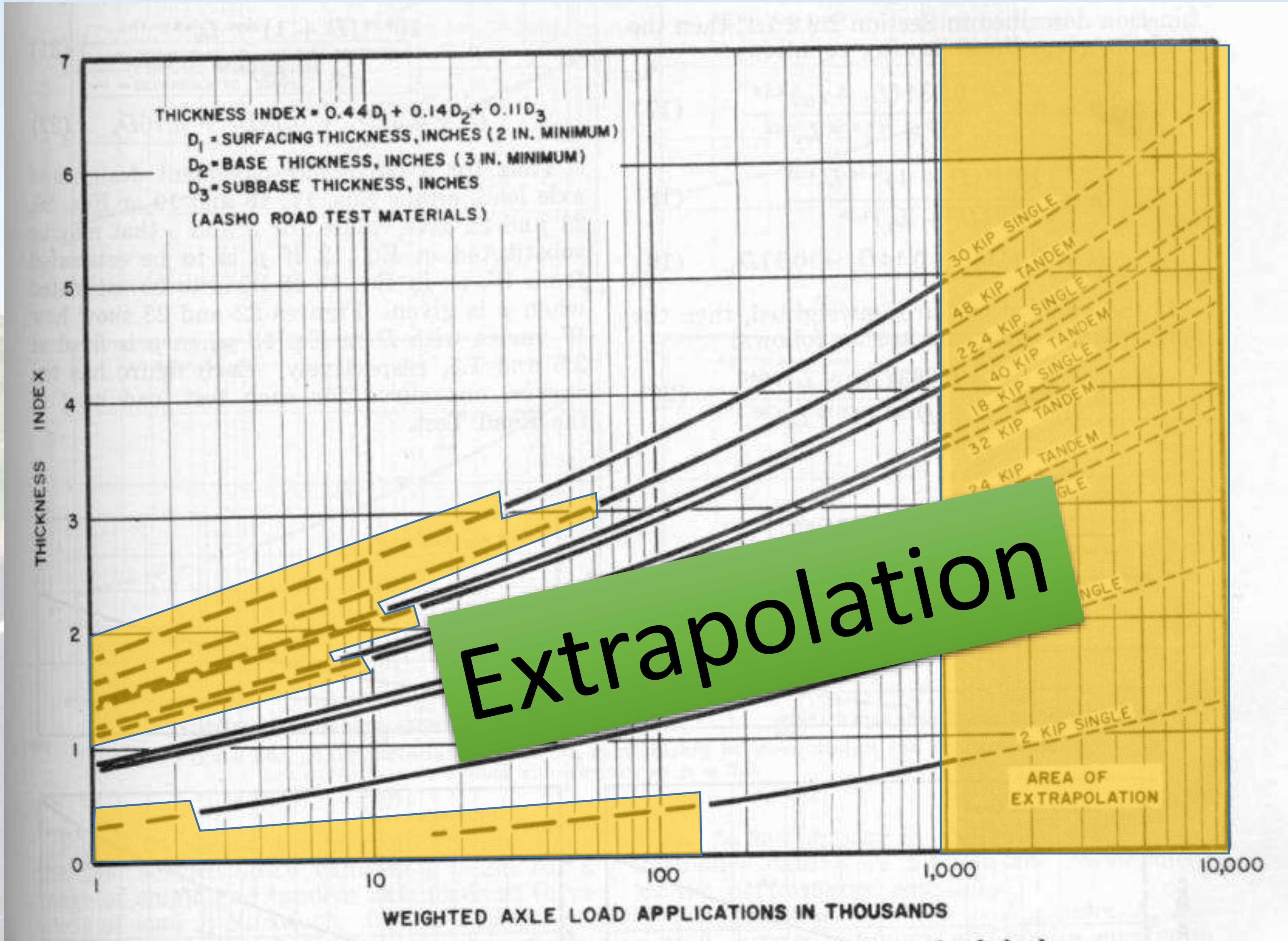
Figure 92. Automatic batch-type plant used to produce binder course mixture; dryers in tandem.

Specific Traffic and Climate

Figure 23. Test vehicles, showing typical axle arrangements and loadings.

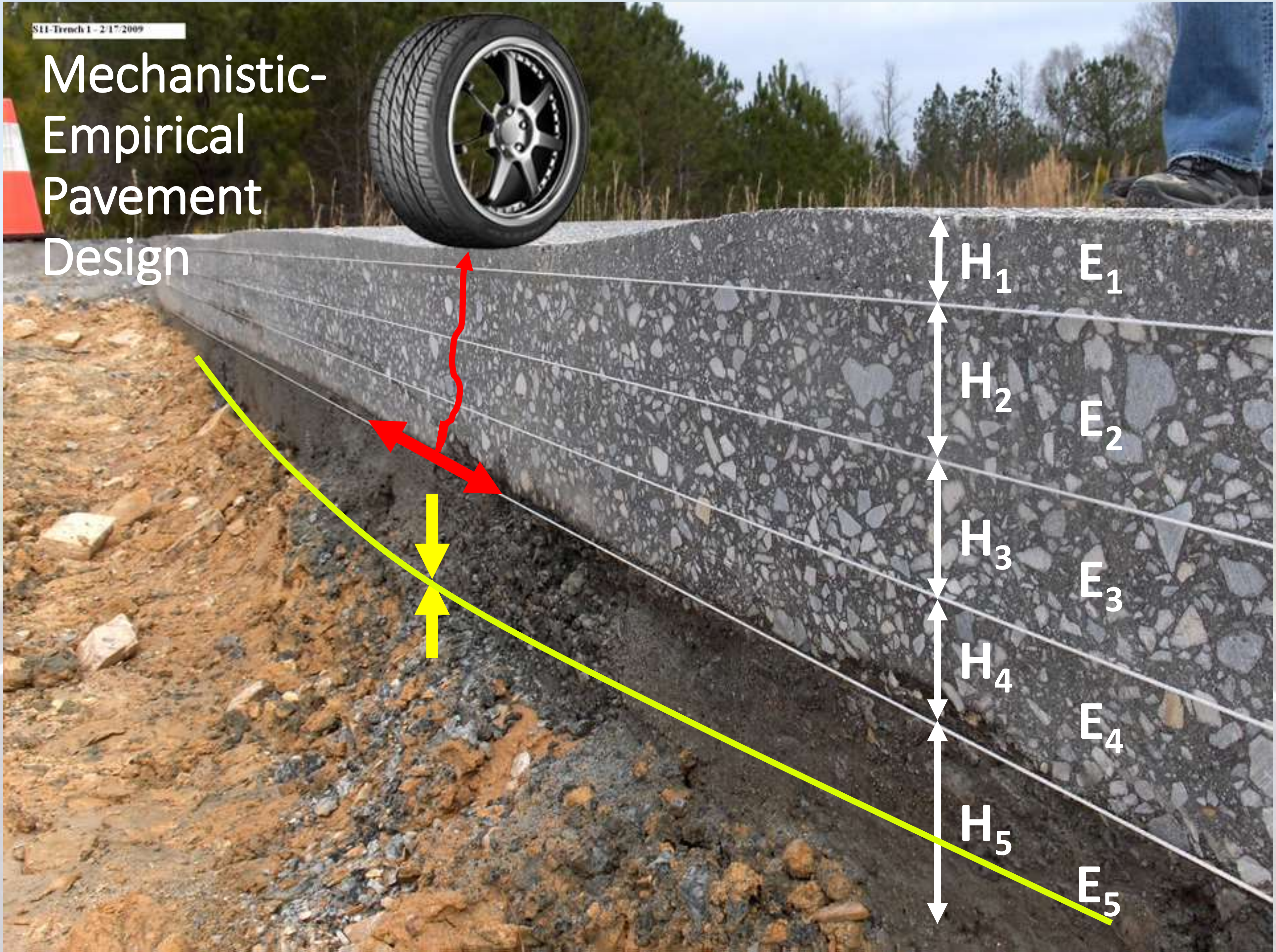
Figure 26. During periods of adverse weather traffic operations were governed by safety considerations. Snow and ice conditions usually resulted in operating at reduced speeds.

Flexible Pavement Design Curves

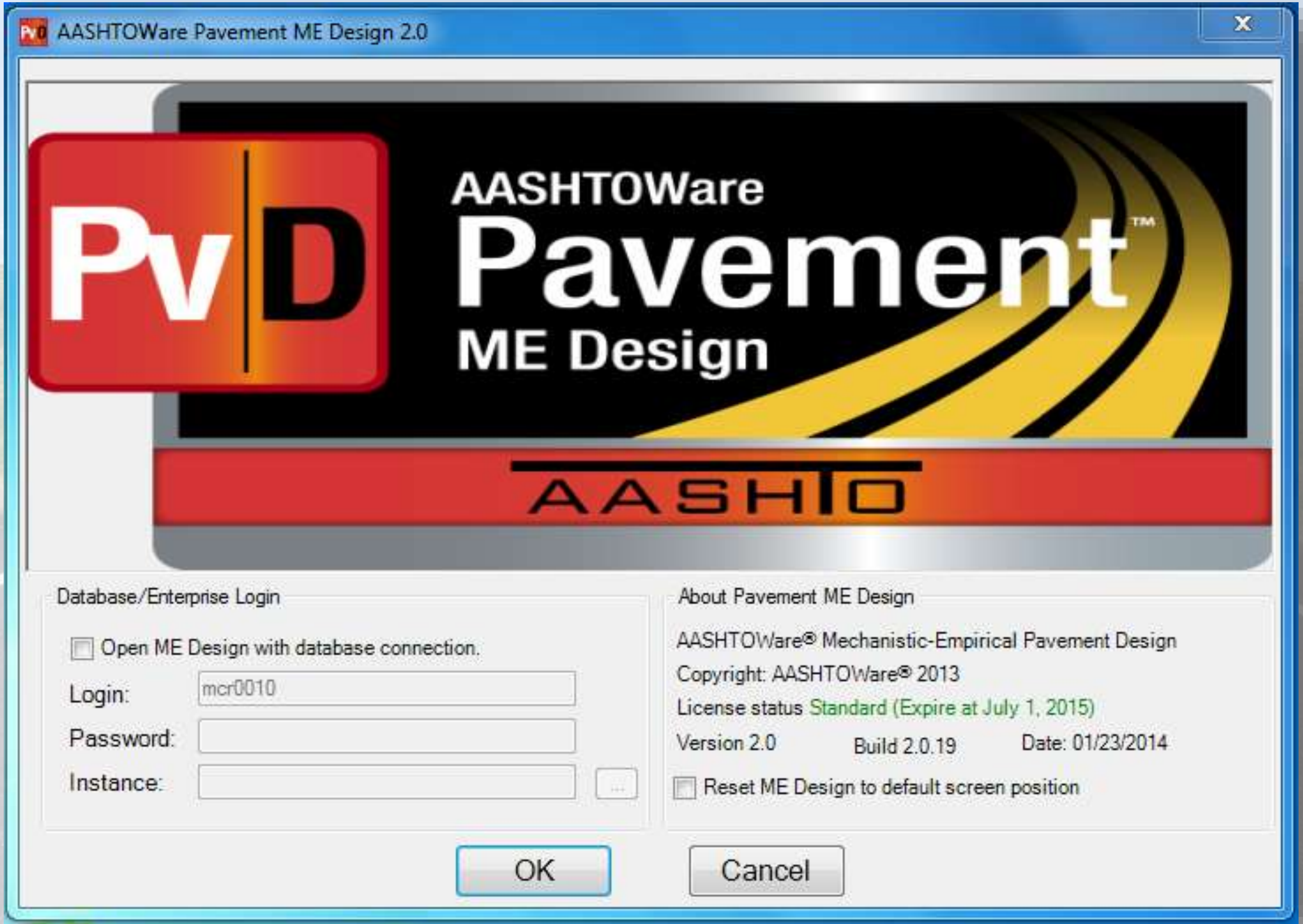


HRB, 1962 Figure 23. Main factorial experiment, relationship between design and axle load applications at $p = 1.5$ (from Road Test equations).

Mechanistic-Empirical Pavement Design

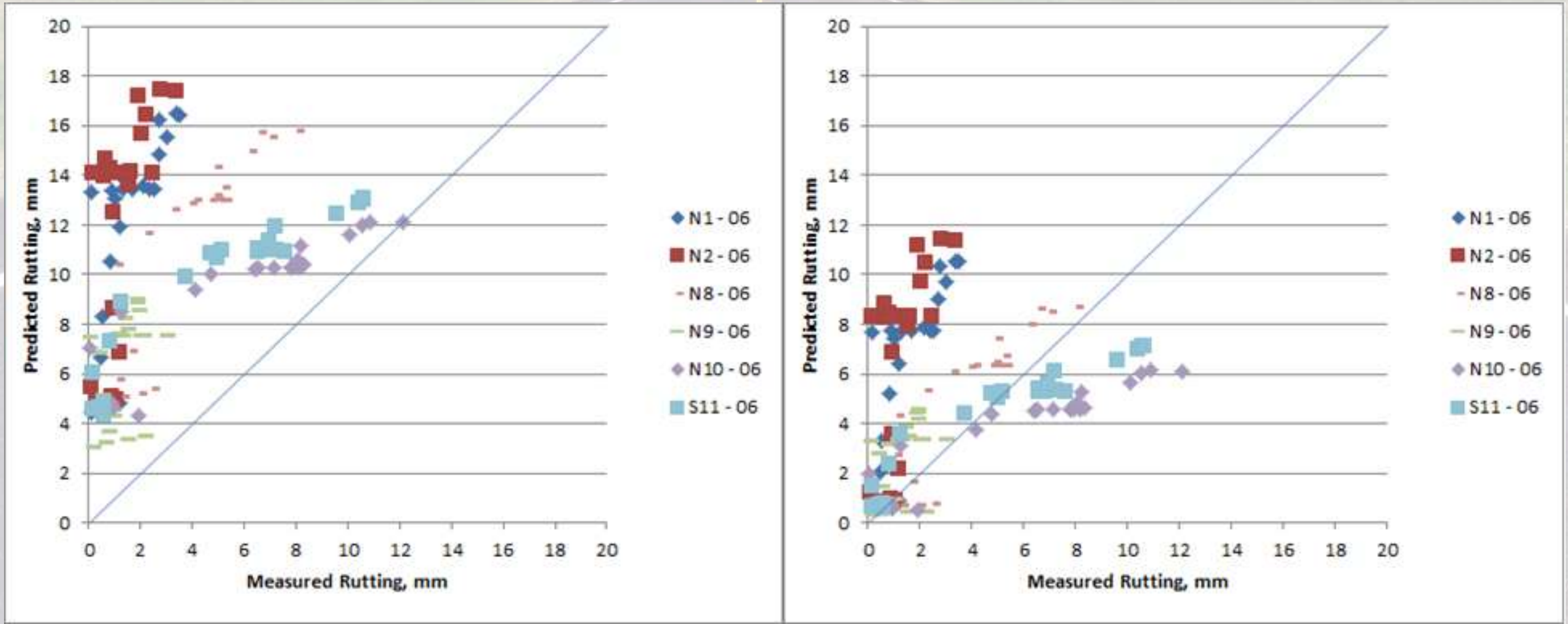


AASHTO M-E Design Software



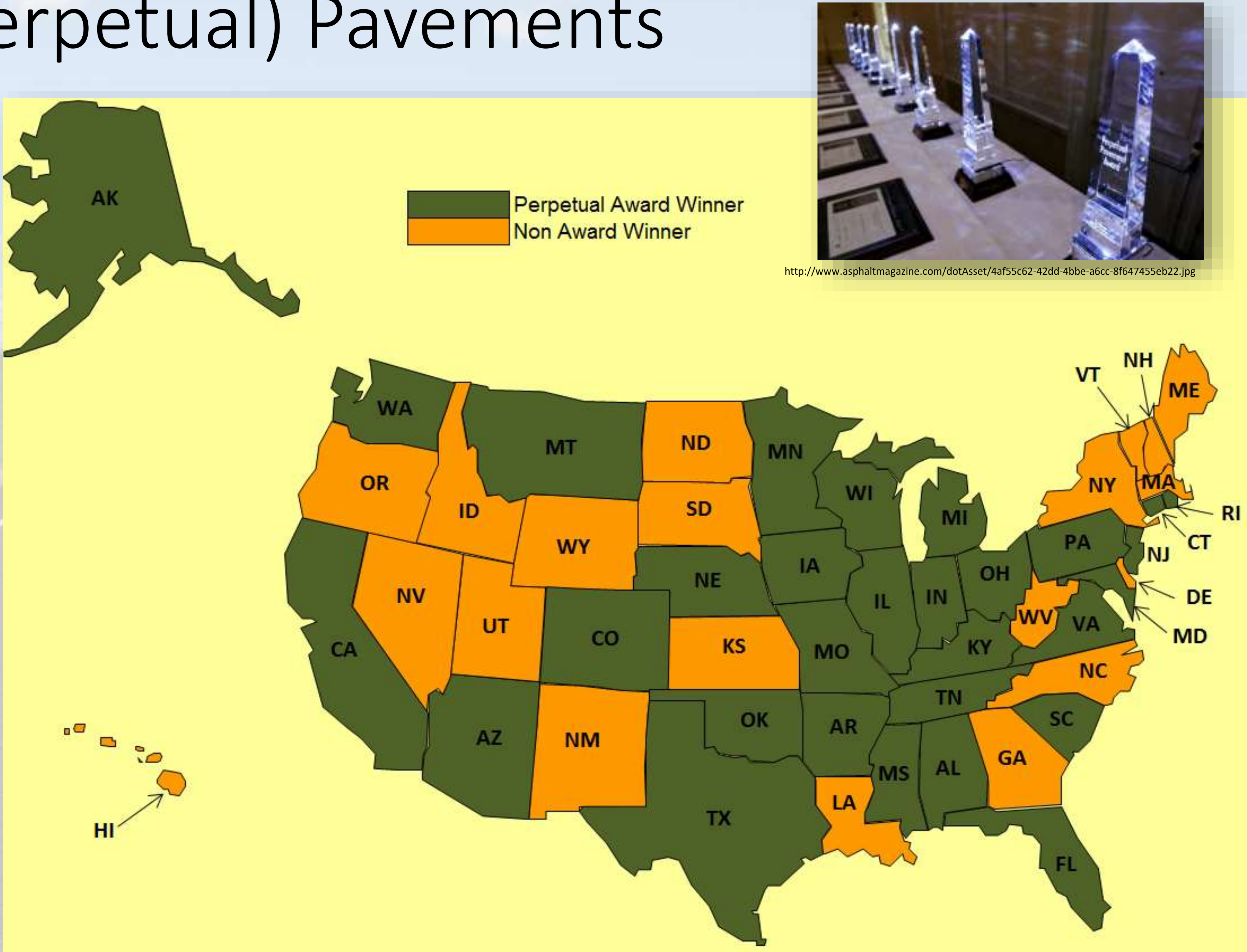
Major Limitations of M-E Design

- Pavement performance prediction
  - Evaluation
  - Calibration
  - Verification
- Pavements are still designed to fail



Long-Life (Perpetual) Pavements

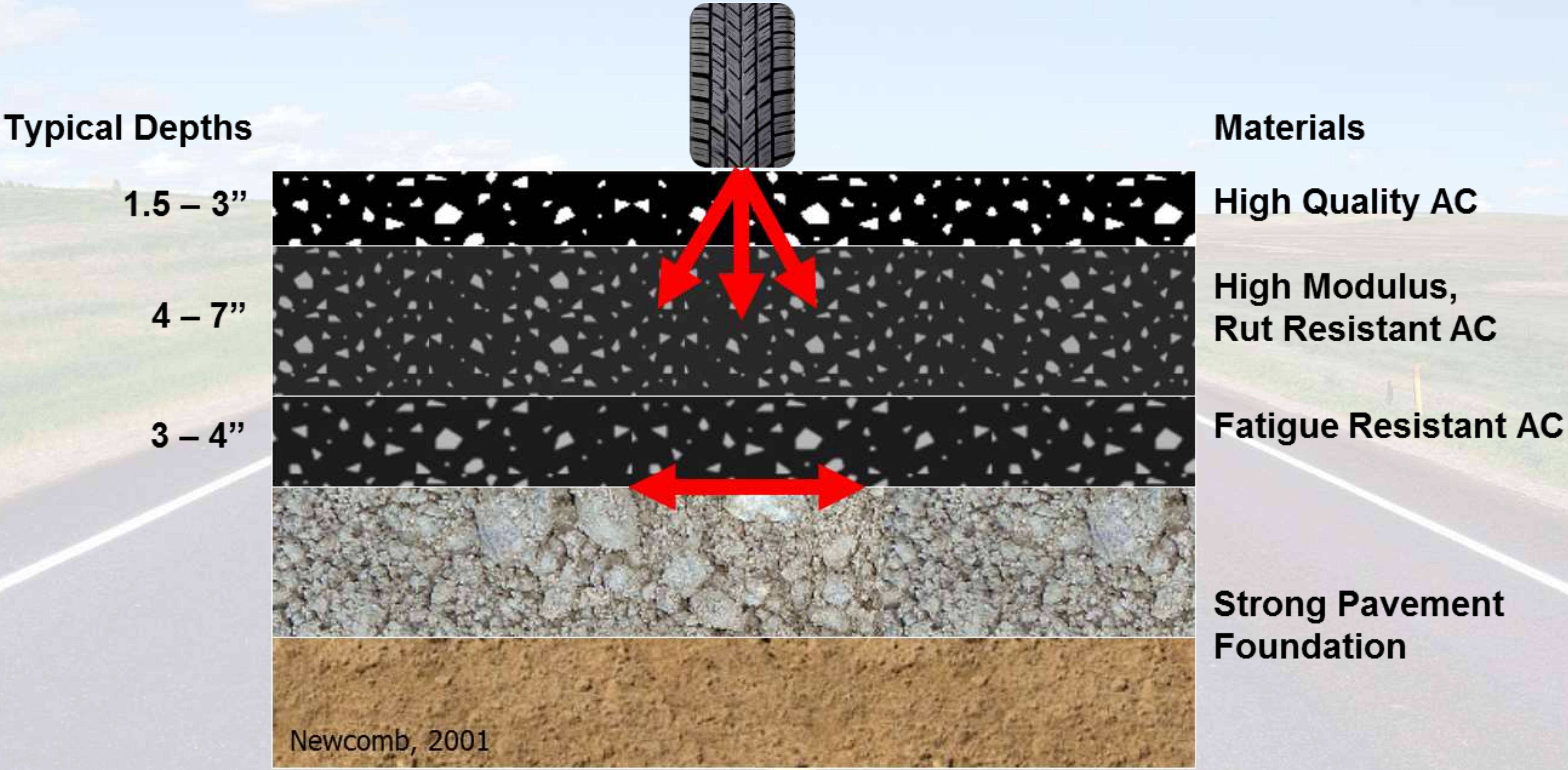
- 35+ Year Service
- Minimal Improvements
- No deep distress
  - Problems only at surface



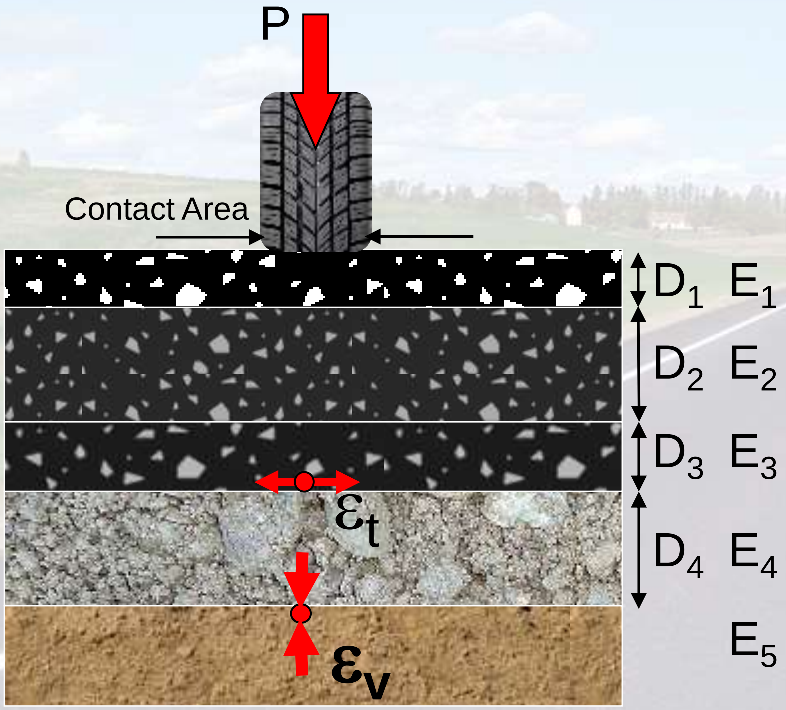
http://www.asphaltmagazine.com/dotAsset/4af55c62-42dd-4bbe-a6cc-8f647455eb22.jpg

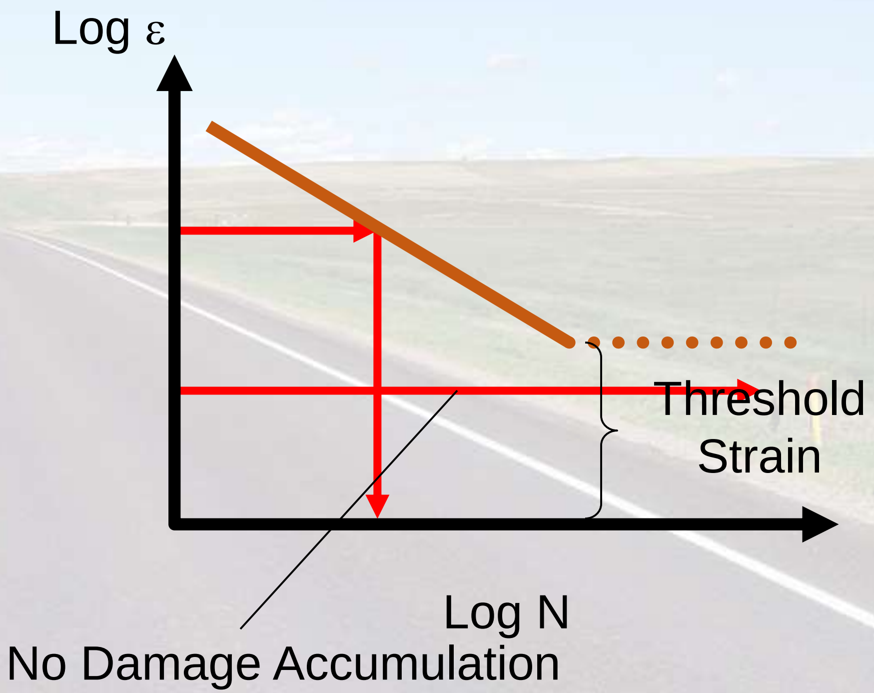
Perpetual Pavements Avoid Deep Structural Problems

Perpetual Pavement Cross-Section



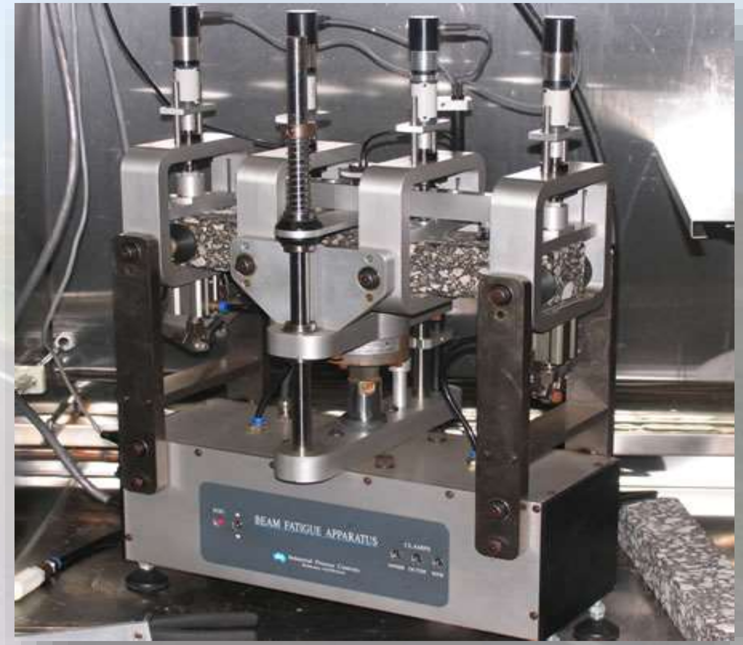
Mechanistic-Empirical Perpetual Pavement Design





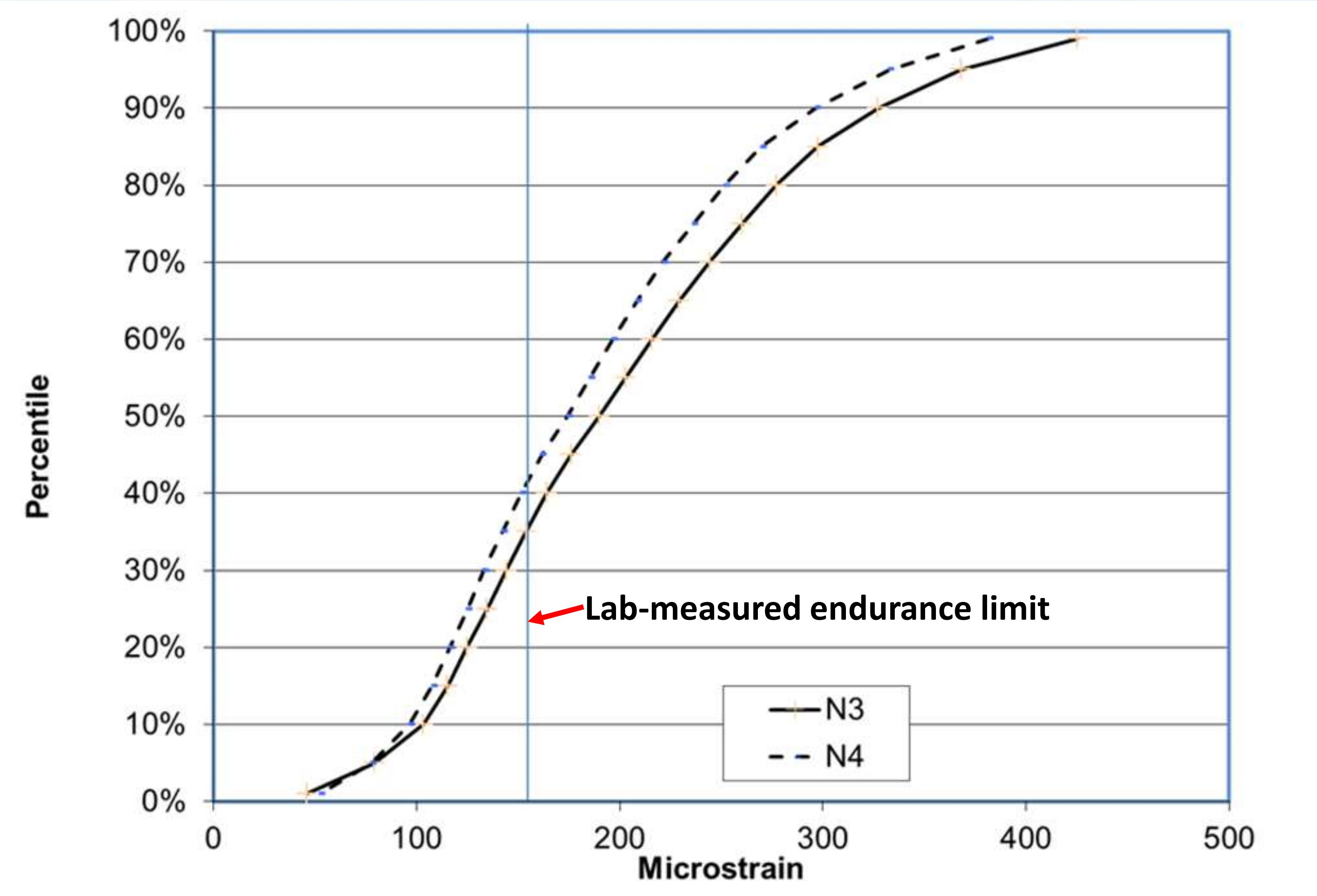
What is the endurance limit for asphalt concrete?

- 1972 – Monismith estimates about 70 $\mu\varepsilon$
- 2001 – I-710 designed at 70 $\mu\varepsilon$
- 2002 – 70 $\mu\varepsilon$ used by APA
- 2007 – NCHRP 9-38 Lab Study
  - 100 $\mu\varepsilon$ for unmodified binders
  - 250 $\mu\varepsilon$ for modified binders
  - Lab conditions more severe than field
- 2007 – MEPDG uses 100 to 250 $\mu\varepsilon$
- 2008 – Measurements at NCAT Test Track show higher strains

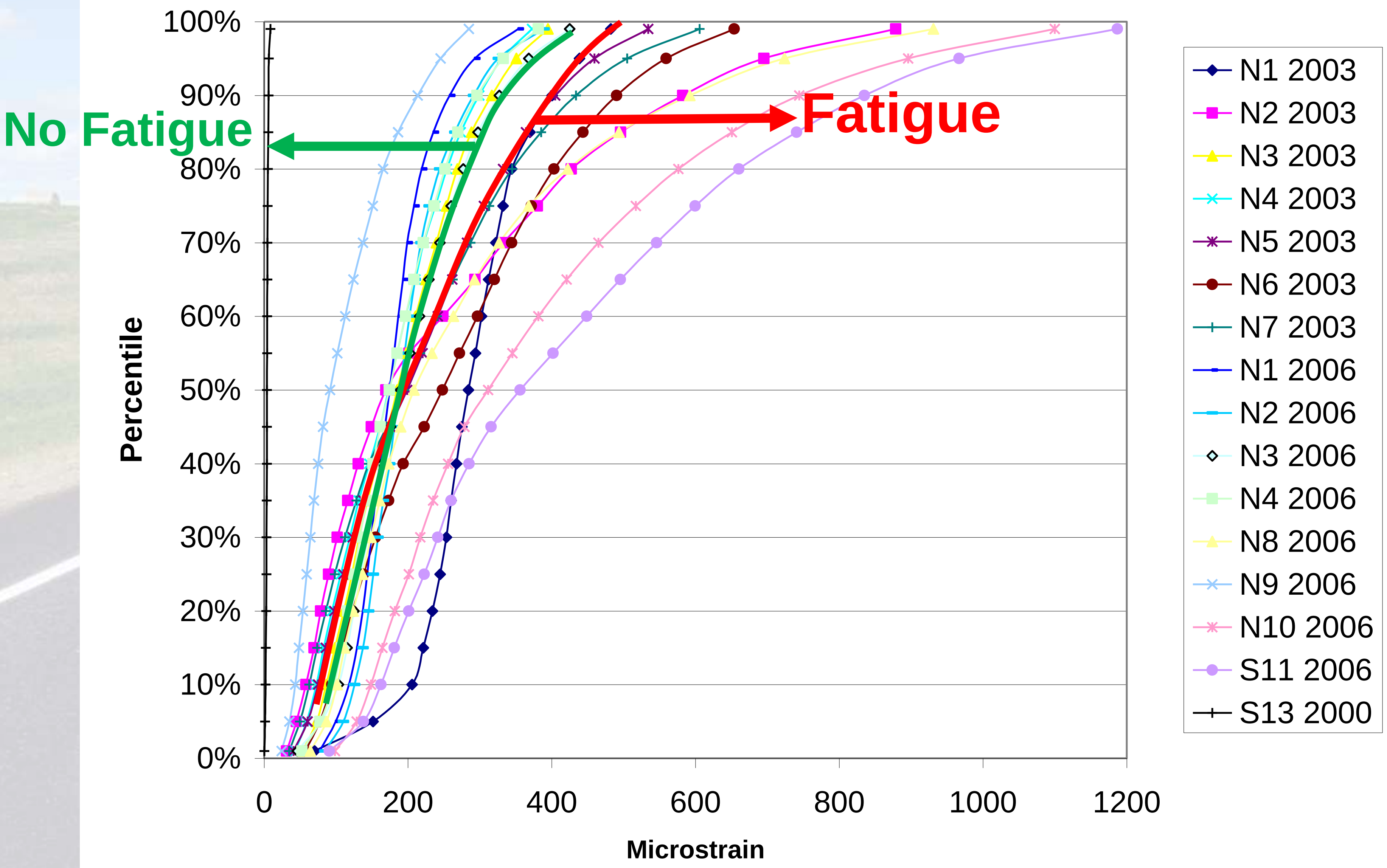


http://www.pavementinteractive.org/wp-content/uploads/2011/07/Device1.jpg

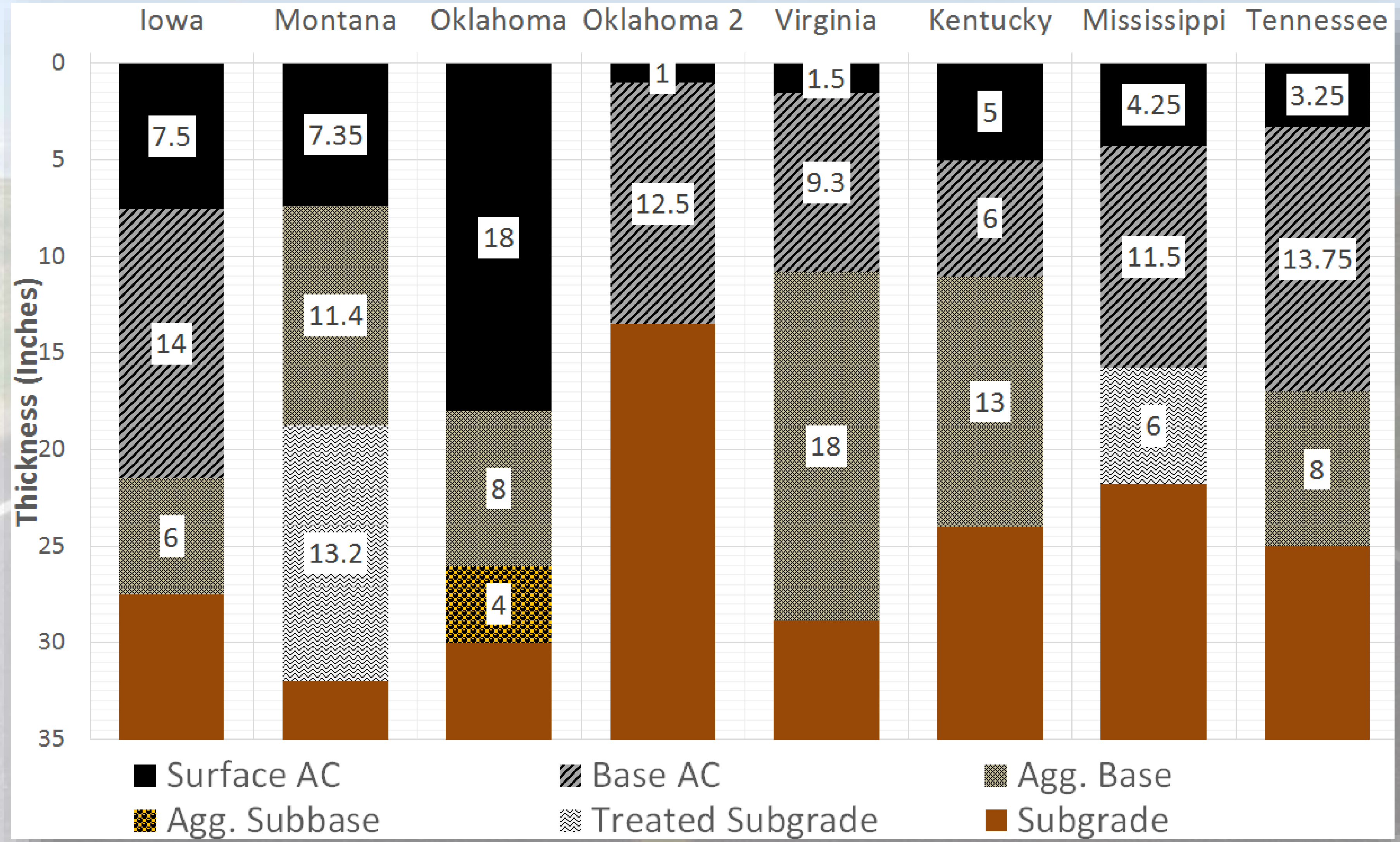
Measured Strains & Endurance Limit



Strain Distributions NCAT Test Track



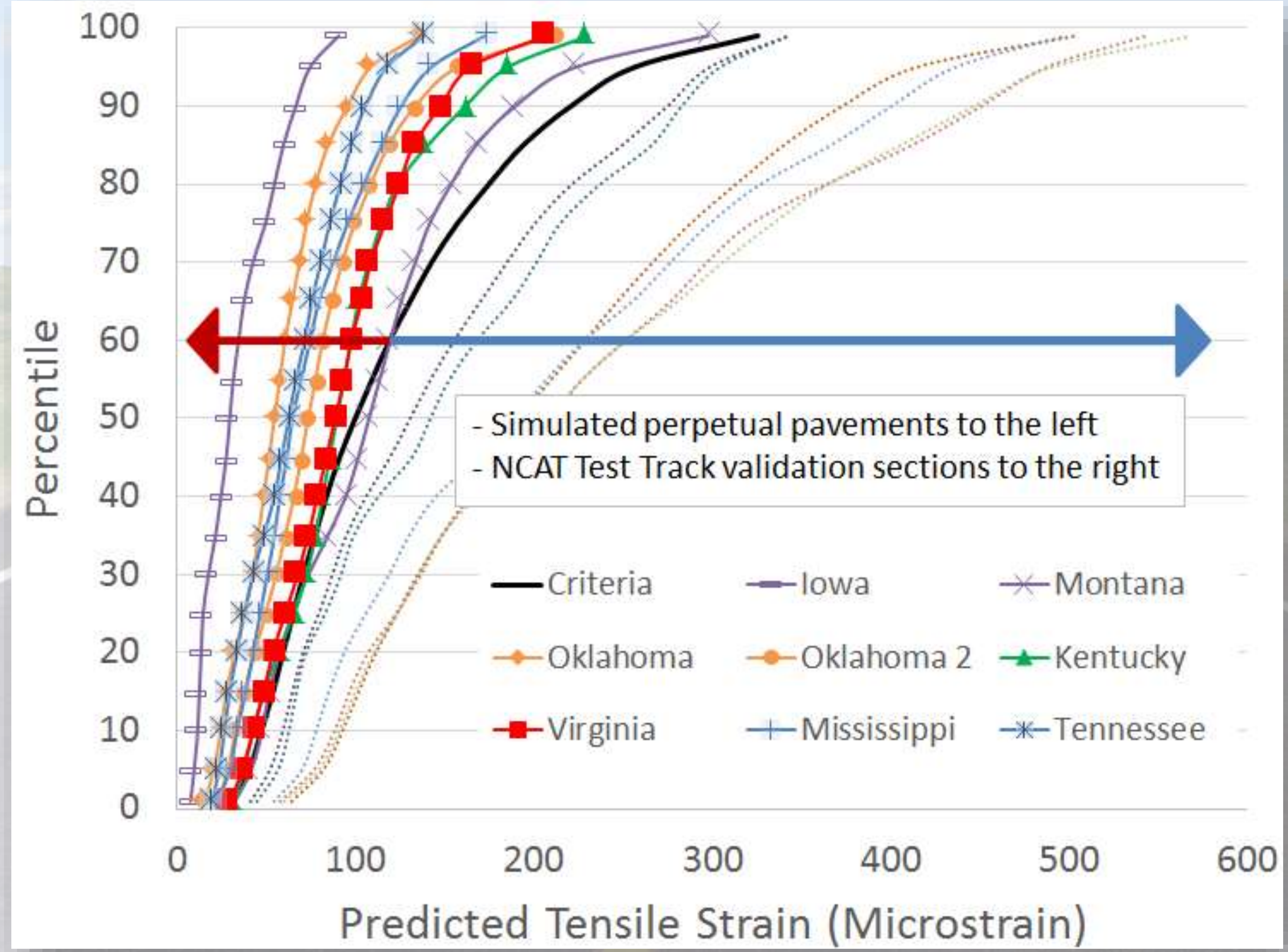
Further Evaluation of Criteria – Perpetual Pavement Award Winners



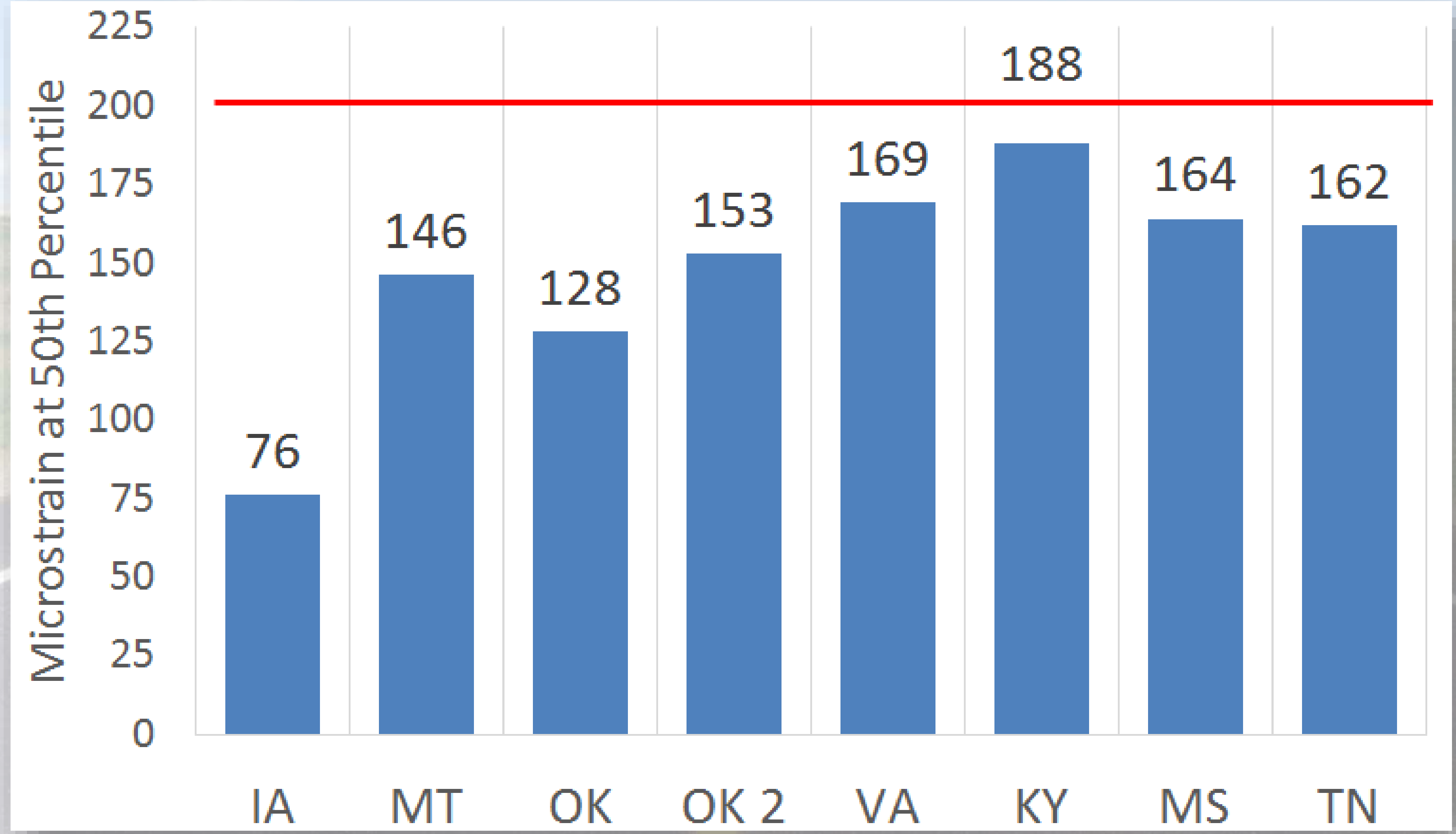
Perpetual Pavement Metrics

State	Project	Year Honored	Service Years (Time of award)	Cumulative Traffic (Time of award)
Iowa	I-80, MP 225.9 to 239.9	2002	38	32,000,000 ESAL
Montana	I-90 MP 439.33 to 445.4	2005	44	15,000,000 ESAL
Oklahoma	I-35, MP 185.6 to 192.6	2003	40	61,000,000 ESAL
Oklahoma	I-40, MP 160.2 to 165.5	2002	40	60,000,000 ESAL
Virginia	I-81, MP 318.4 to 324.9	2006	41	29,000,000 ESAL
Kentucky	I-65, Hart County	2009	44	76,000,000 ESAL
Mississippi	I-22, Desoto County	2007	39	60,000,000 ESAL
Tennessee	I-65, MP 22.4 to 32.56	2002	35	25,800,000 ESAL

Further Evaluation Results – Fatigue Cracking



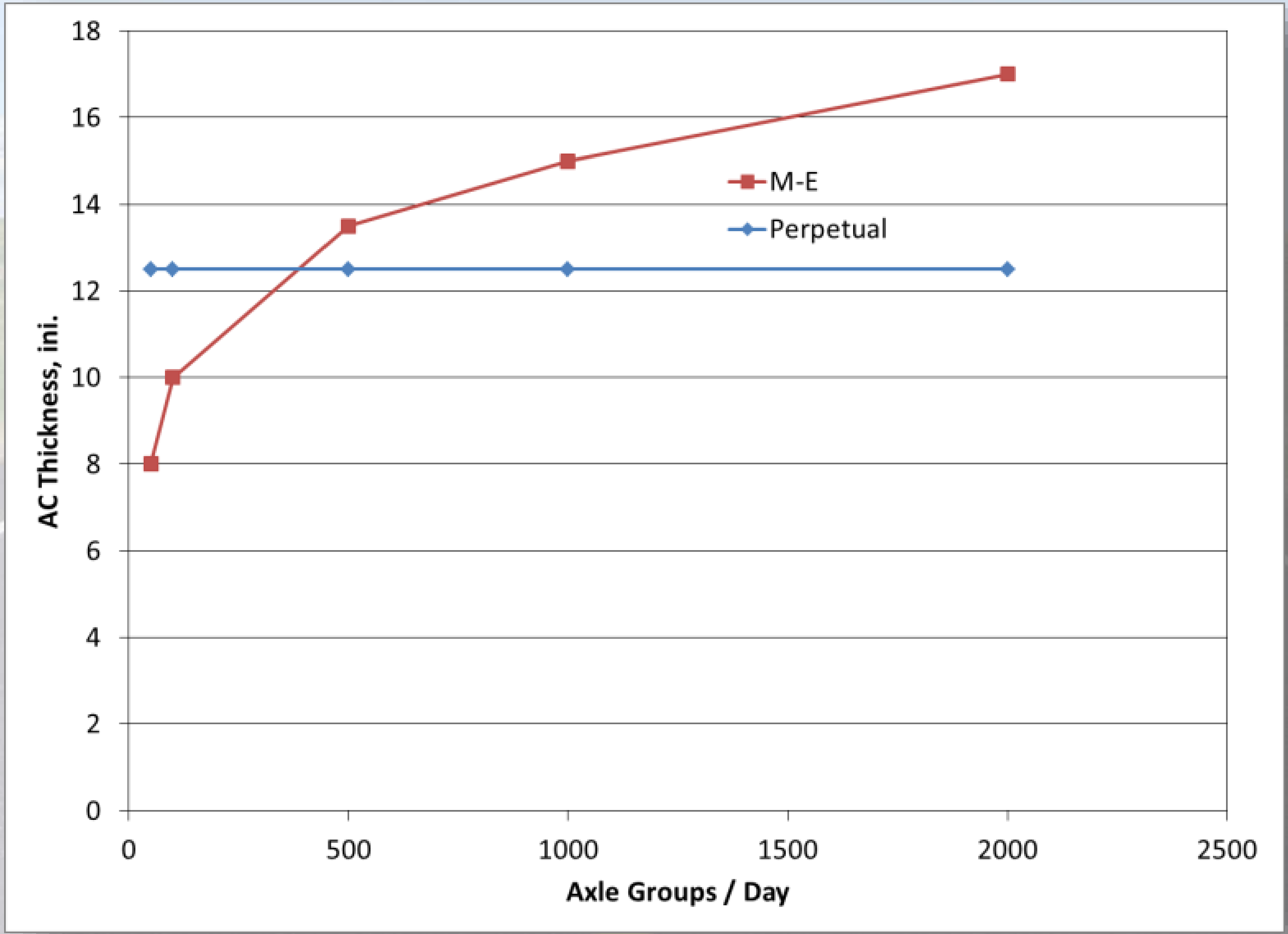
Further Valuation Results – Rutting



Example Designs with New Criteria

Subgrade Mr (ksi)	Base Mr (ksi)	Calculated AC Thickness (in.)				Range of Maximum Thicknesses (in.)
		Minneapolis (PG 64-34)	Phoenix (PG 70-22)	Baltimore (PG 64-22)	Average	
5	30	12.5	15.5	14	14.0	12.5-15.5
5	50	12	15	14	13.7	12-15
5	100	12	14	13.5	13.2	12-14
10	30	10.5	14	12	12.2	10.5-14
10	50	10.5	13	12	11.8	10.5-13
10	100	10	12	11	11.0	10-12
20	30	9	12.5	10	10.5	9-12.5
20	50	8.5	12.5	9.5	10.2	8.5-12.5
20	100	8	12	9	9.7	8-12

Design Comparison – M-E vs Perpetual Minneapolis – 6” 30 ksi Agg Base – 5 ksi Soil



Need for Distribution-Based Design

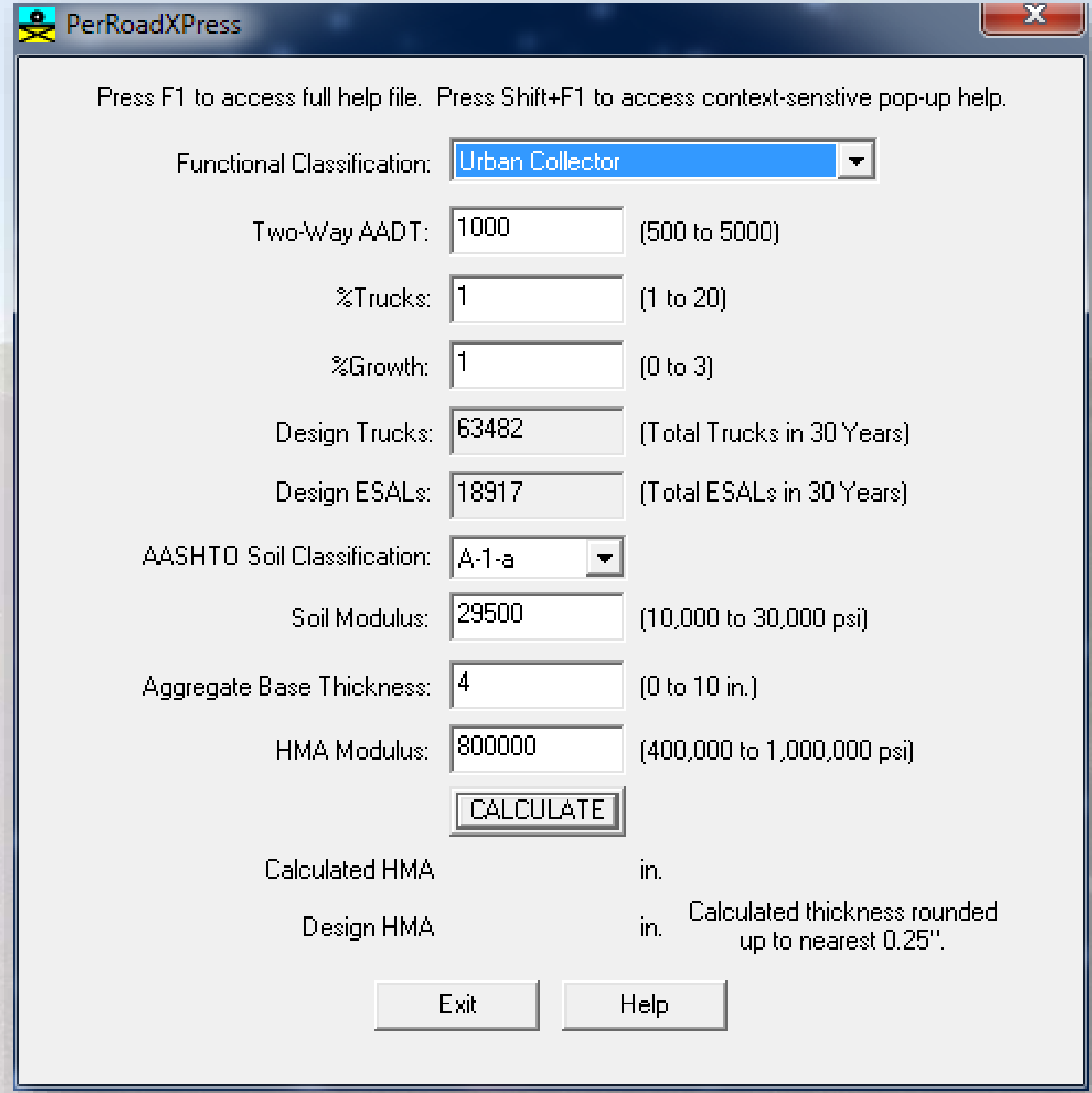
- Pavements experience wide range of loading and environmental conditions
  - Results in wide range of strain responses
- Traditional M-E design uses transfer functions and Miner’s Hypothesis to sum damage over time
  - Fatigue transfer functions difficult to develop and may not provide sufficient accuracy
  - Transfer functions not needed with perpetual pavement design
- Designing with a strain distribution will limit fatigue cracking and avoid transfer functions
  - Also arrive at reasonable perpetual (maximum) pavement thicknesses

Long-Life Pavement Design Software

Software Available @

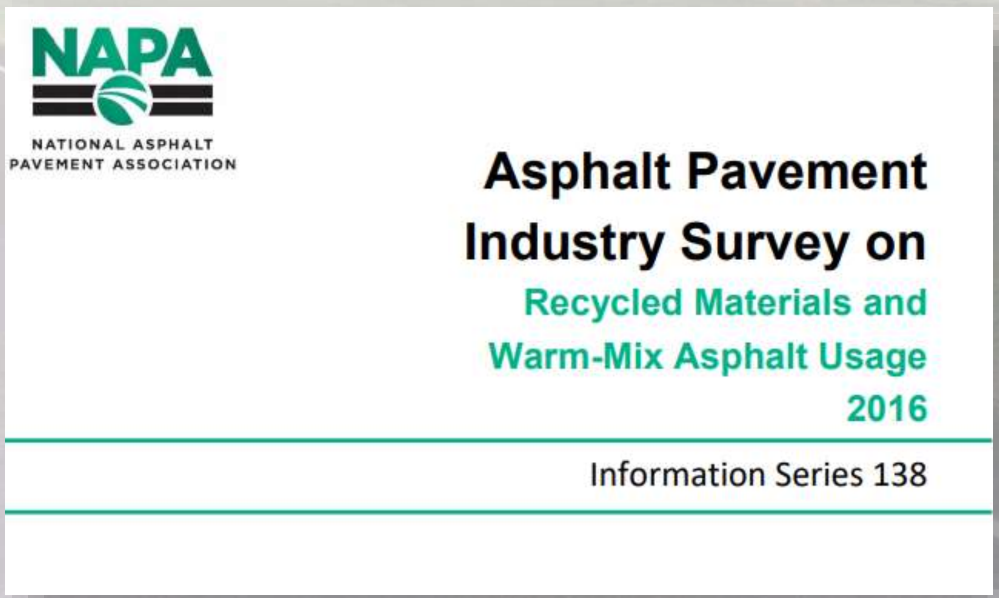
https://goo.gl/r1yiwQ

http://www.eng.auburn.edu/users/timmdav/Software.html



Cold Central Plant Recycled Perpetual Pavements

- RAP usage common
  - 81.8 million tons used in 2016
  - Majority used as HMA or WMA
- Opportunity to use RAP with cold recycling techniques
  - Fewer virgin materials
  - Less fuel consumption
  - Fewer emissions
  - Faster construction time
- Cold RAP usage in 2016 = 0.2 million tons


NAPA
NATIONAL ASPHALT PAVEMENT ASSOCIATION

Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage 2016

Information Series 138

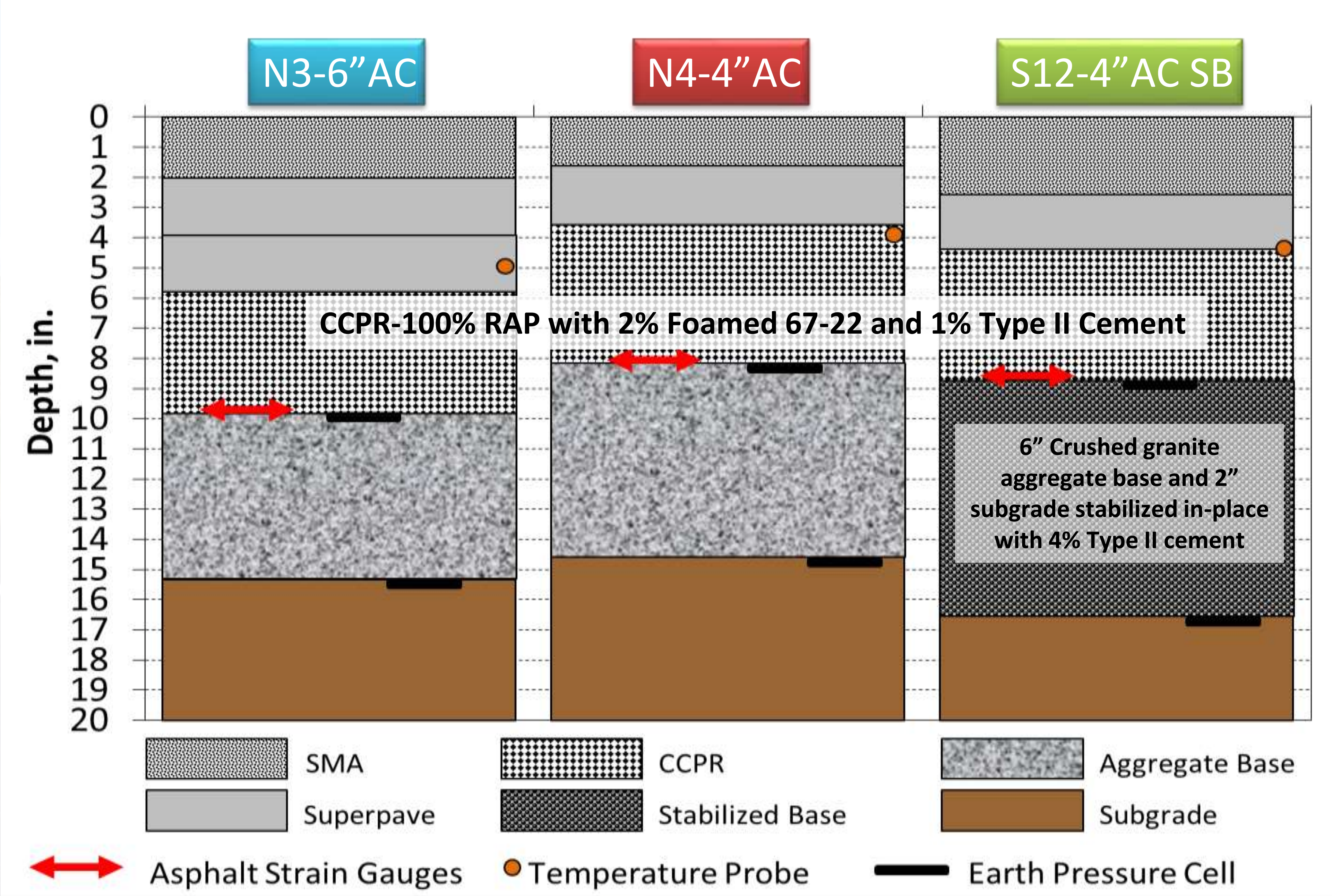
Cold Central Plant Recycling

Virginia DOT CCPR Experience

- 2011: I-81
  - CIR, FDR & CCPR
  - 6000 trucks/day
- 2012: NCAT Test Track
  - CCPR and Stabilized Base Sections
  - 10 million ESALs/test cycle
- 2016: I-64
  - CCPR and Stabilized Base

VDOT Sections at the NCAT Test Track

VDOT Test Sections



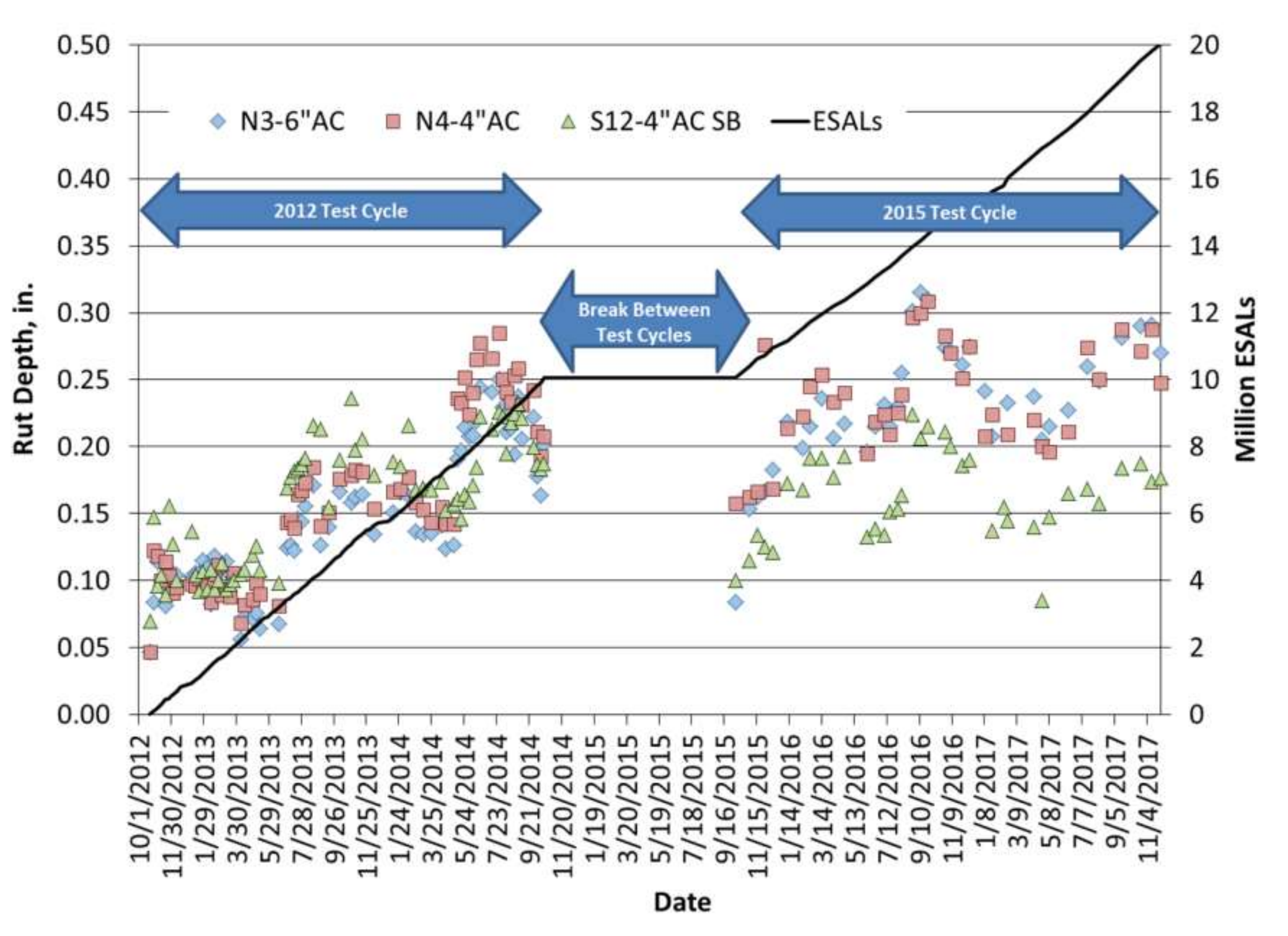
Cracking Performance after 20 Million ESALs

N3-6”AC

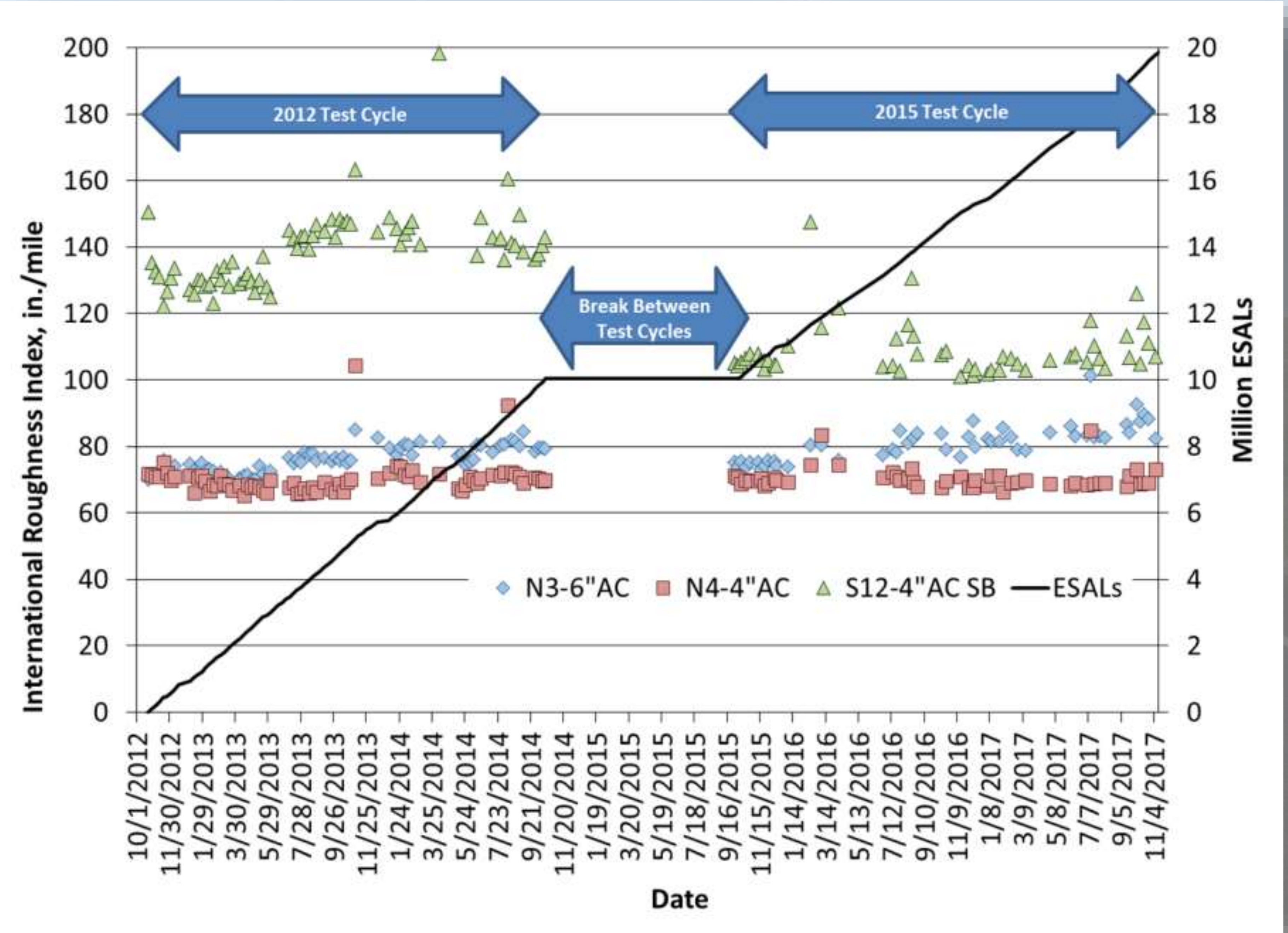
N4-4”AC

S12-4”AC SB

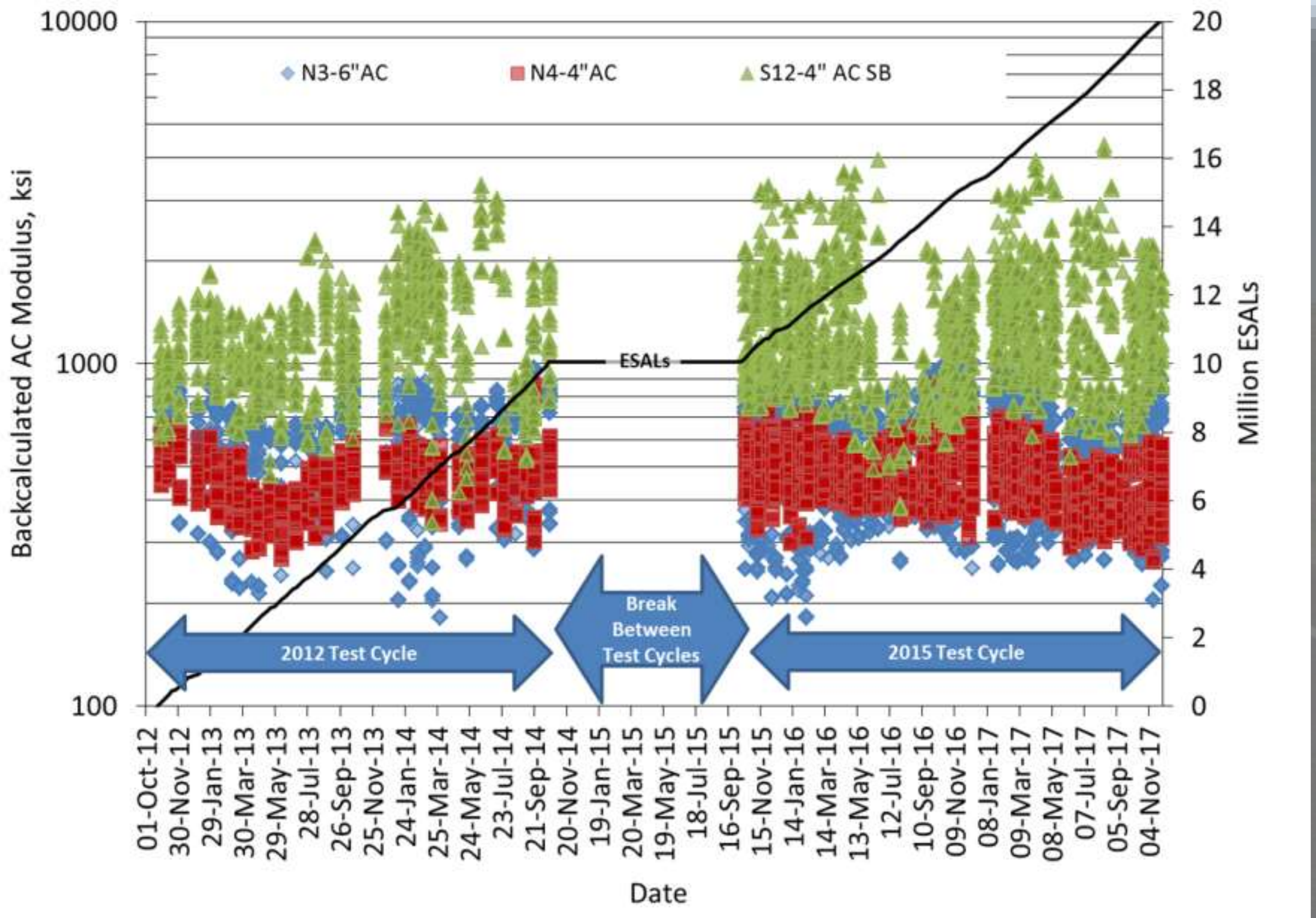
Rutting Performance After 20 Million ESALs



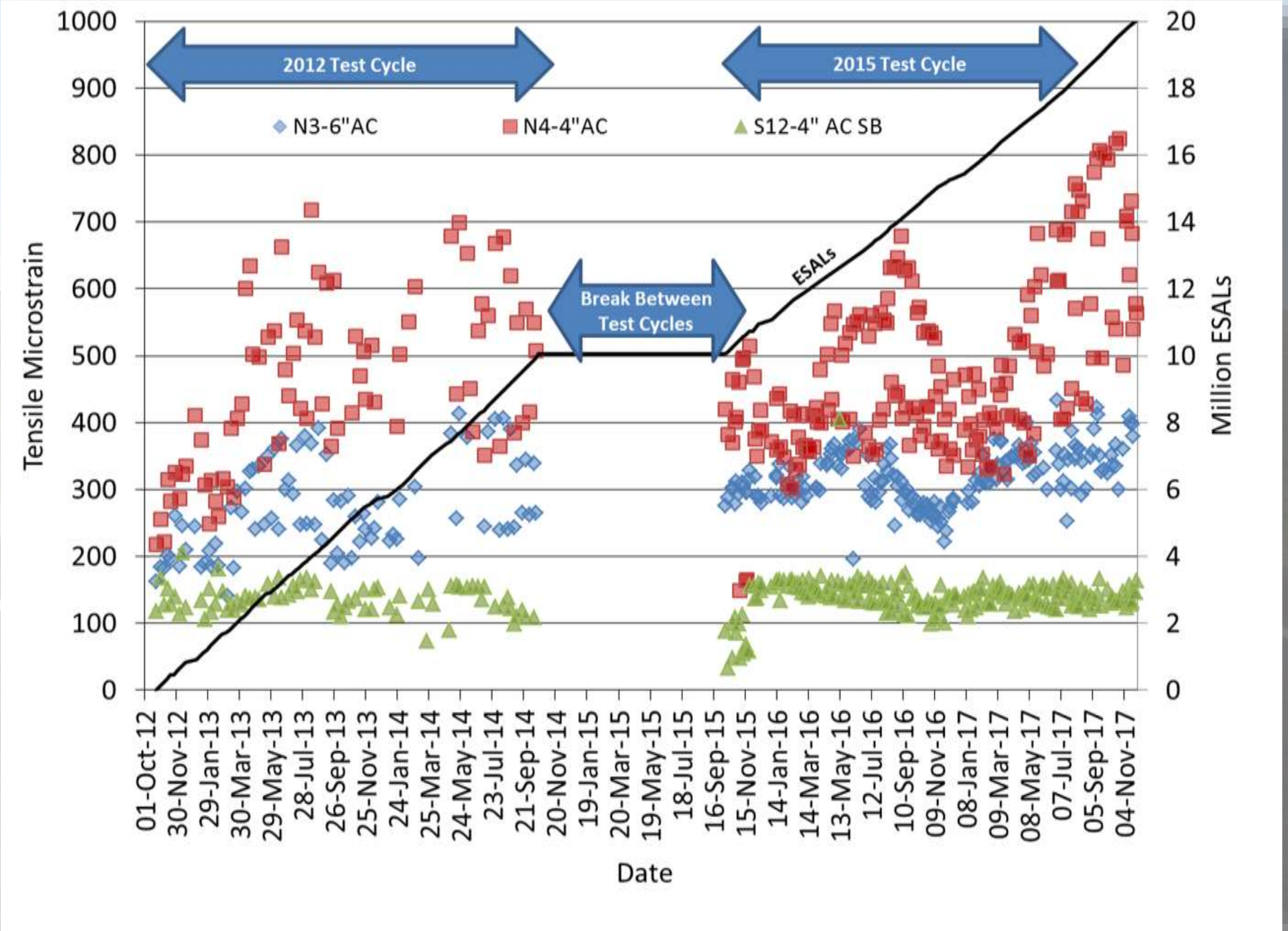
Ride Quality after 20 Million ESALs



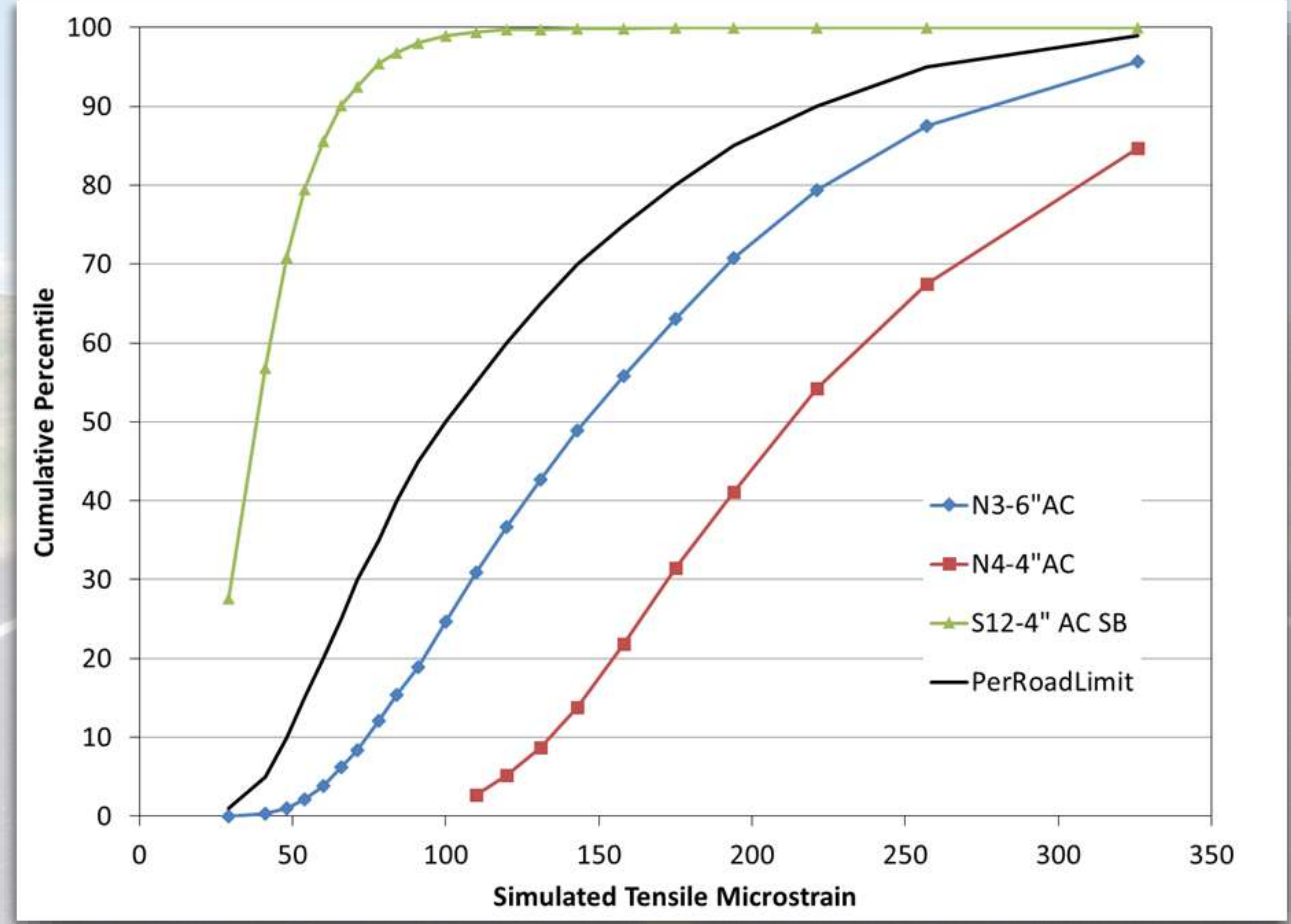
In-Place AC Modulus @ 68F



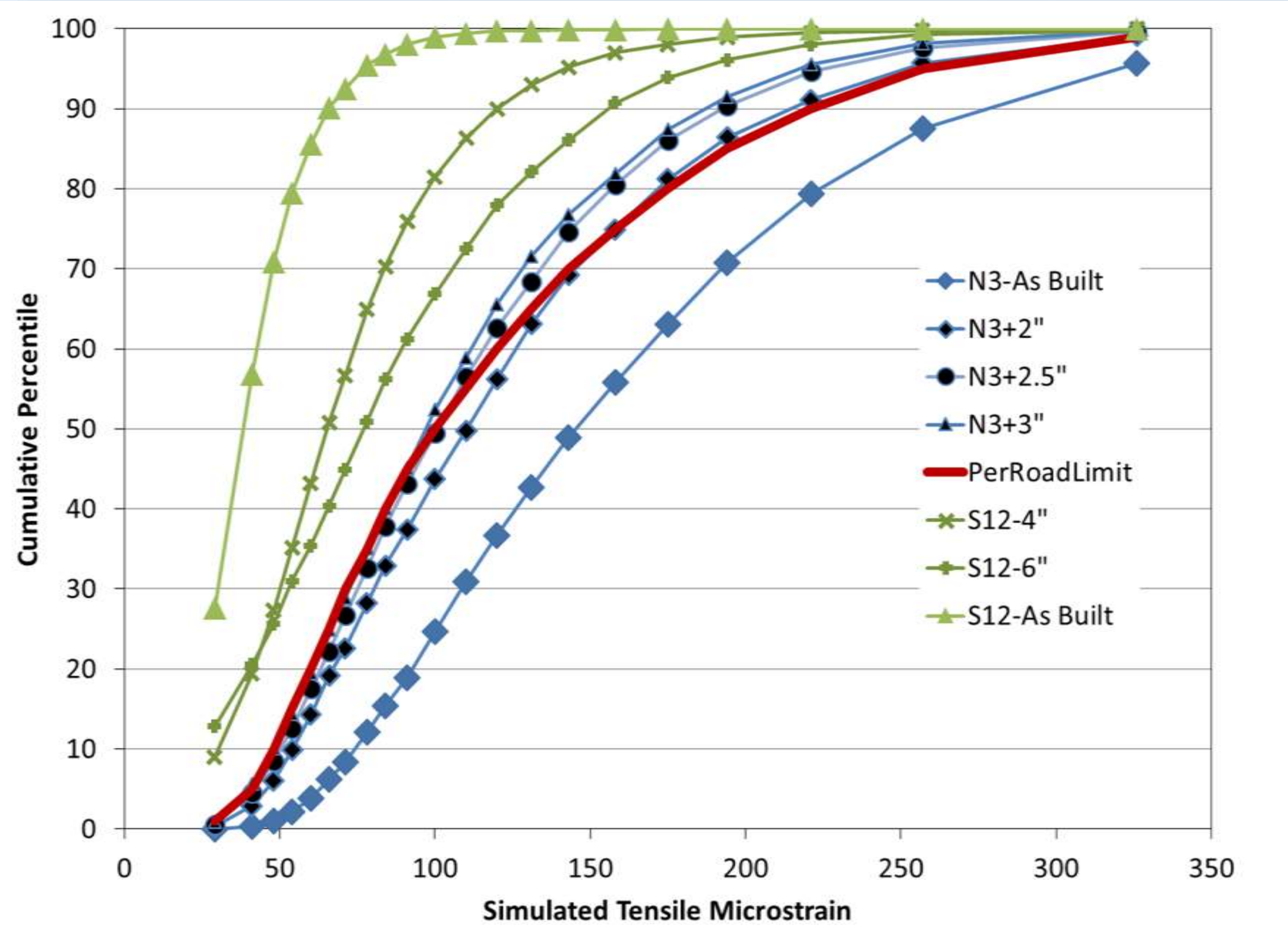
Tensile Strain @ 68F



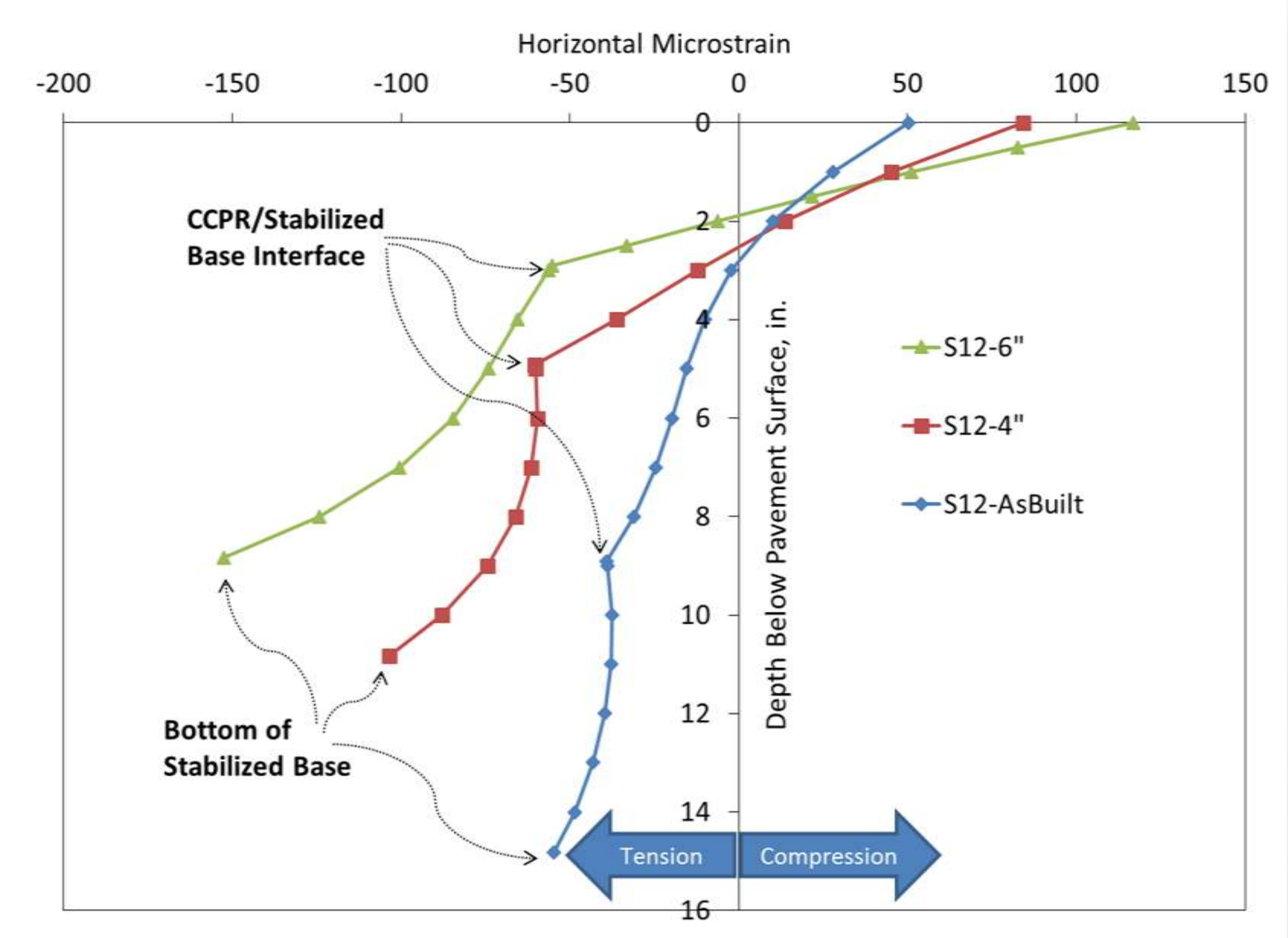
Perpetual Pavement Analysis



Additional Perpetual Analysis

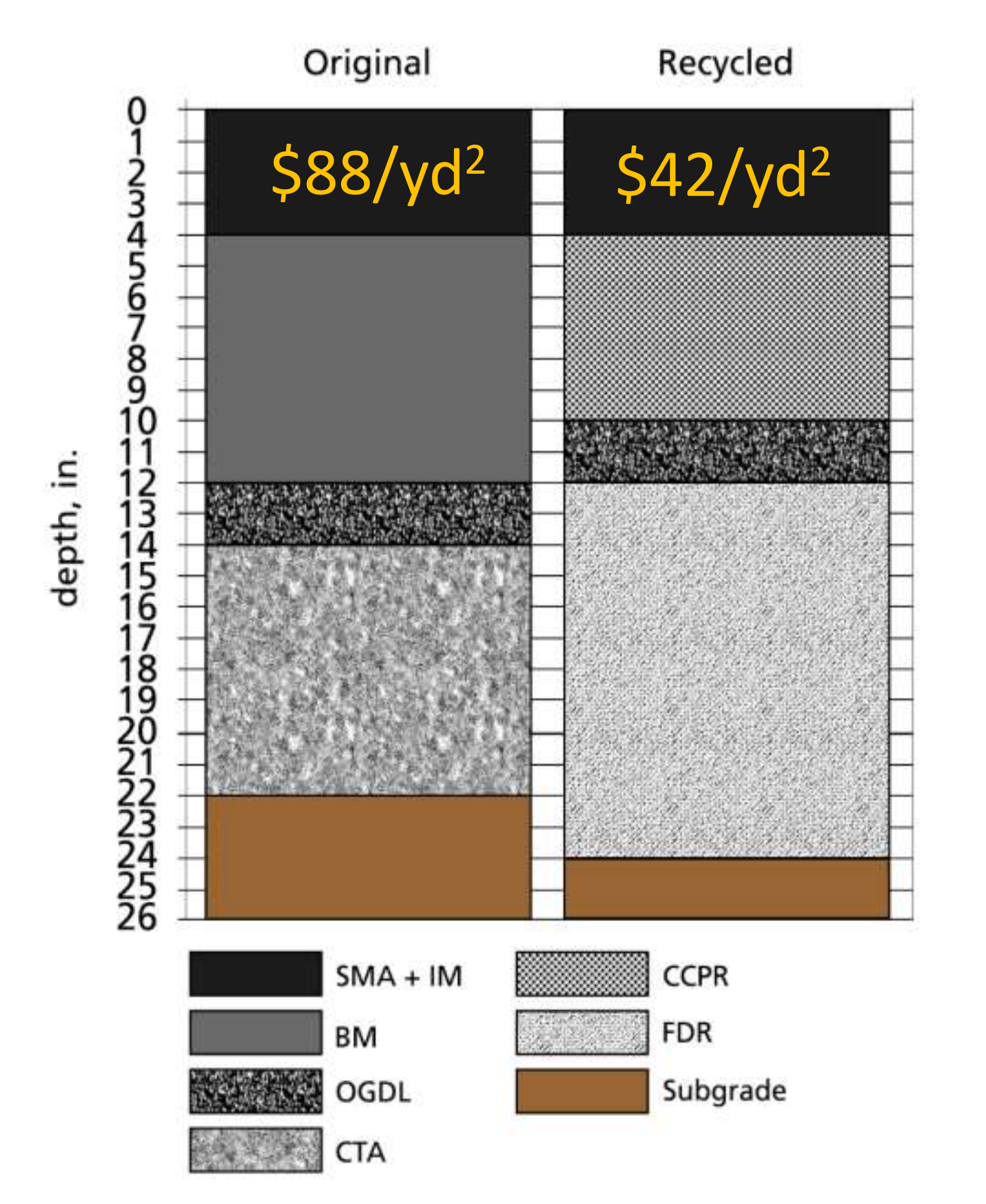


Stabilized Base? Use Caution!



VDOT Implementation

- I-64 Williamsburg, VA
- 7.08 miles
- 200,000 tons of RAP
- $10,000,000 savings

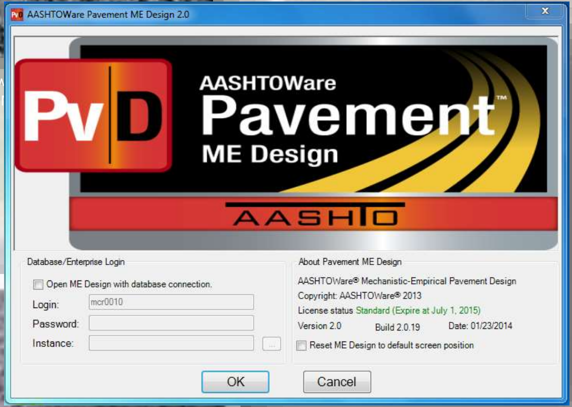


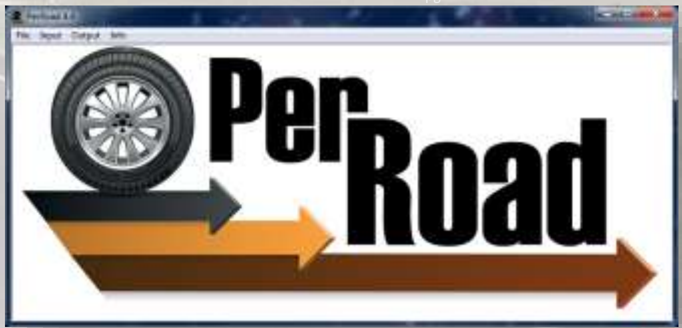
Future Challenges

http://www.vaasphalt.org/w
content/uploads/2012/07/S

content/uploads/2012/10/Recycling-asphalt-roofing-shingle.png

http://www.fhwa.dot.gov/pavement/recycling/rap/images/rap04.j
pg



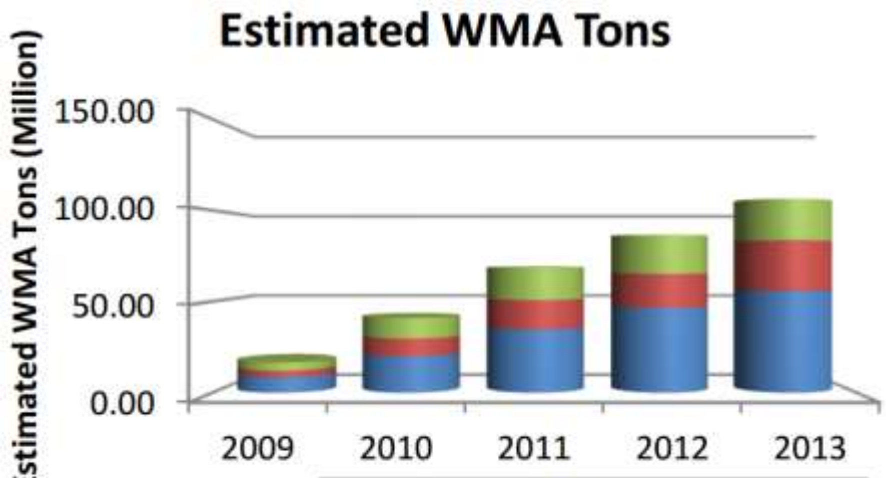


http://www.hgmeigs.com/images/evotherm_temp.jpg

http://www.calrecycle.ca.gov/ Assist/images/CrumbRubber.jpg

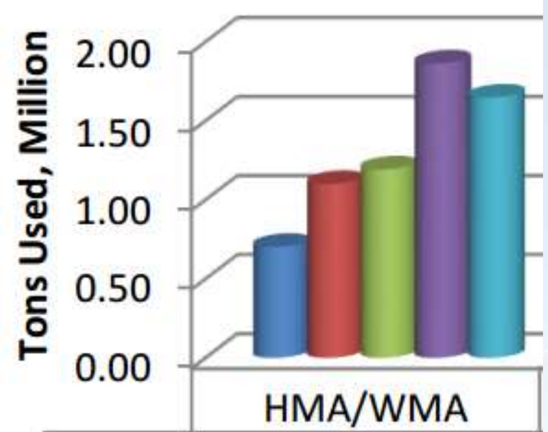
http://www.dot.ca.gov/hq/maint/Pavement/images/cold-foam-in-plc-recycl.jpg

U.S. Asphalt Concrete Industry

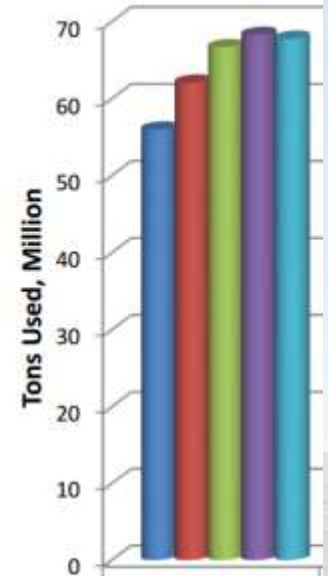


	2009	2010	2011	2012	2013
Commercial & Residential	4.55	11.31	17.81	21.35	22.78
Other Agency	3.60	9.84	16.29	18.86	27.85
DOT	8.55	19.99	34.60	46.41	55.68

Year



	HMA/WMA
2009	0.70
2010	1.10
2011	1.19
2012	1.86
2013	1.65



	HMA/WMA
2009	56
2010	62.1
2011	66.7
2012	68.3
2013	67.8

Concluding Remarks

- Pavement thickness design in transition
  - From empirical to mechanistic-empirical
- M-E design much more robust
  - Better traffic/climate/materials/performance characterization
  - Capable of adapting to new conditions
- Perpetual pavements are key to sustainable future
  - Incorporation of sustainable materials is critical
- Innovative materials can achieve long-life

Thank you!

Reach me at

timmdav@auburn.edu

Dakota Asphalt Pavement Association, Inc.

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"Build with Asphalt"

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Federal Highway Administration