Highly Modified Binders for Enhanced Pavement Performance

- Dallas Little, P.E., Kraton Polymers
- AMAP → Savannah, GA –
  February 1-3, 2010

Participants

- Kraton Polymers
  - Willem Vonk
  - Erik Jan Scholten
  - Bob Kluttz
- Technical University Delft – Road & Railways
  - Andre Molenaar
  - Martin van de Venn
  - Tariq Medani
- Technical University Delft - Mechanics
  - Tom Scarpas
  - Xueyan Liu

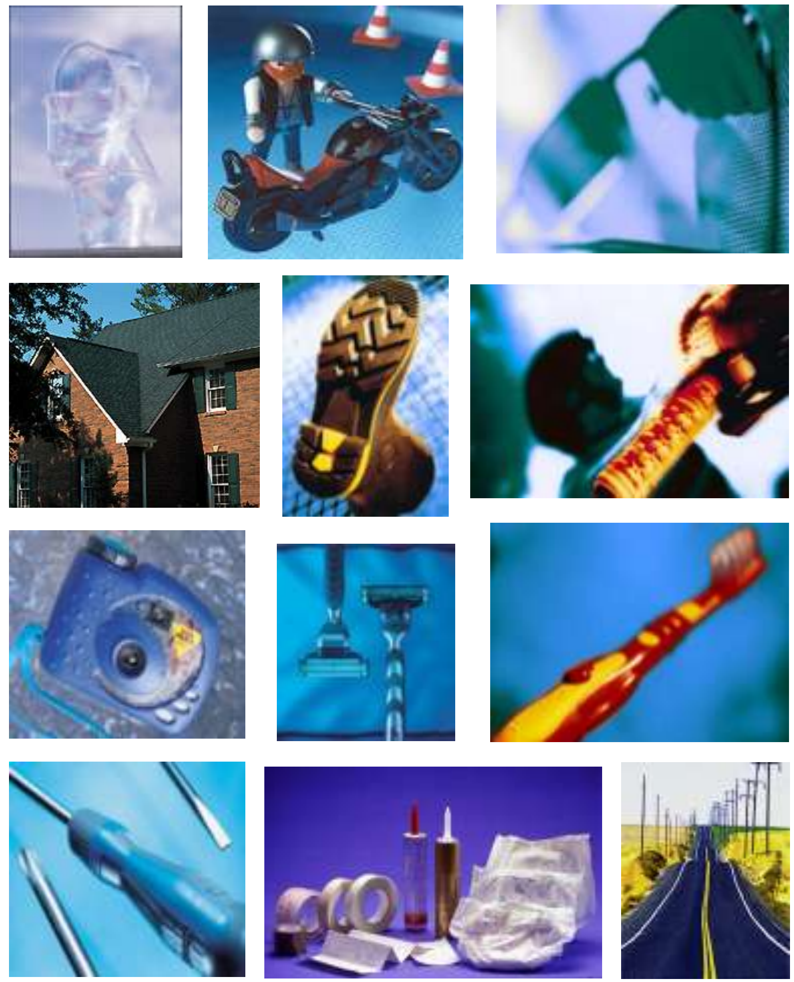
Delft University of Technology

Outline

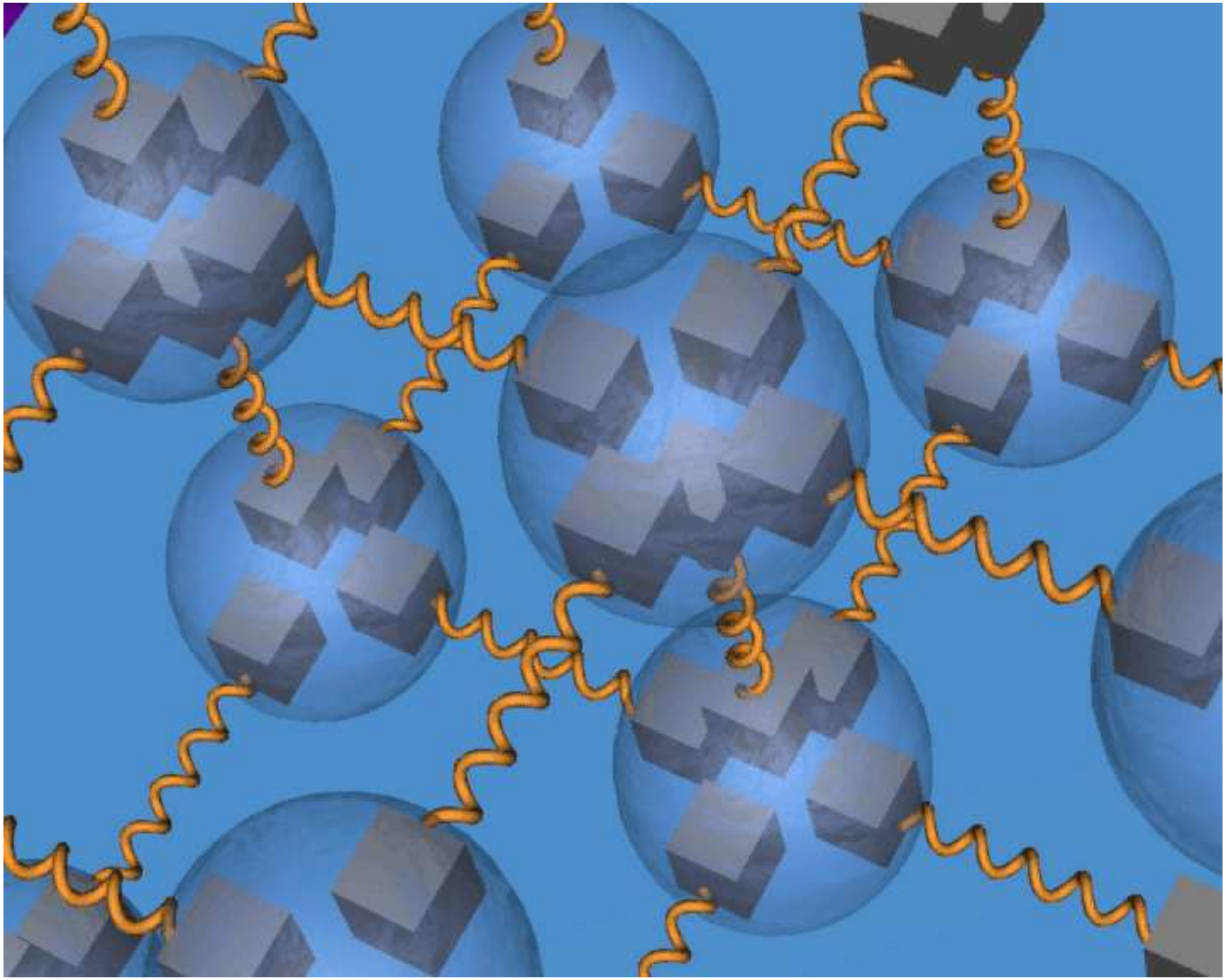
- Kraton Polymers
- How SBS Works in Bitumen and Asphalt Pavement
- Background of the Study
- Framework
- Testing phases
- Results
- Advanced Modeling
- Conclusions

Kraton Polymers

- Inventor and world's leading producer of styrenic block copolymers ("SBCs")
  - First commercialized as part of Shell Elastomers in the 1960s
- Produces over 1000 products from six plants in the US, Europe, Latin America and Asia
- Serves three groups of end-uses:
  - Paving & Roofing
  - Adhesives, Sealants & Coatings
  - Advanced Materials



SBS in Bitumen

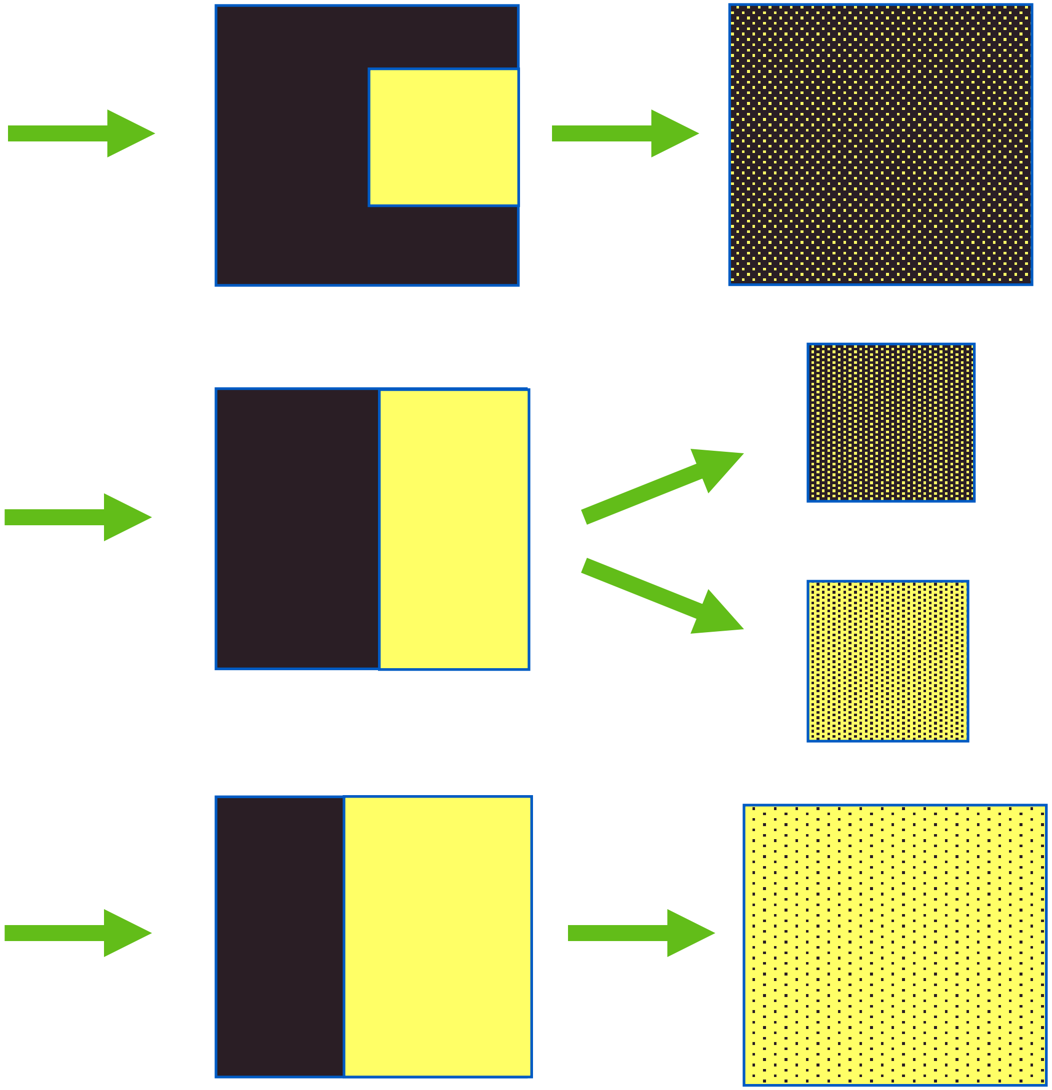


Phase Morphology

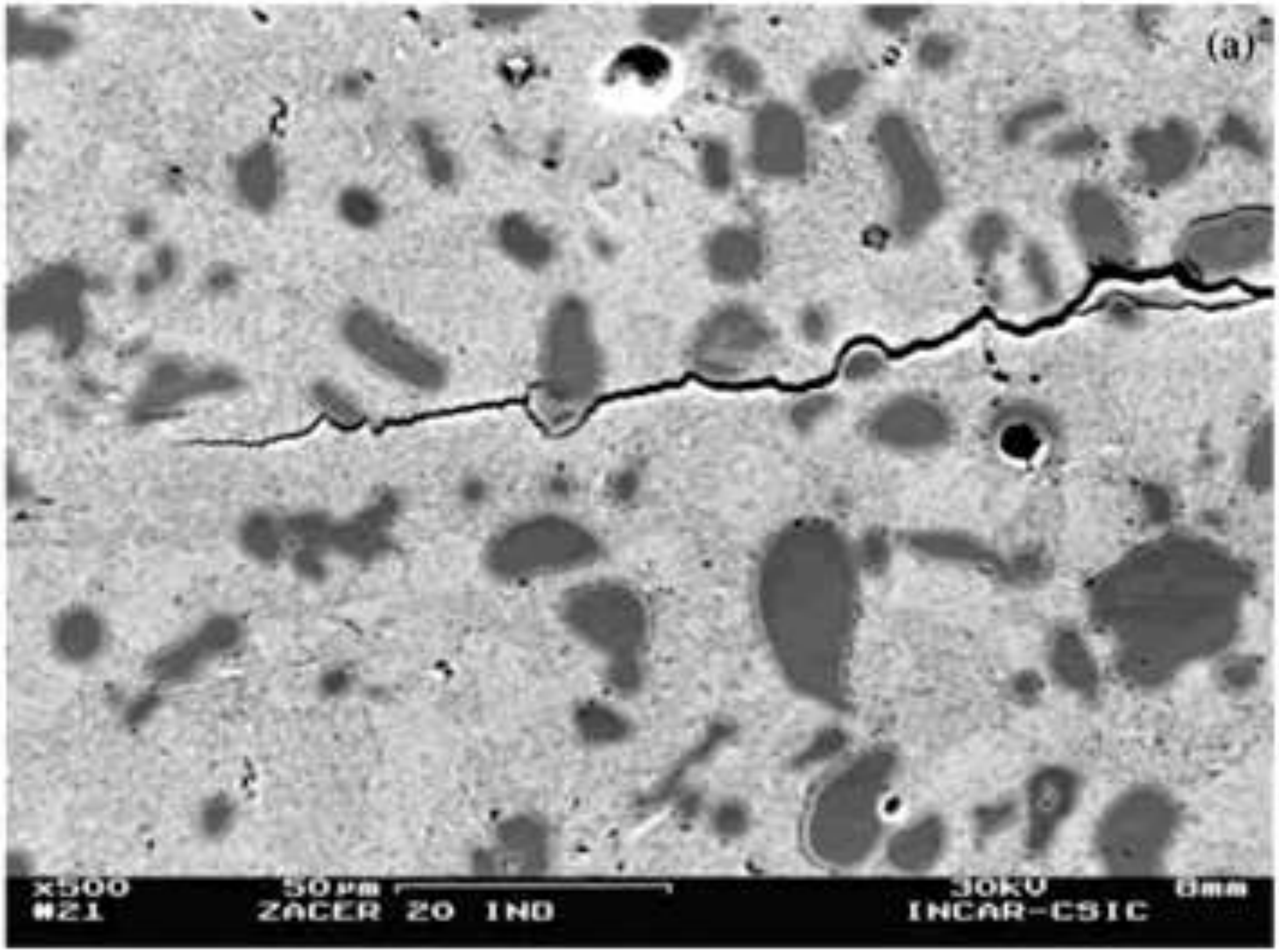
Bitumen + 2½% polymer

Bitumen + 5% polymer

Bitumen + 7½% polymer



Crack Propagation in Toughened Composite



Source: www.scielo.br/img/fbpe/mr/v4n3/a13fig5a.gif

Background of the Study

- Higher traffic intensities and pavement loadings require more durable pavements
- Higher traffic intensities also command longer maintenance intervals to increase availability of the road
- Environmental pressure is increasing; reduction of use of natural resources such as aggregate and less emissions are highly desired
- SBS modification has proven benefits in wearing courses over the past decades in every relevant property

→ Use the benefits of SBS to create a polymer modified base course asphalt that can fulfill the requirements of today and tomorrow

→ Technical challenge: compatibility and workability with relatively hard base bitumen

Framework of the Study

- 2004: start of a joint research program with Road Engineering Section of Delft University of Technology
- Asphalt mix knowledge of DUT combined with polymer-bitumen technology of Kraton Polymers to investigate whether SBS modification of base layers would increase life time and/or enable layer thickness reductions of the asphalt pavement

Testing Phases

- 2004 (phase 1):

Asphalt mix testing by DUT of base course asphalt containing standard Kraton® polymer grades

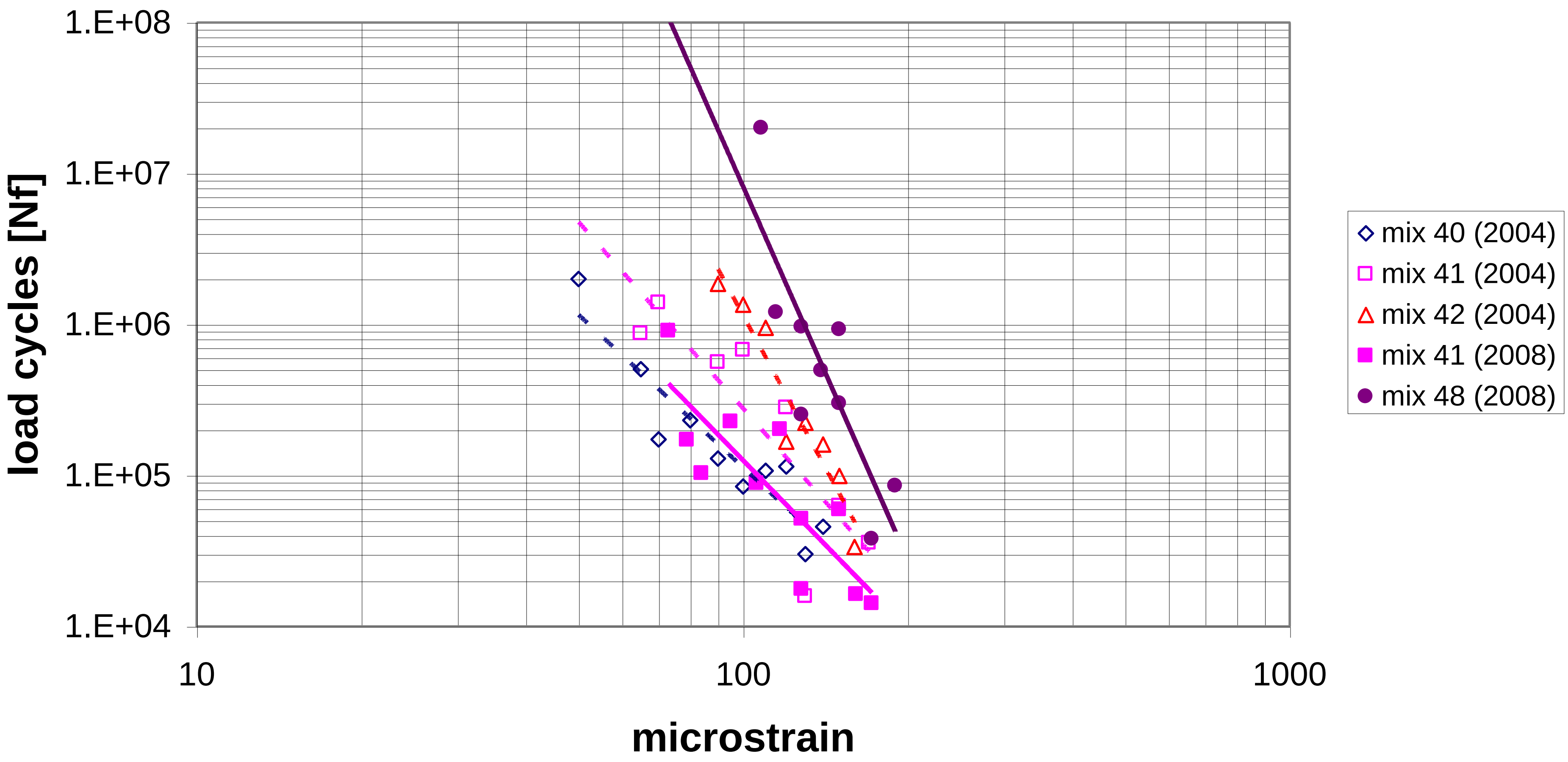
- 2005:

Binder testing by Kraton Polymers Research of best performing mixes

Selection of additional polymer grades for testing in phase 2

Recent Beam Fatigue Results

- 2004 Data with rerun of mix 41 and new data for mix 48 (very similar to mix 45)



Full sinusoidal loading. Cited strains are ½ amplitude

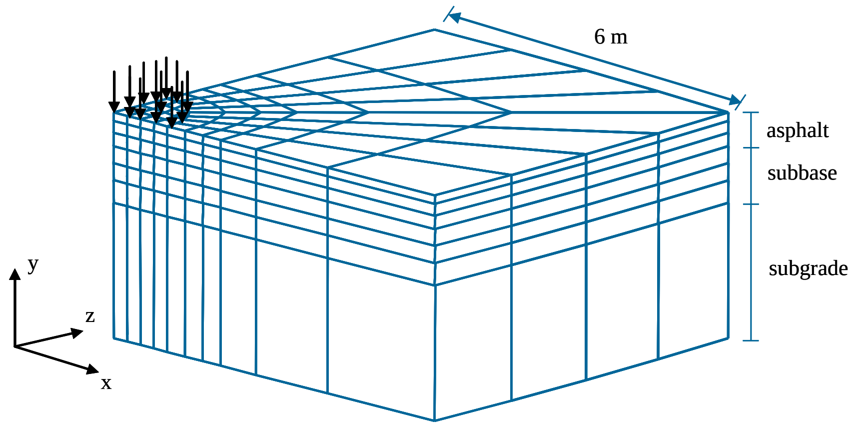
Testing Phases

- 2006 (phase 2):

Fundamental asphalt mix testing using standard base course mix with selected binders: monotonic uniaxial compression and tensile tests, indirect tensile tests

- 2007:

Use of fundamental asphalt mix data in advanced modeling to compare damage development in pavement



Advanced Modeling

- Asphalt Concrete Response (ACRe) model developed at Delft University
- Desai response surface for hardening and softening
- Crack plane response simulation with Hoffman surface
- CAPA 3D Finite Element Code developed at Delft University

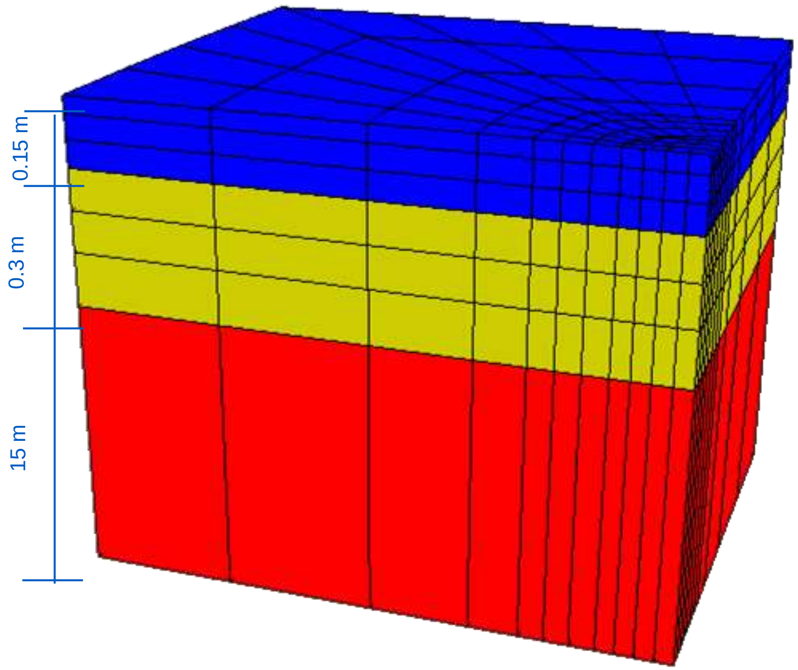
Scarpas, A, Gurp, C.A.M.P. van, Al-Khoury, R.I.N. and Erkens, S.M.J.G., Finite Element Simulation of Damage Development in Asphalt Concrete Pavements. 8th International Conference on Asphalt Concrete Pavements, Seattle, Washington, U.S.A., 1997.

Pavement Structure and Loading

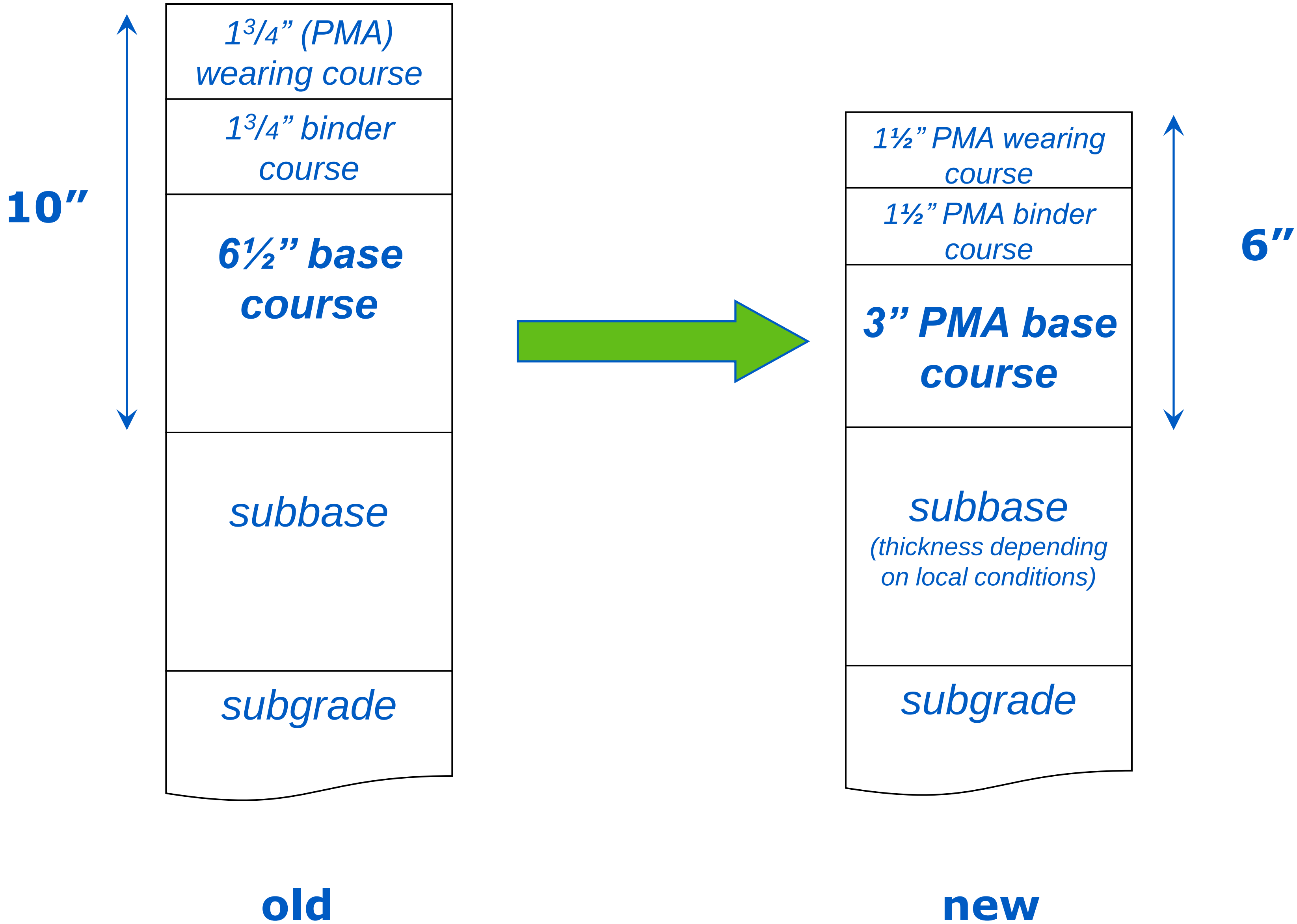
Three layers structure:
- Bound layer - E1 = 1000 MPa (145,000 psi); h = 6” or 10”
- Unbound subbase - E2 = 300 MPa (43,500 psi); h = 12”
- Subgrade - E3 = 100 MPa (14,500 psi); h = 50’

Constant temperature: T = 20 °C (68 °F)

Stationary dynamic load:
800 kPa (115 psi) – 25 ms



Proposed System



This an example; depending on local conditions other types may apply

Cost Comparison: Base Case with Modified Wearing Course

mix type	thickness	cost per ton	per sq yd	total	cost reduction per sq yd	% cost reduction
modified wearing course	1.75 "	$84.00	$16.52			
unmodified binder course	1.75 "	$70.00	$13.77			
unmodified base course	6.5 "	$65.00	$47.48			
total	10.0 "			$77.77		
modified wearing course	1.75 "	$84.00	$16.52			
modified binder course	1.75 "	$84.00	$16.52			
modified base course	6.5 "	$91.00	$66.48	$99.52	-$21.75	-29%
	5.5 "	$91.00	$56.25	$89.29	-$11.52	-15%
	5.0 "	$91.00	$51.14	$84.18	-$6.41	-9%
	4.5 "	$91.00	$46.02	$79.07	-$1.29	-2%
	4.0 "	$91.00	$40.91	$73.95	$3.82	5%
	3.5 "	$91.00	$35.80	$68.84	$8.94	12%
	3.0 "	$91.00	$30.68	$63.73	$14.05	19%

based on example from previous slide, material costs only

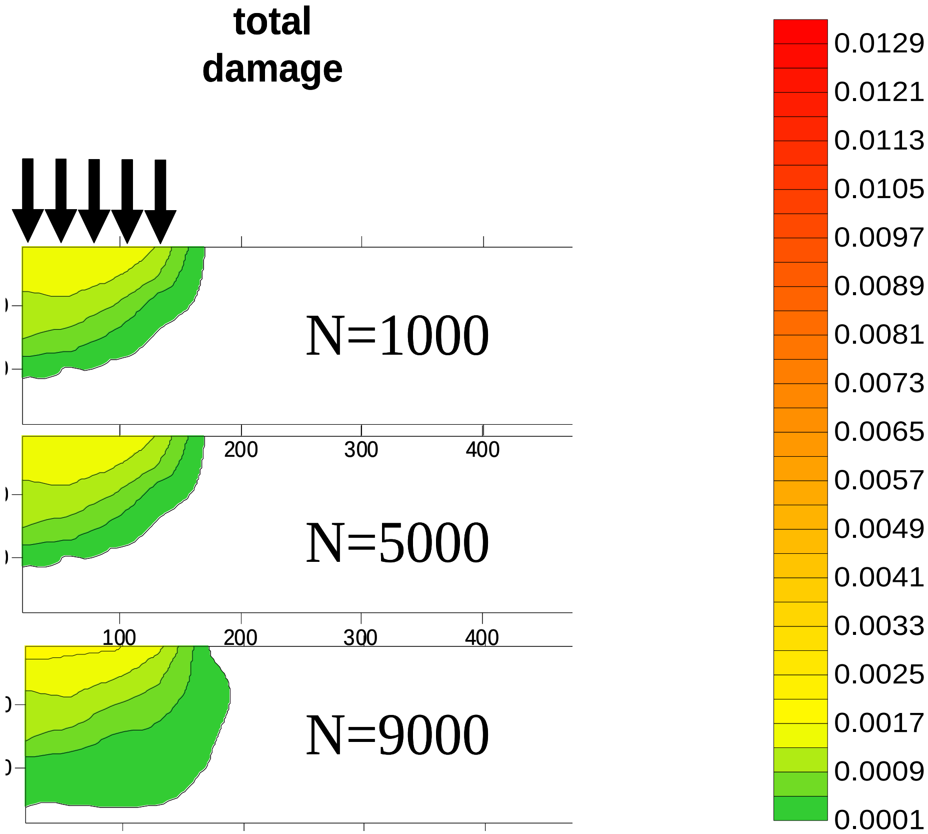
base data:
SMA unmodified wearing mix: $70/ton
unmodified base mix: $65/ton

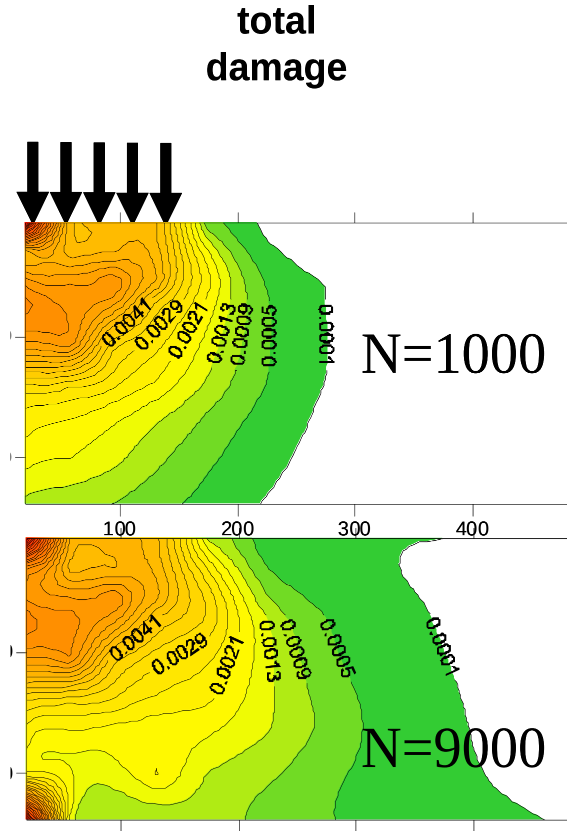
assumptions:
PMA wearing mix + 20%
PMA base mix + 40%

Modeling Results

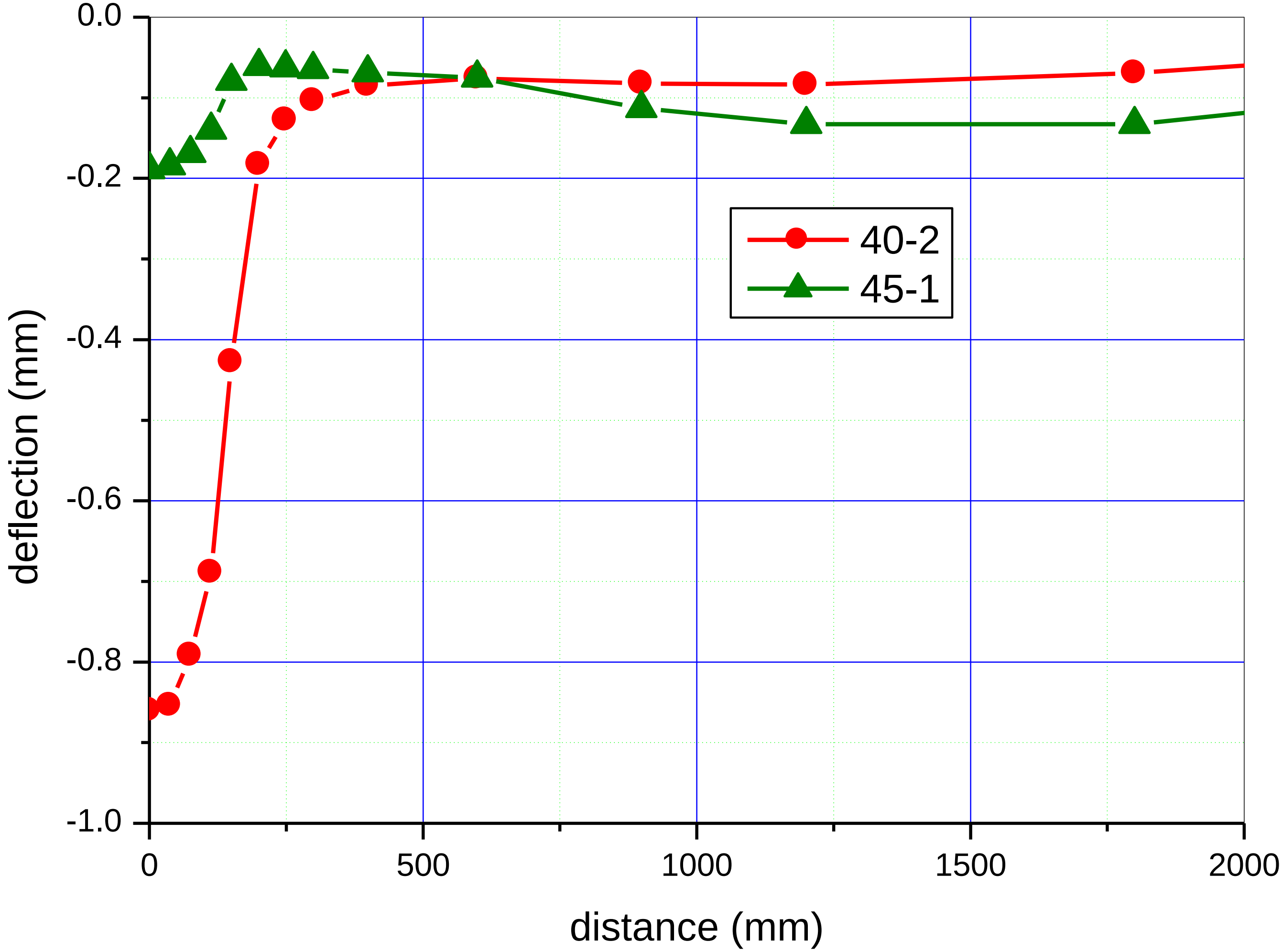
Kraton Polymer Modified (6”)

Unmodified (10”)





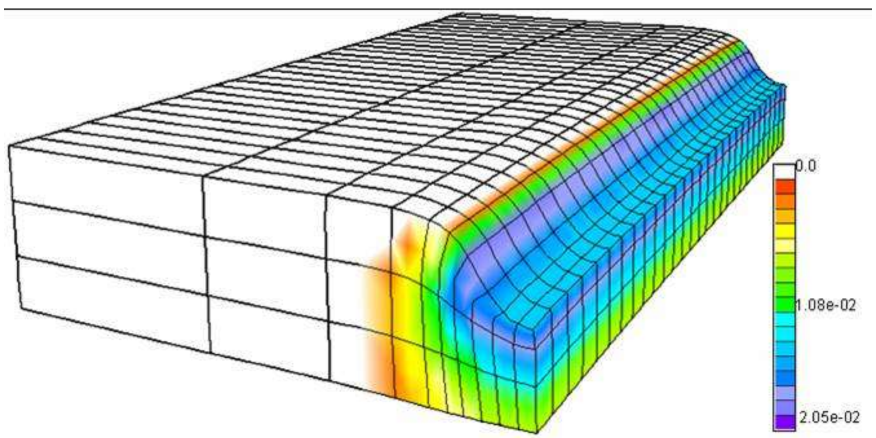
Rutting Profile



>4X reduction in permanent deformation at 60% thickness

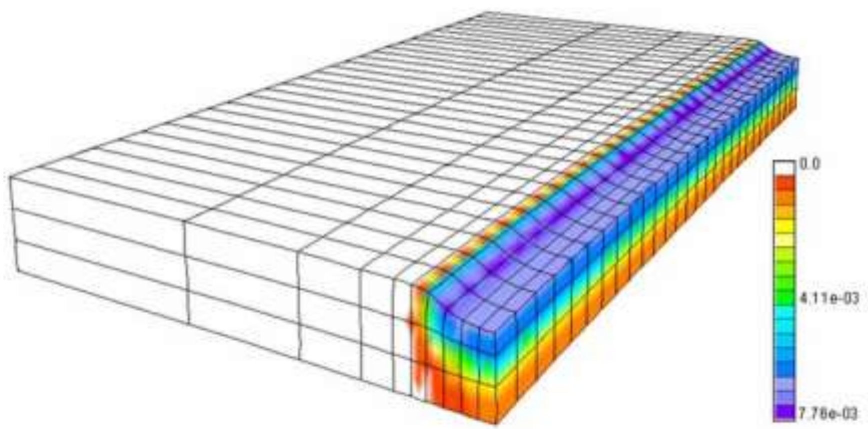
40-2 = 10" unmodified asphalt
45-1 = 6" SBS modified asphalt

Initial Wheel-Tracking Results
Deviatoric Deformation



Deviatoric damage distribution in thicker unmodified pavement

Max = 2.05E-2



Deviatoric damage distribution in thinner modified pavement

Max = 0.78E-2

Comparative Damage

Distress	10″ unmodified	6″ highly modified
Shear deformation	2.05E-2	0.78E-2
Compressive deformation	1.27E-2	0.70E-2
Longitudinal cracking	1.31E-3	0.02E-3
Vertical cracking	7.72E-4	4.41E-4
Transverse cracking	8.65E-4	0.79E-4

Paving Trials to Date

- June, 2009 – Thirteen city streets in Belpre, OH. Two 1” lifts, 3/8” NMAS fine mix. No production or construction problems despite inclement weather.
- July, 2009 – Section N7 (part of pooled fund group program) at NCAT test track. Again, no problems with production or construction. Mix behaved like conventional PG 76-22 asphalt concrete.

Cross Sections Evaluated

Kraton

Control (7” HMA)

1¼” (PG 76-22; 9.5mm NMAS; 80 Gyrations)

2¾” (PG 76-22; 19mm NMAS; 80 Gyrations)

3” (PG 67-22; 19mm NMAS; 80 Gyrations)

Experimental (5¾” HMA)

1¼” (Kraton Modified, 9.5 mm NMAS)

2¼” (7½% polymer;19mm NMAS; 80 Gyrations)

2¼” (7½% polymer;19mm NMAS; 80 Gyrations)

Dense Graded Crushed Aggregate Base
M_r = 12,530 psi
ν = 0.40

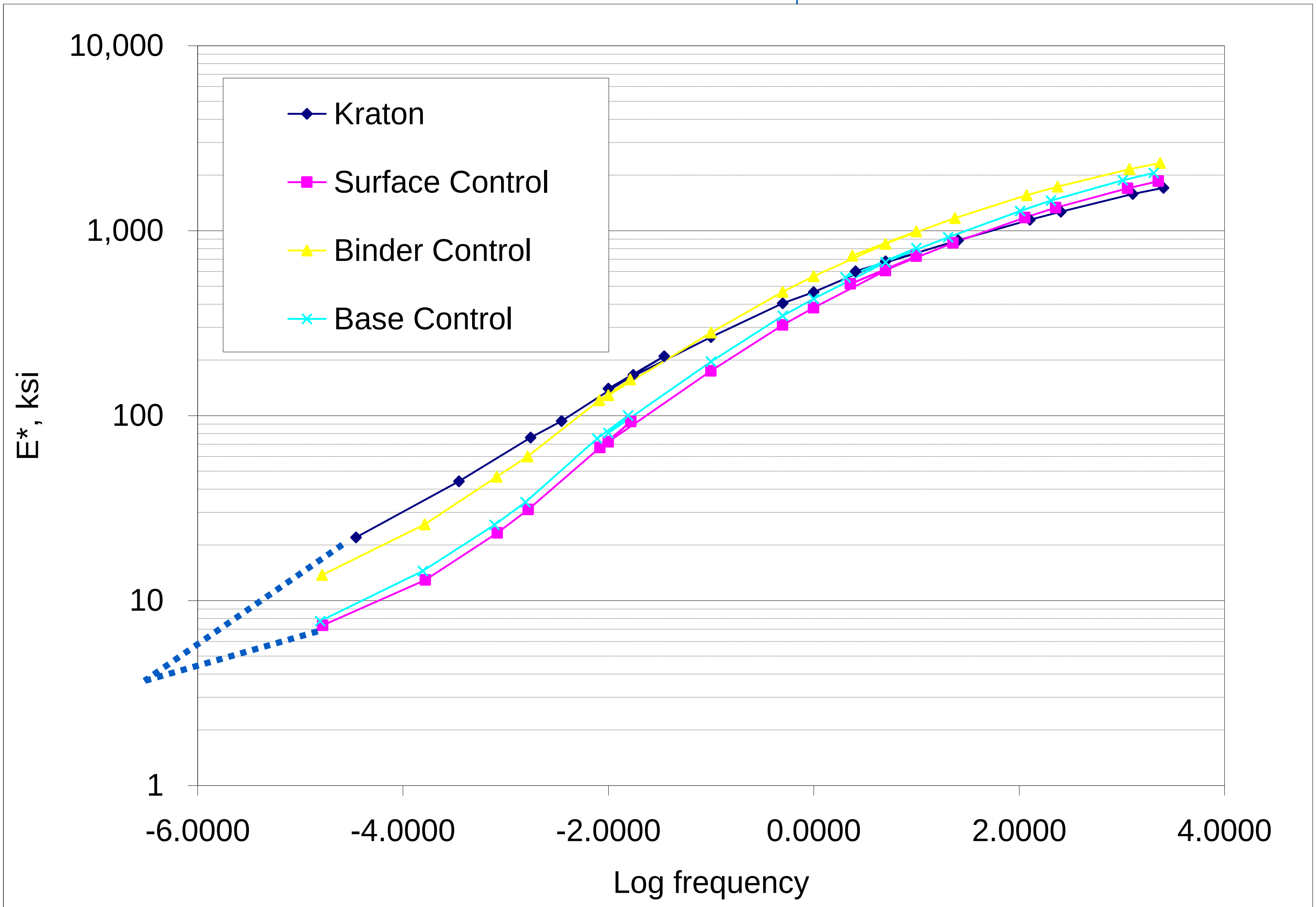
Lift thicknesses limited by 3:1 thickness:NMAS requirement

6”

Test Track Soil
M_r = 28,872 psi
ν = 0.45

Courtesy Prof. David Timm, Auburn U.

Master Curve Comparison



Courtesy Prof. David Timm, Auburn U.

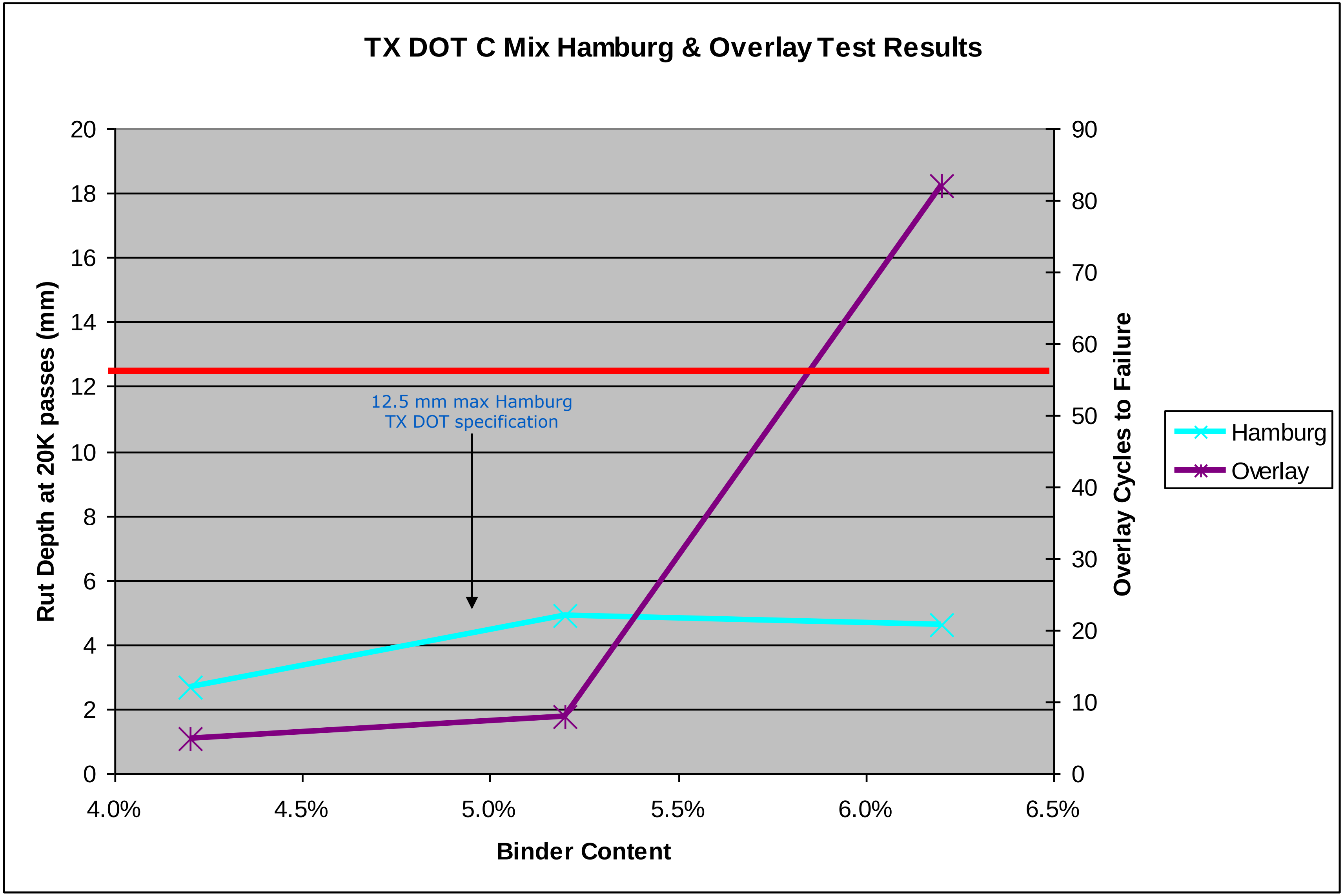
NCAT Construction Overview

- Binder, PG 67-22 + 7½% SBS polymer, shipped 6+ hours. No issues with handling.
- Mixing temperature 340°F (same used for PG 76-22 surface mixes), delivered to track 335°F, temperature behind screed 300°F.
- Mix came out of truck cleanly. Density easily achieved with conventional rolling pattern.
- No issues with shoving, however mixture appeared to "knead" as a unit under the roller.
- Truck trafficking commenced 8/28/09.

Testing for Overlay Applications

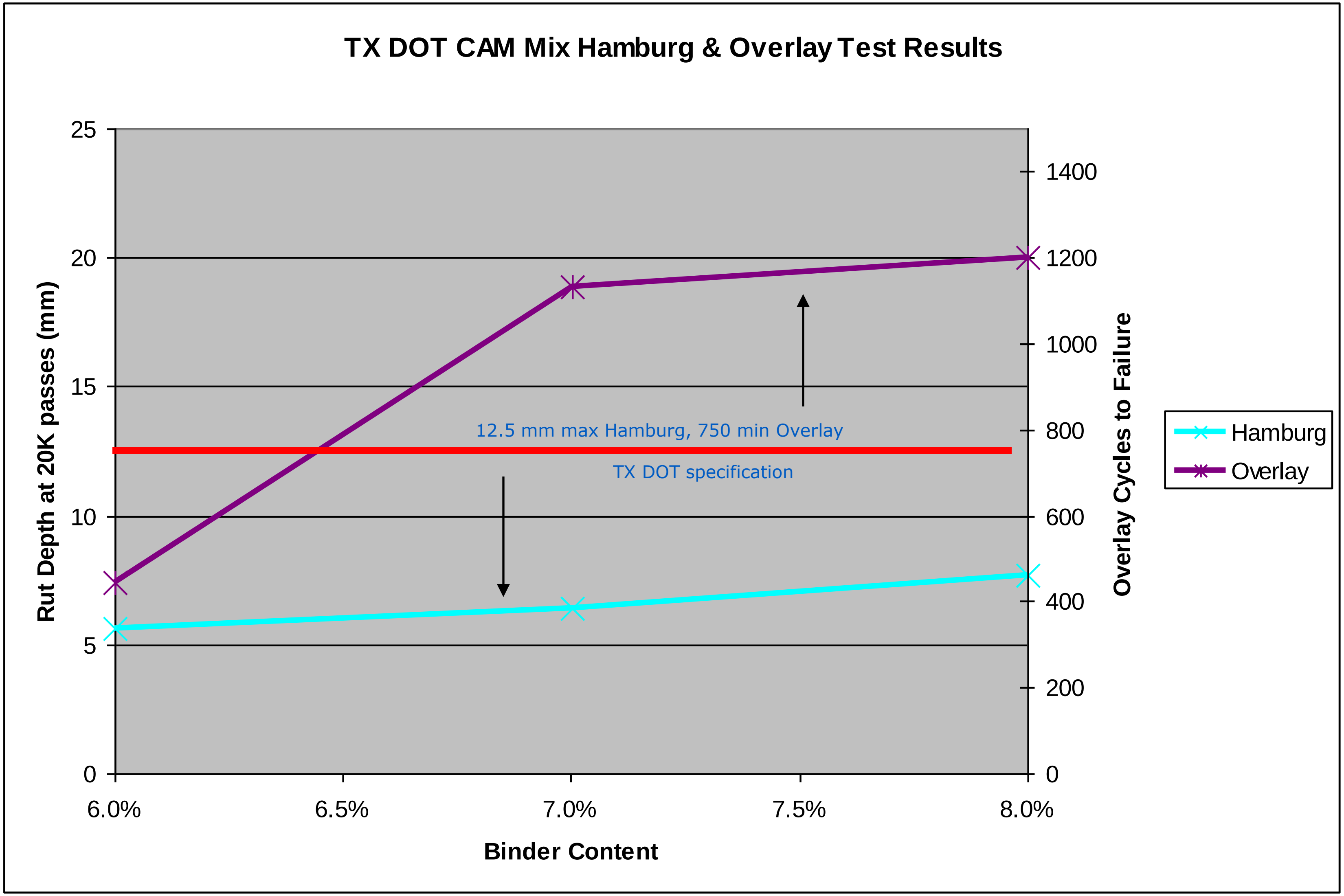
- Evaluations for TX DOT specs on Hamburg wheel track and TX DOT overlay tester.
- Evaluations for NJ DOT specs on APA and high strain beam fatigue.

TX DOT Overlay Specifications



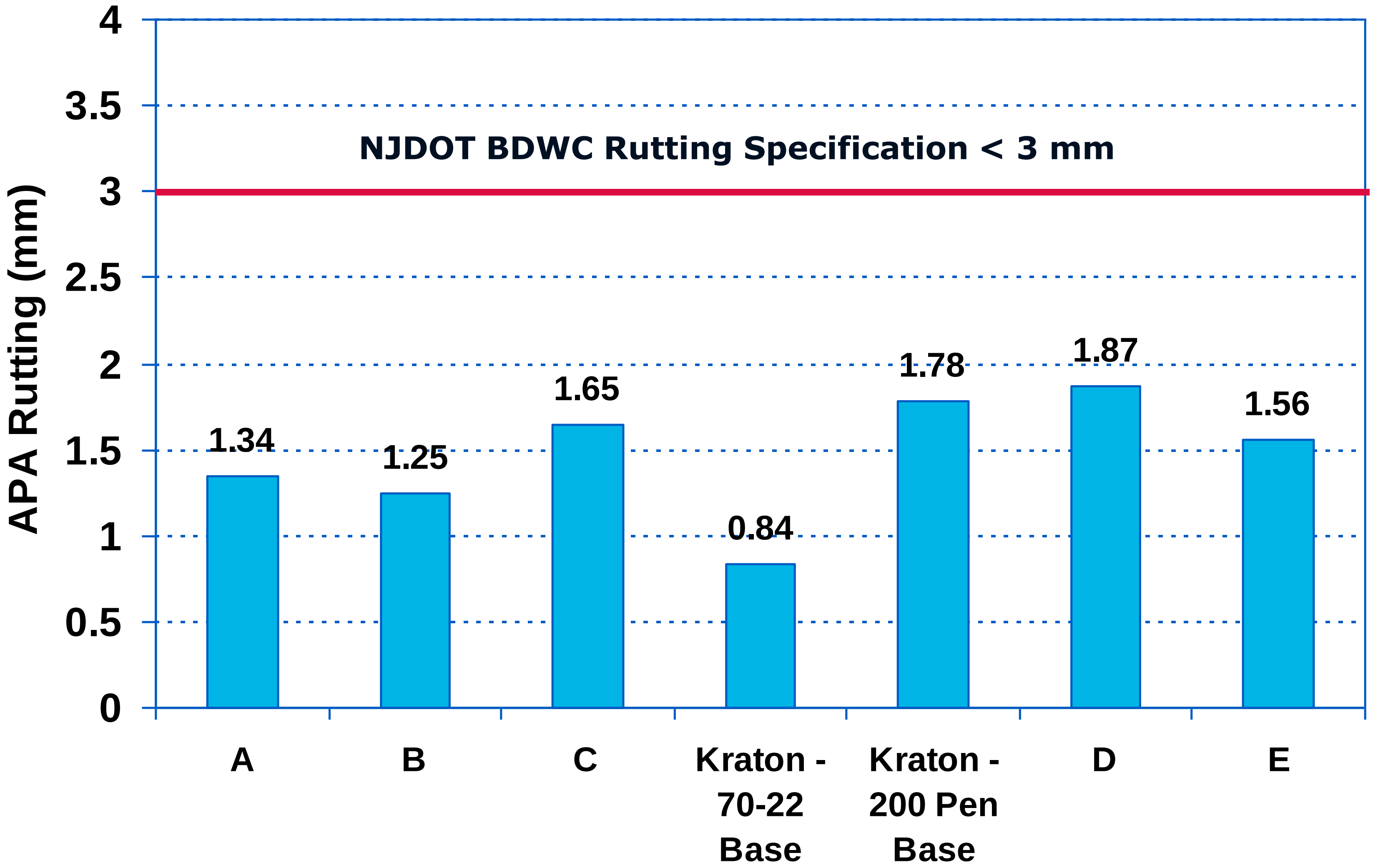
NCAT binder, based on PG 67-22

TX DOT Overlay Specifications



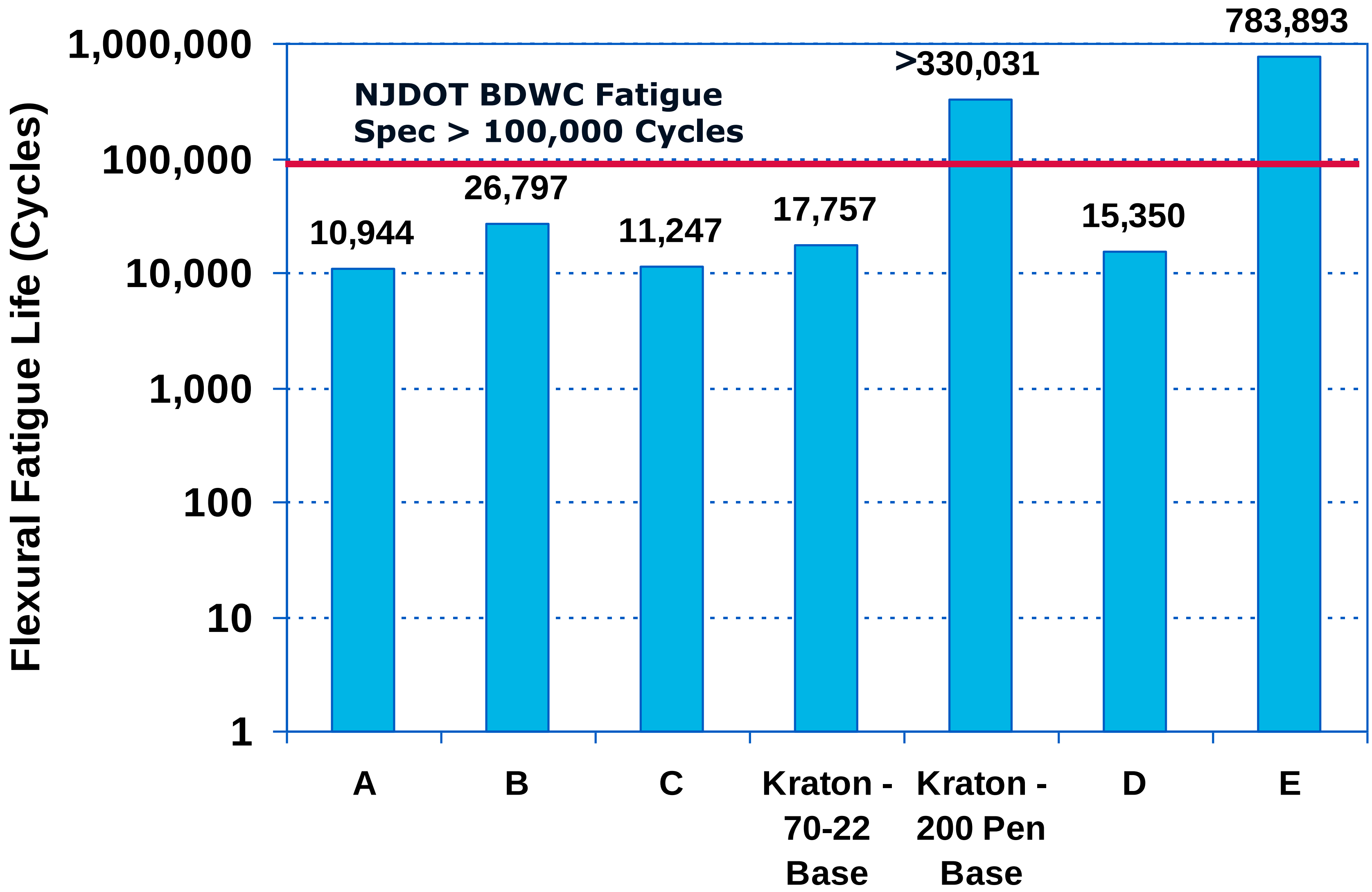
NCAT binder, based on PG 67-22

NJ DOT Flexible Bridge Deck Specifications



Asphalt Pavement Analyzer: 64 ˚C, 100 lb Wheel Load, 100 psi Hose Pressure
Courtesy Tom Bennert, Rutgers U.

NJ DOT Flexible Bridge Deck Specifications



Flexural Beam Fatigue: 15 ˚C, 1500 micro-strain, 10 Hz Courtesy Tom Bennert, Rutgers U.

Test Sections/Wheel Tracking

- Discussions underway with several agencies in US, Europe, Middle East and Asia for potential test sections.
- Wheel tracking trials in planning at TRL, the UK Transportation Research Laboratory and/or TFHRC accelerated loading facility
- Bridge deck project and full depth construction project in New Jersey.
- Overlay projects in Louisiana and Georgia.

Future work

- Advanced mix testing and modeling based on NCAT mixtures – **FHWA work will be presented at ETGs**.
- Evaluation in softer binders to define value in high strain environments such as overlays on cracked pavements.
- Development of suitable binder specifications for purchase specifications.
  - MSCR
  - ABCD / M320 Table 2
  - Force ductility energy
  - Fatigue torture test (?)

QUESTIONS