Modified Asphalts in Pavement Design

Optimization of Asphalt Mixtures and Pavement Thickness with Specialty Polymers

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Joint Technical Committee on Pavements
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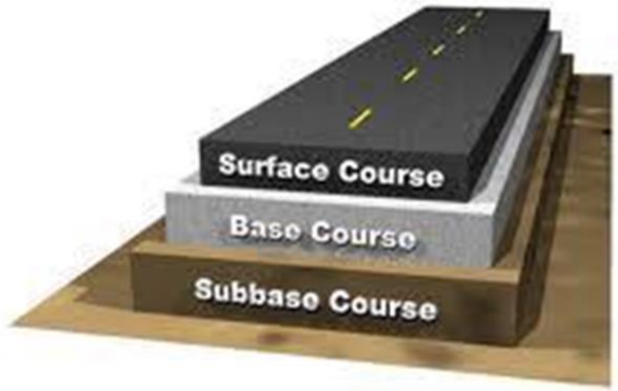
Outline

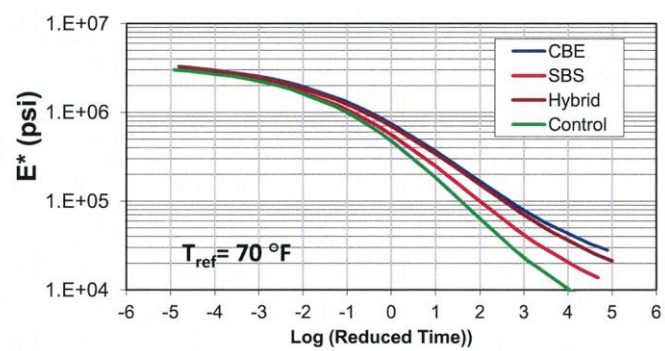
- Asphalt Mixtures Quality and Pavement Thickness - Past and Future
- How Modified Asphalts has changed and will impact the "return on investment in roads"
- Pavement ME and its role in expediting the change, or gain on the investment of asphalt roads.

Pavement Design Methods

- AASHTO 1993
  - $SN = a_1 D_1 + a_2 D_2 + a_3 D_3$
    - SN= Structural Number
    - D: Thickness
    - a_i : Layer coefficient ~ Modulus

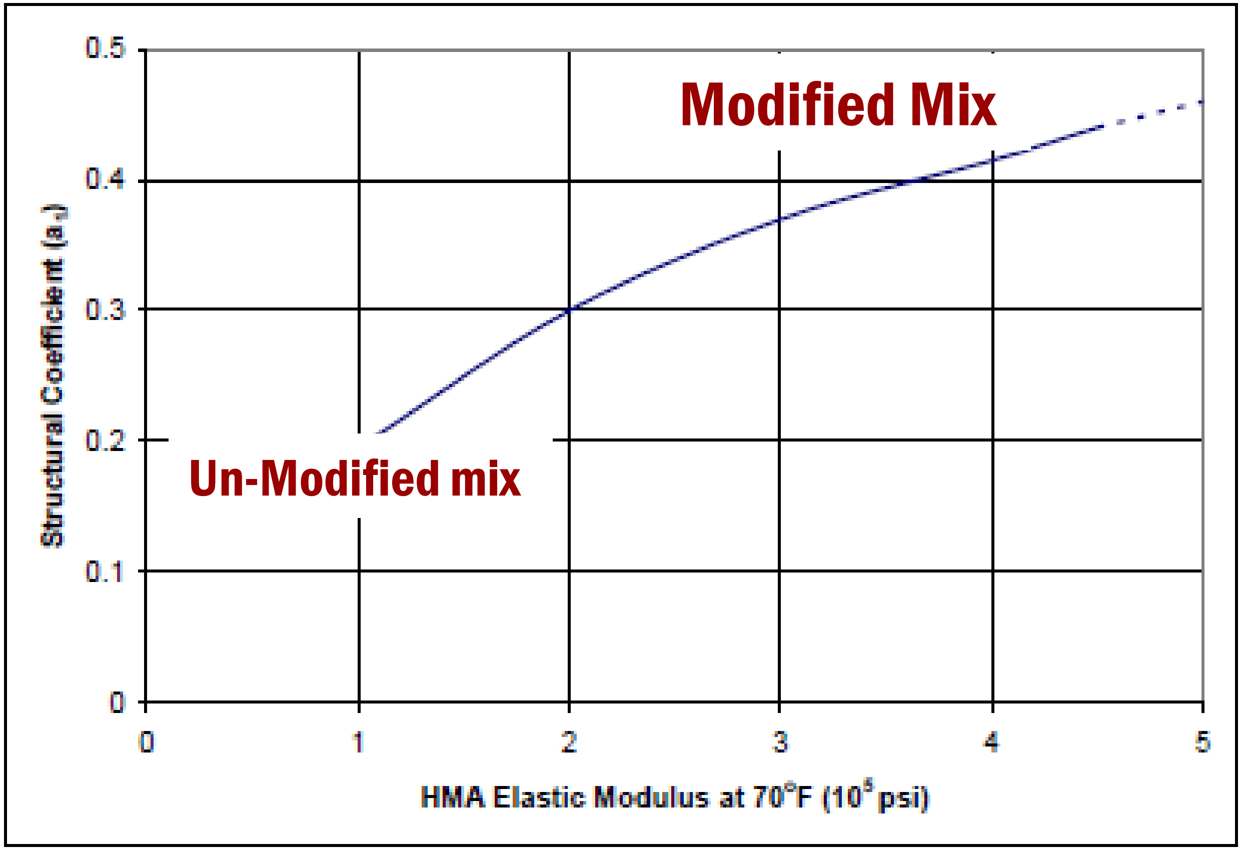


- Pavement ME – 2012--→
  - Mixture Dynamic Modulus : E*
    - Higher E*= Less deformation, less damage



Asphalt Mixture Modulus Impact:

Higher E of mix = Higher a_i – less thickness



AASHTO 1993

Europe has used this concept for more than 25 Years – EME

- *“.. to reduce the consumption of non-renewable resources (aggregates and also bitumen) by using Enrobés à Module Elevé (EME - High Modulus Asphalt mixes), since more than 25 years.*
- ***The thickness reduction can reach to 30 – 35% less compared to traditional flexible pavement.***
- *This technique presents an excellent solution to reduce the use of materials while maintaining a very long service life..”*

Source : ISAP 2012 – Yves Brosseaud, *French Institute of Science and Technology for Transport, Development and Networks (*IFSTTAR), France

NCAT Study – 18% thickness reduction

Kendra Peters-Davis and Dr. David H. Timm, P.E. (NCAT Report 09-03)

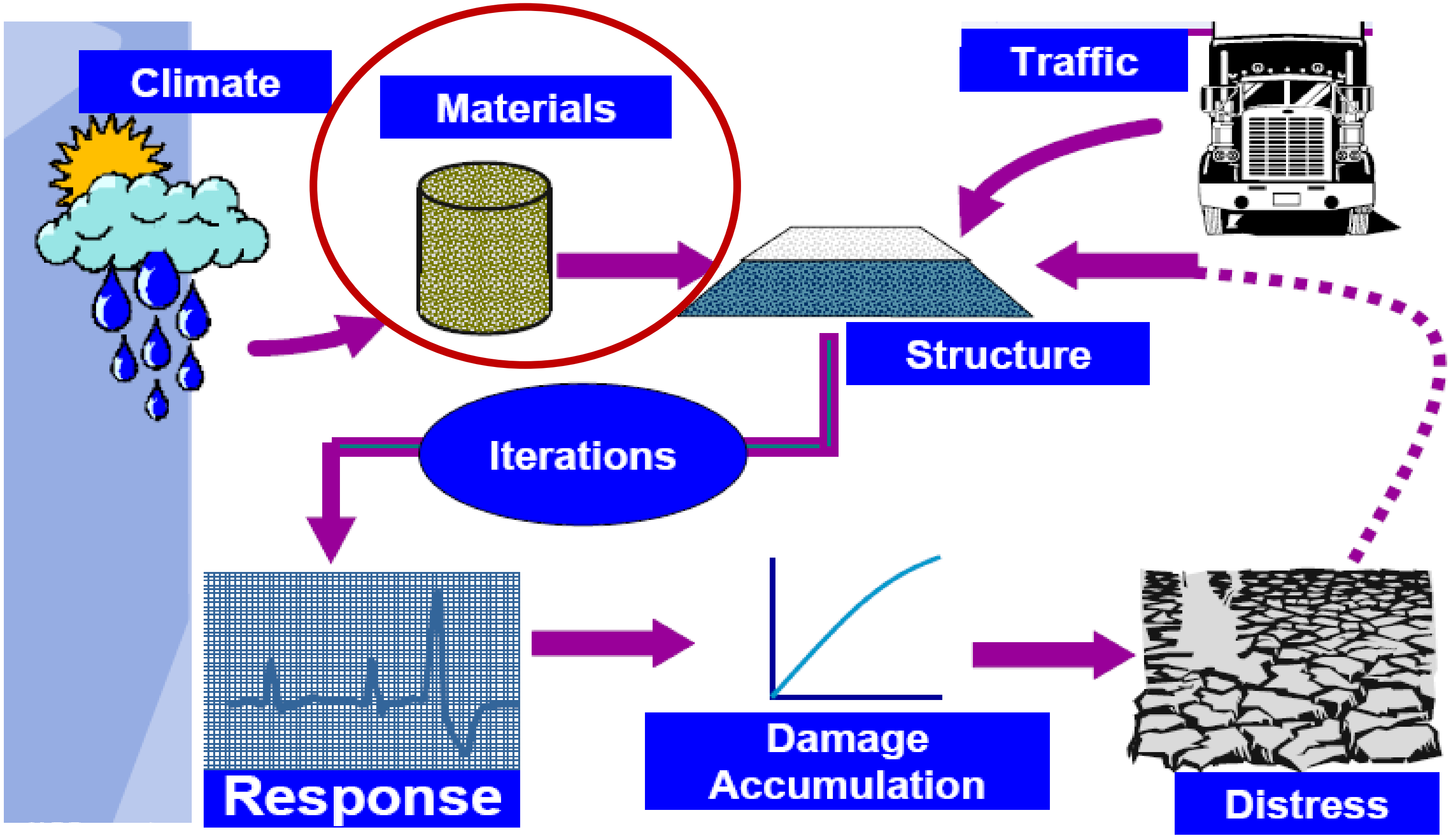
- Two sections placed in 2003 designed with AASHTO 1993 to reach terminal serviceability at 10 million ESALs have survived an impressive 30 million ESALs at the test track.
- The sections differ with respect to binder grade—one used PG 67-22, whereas the other used **modified PG 76-22**.
- Based on calibration, the a_i can be increased to 0.54.
- Increasing the **coefficient from 0.44 to 0.54 results in approximately 18% percent thinner asphalt** cross-sections.
- Alabama DOT estimates **savings of approximately $40** million per year since implementing the revised layer coefficient.

NCAT newsletter

- MEPDG Predictions vs. Actual Performance
- Performance data from the 2003 and 2006 sections at the test track were compared with MEPDG predictions
- Using the national calibration coefficients generally over-predicted rutting. However, newly calibrated coefficients for the unbound layers produced acceptable rutting predictions.
- Fatigue cracking: Grouping sections with similar characteristics may result in better fatigue calibration results, an approach which may be helpful in analyzing data for the 2009 sections.

M-E Pavement Design Process

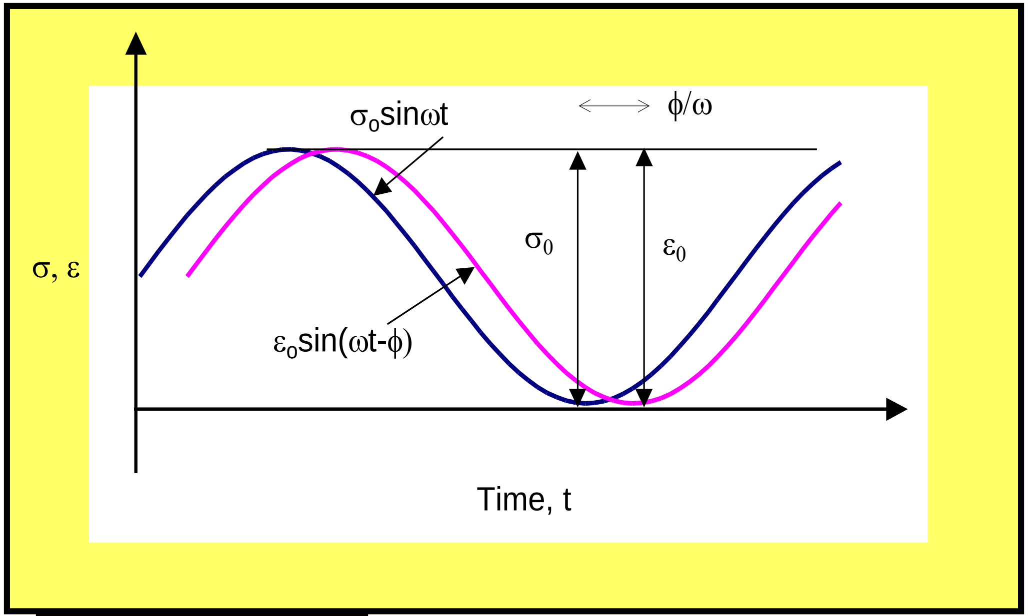
Options to improve return on investment are limited:
Modifying Mixtures is the best option



Mixture E*- Complex Modulus

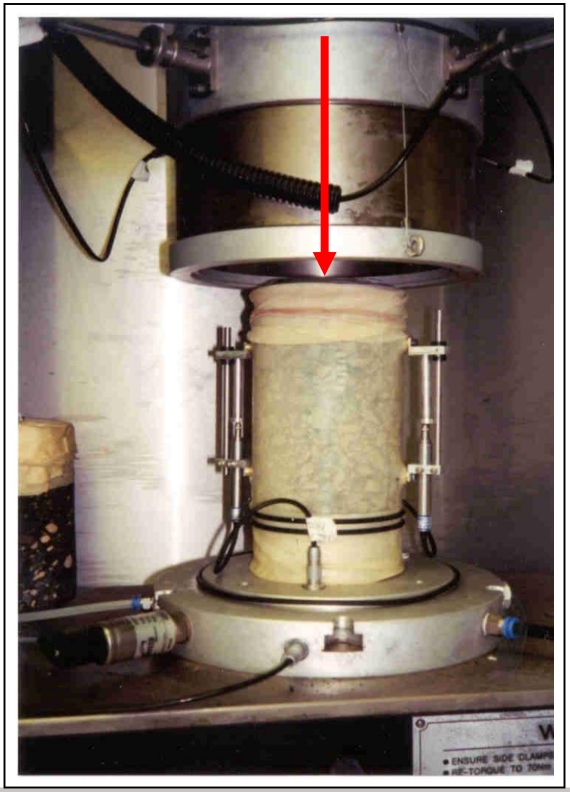
	Input Level 1	Input Level 2	Input Level 3
Asphalt Concrete	**Measured |E*| (mixture-specific testing)**	**Estimated |E*| (predicted models & lab measured binder data)**	**Default |E*| (assumed |E*| & assumed binder data)**
Stabilized Materials	Measured M_R	Estimated M_R	Default M_R
Granular Materials	Measured M_R	Estimated M_R	Default M_R
Subgrade	Measured M_R	Estimated M_R	Default M_R

Mixture Performance and Impact of Modifiers-
Can be measured Effectively Dynamic Modulus: E*/ϕ



$$|E^*| = \frac{\sigma_0}{\varepsilon_0}$$

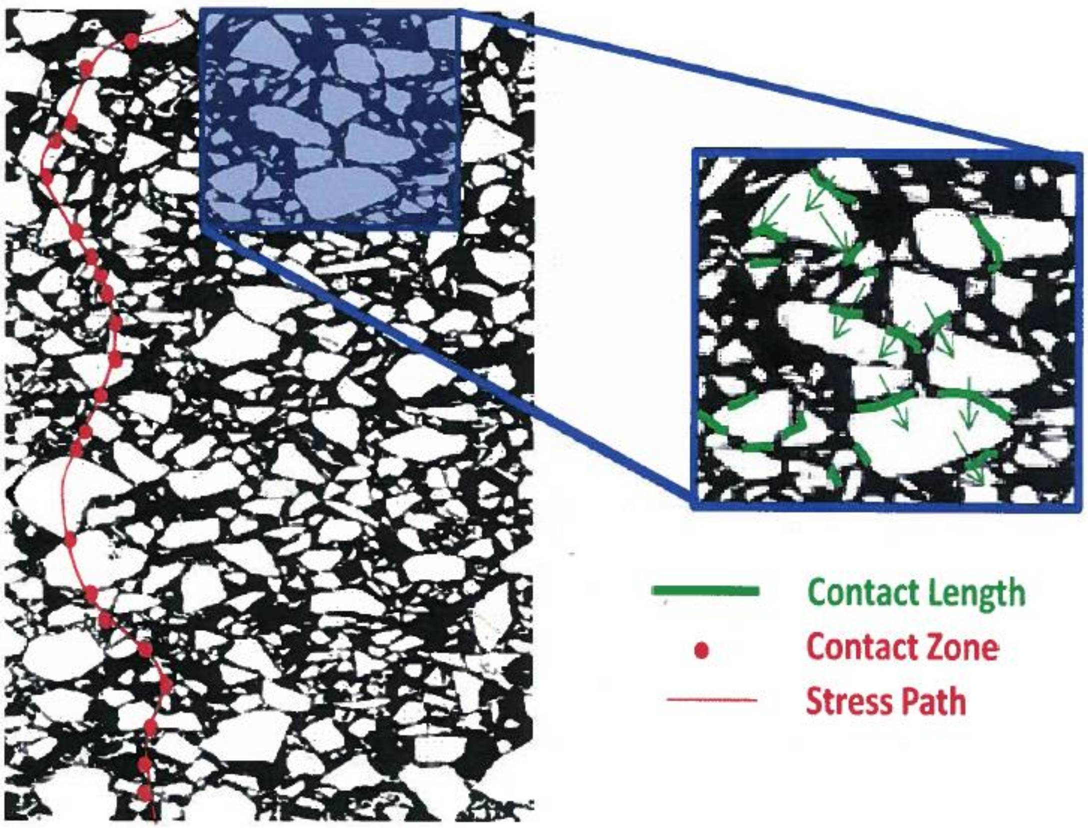
$$\phi = \omega t_i$$



How to Improve E* with Modifiers

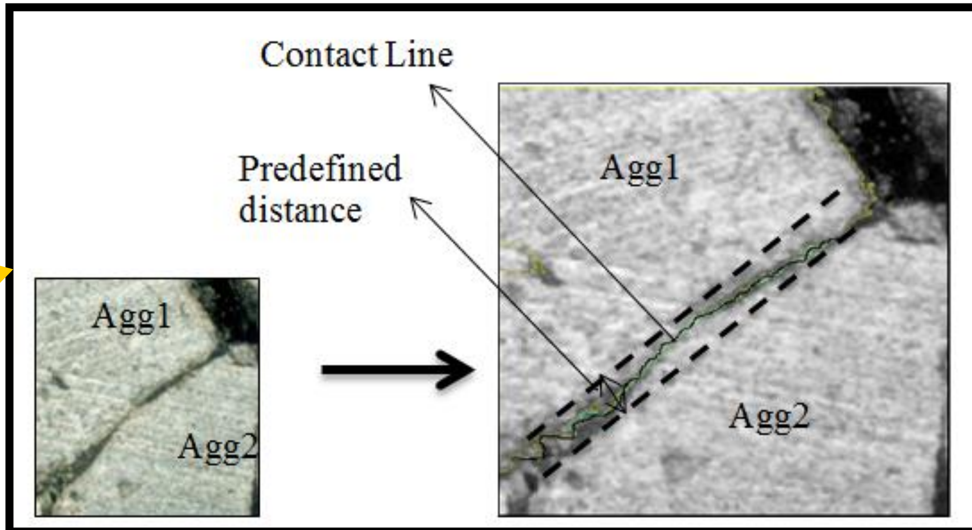
- Traditional approaches:
  - Increase binder grade: PG 64-22 to PG 76-22
  - Improve Aggregate gradation
- Newly discovered approach:
  - Improve Aggregate structure
  - Some additive improve aggregate structure by allowing better packing
  - Lubrication theories allow using additives to improve packing during construction

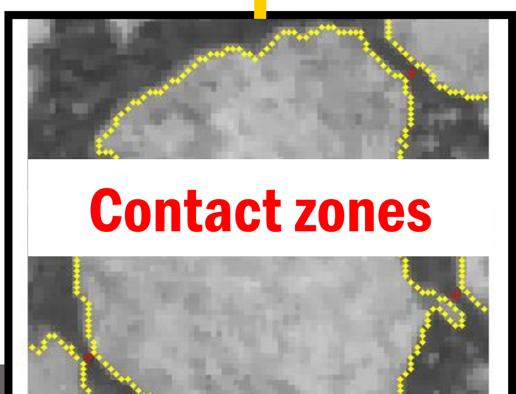
How It Works: Optimize Aggregate Structure with Asphalt Polymers



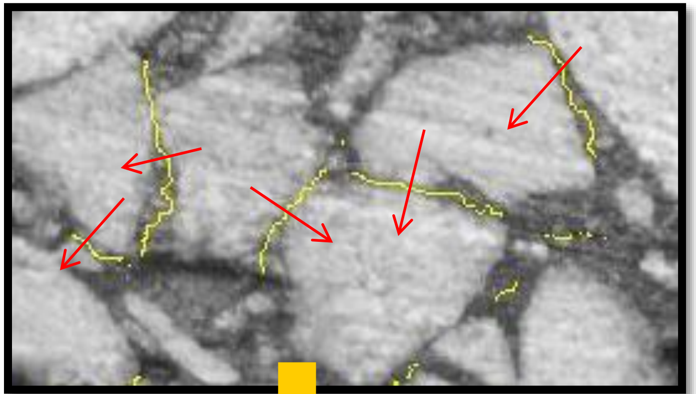
- The rocks are stronger than the asphalt binder and better able to bear the traffic load
- Certain Polymers helps arrange the rocks to bear the traffic load
- Increased contact points allows better distribution of load, which leads to
  - Higher E*
  - Longer-lasting pavement and
  - Improved rutting Resistance

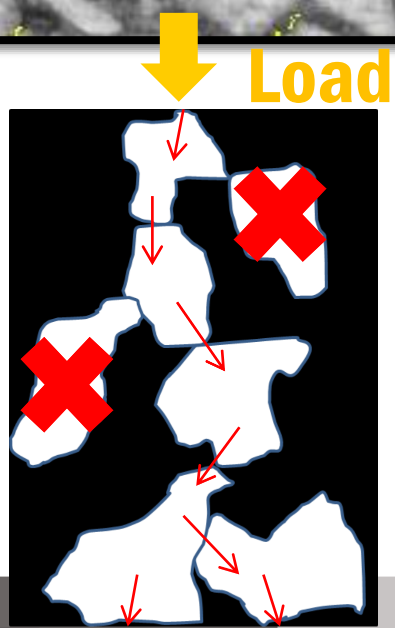
Aggregate Skeleton Characterization Using iPas-2 Software

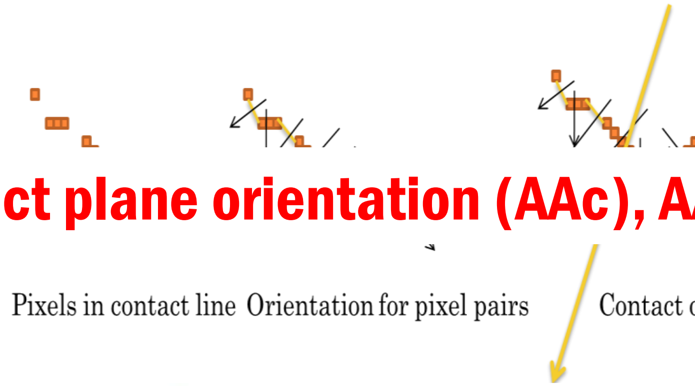




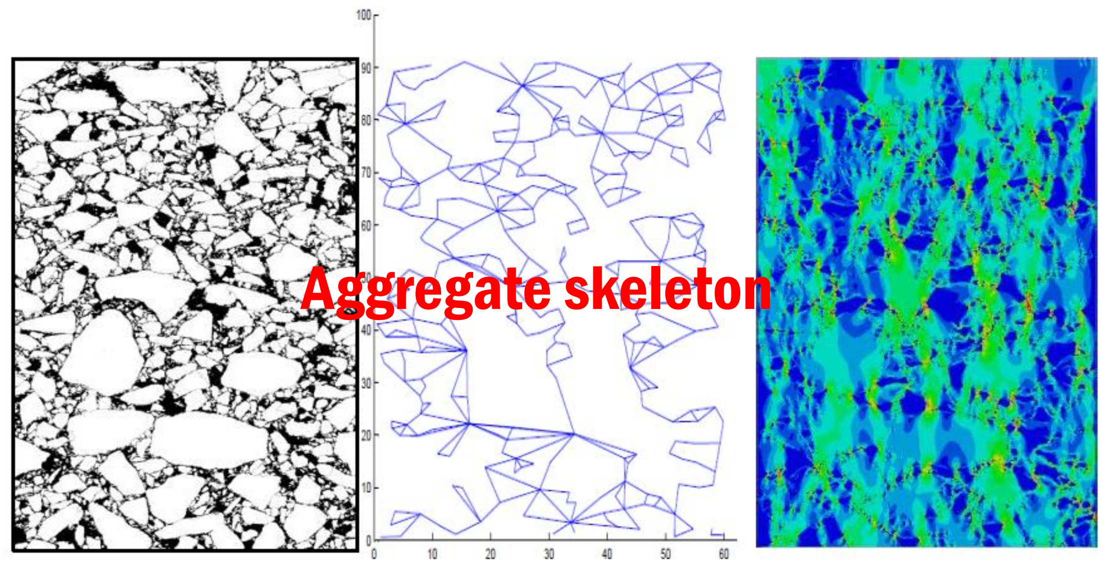
Aggregate Skeleton Characterization





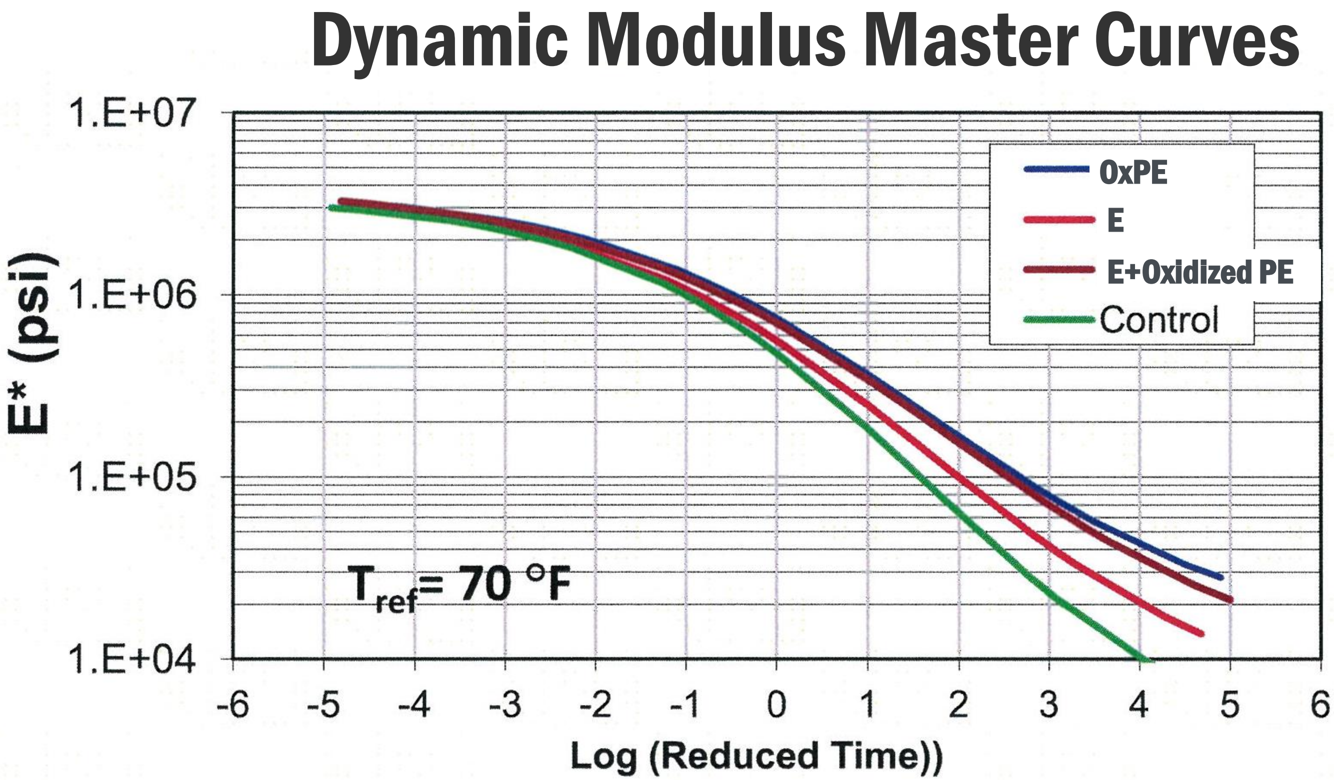


Contact plane orientation (AAc), AAAc, Δc



Dynamic Modulus (E*)-AASHTO TP79

Sample	Air Voids (%)
Control	6.8%
Control	7.0%
E	7.1%
E	6.8%
OxPE	7.1%
OxPE	7.0%
E+OxPE	7.3%
E+OxPE	6.9%



Certain Polymer combination has higher stiffness at high temperature

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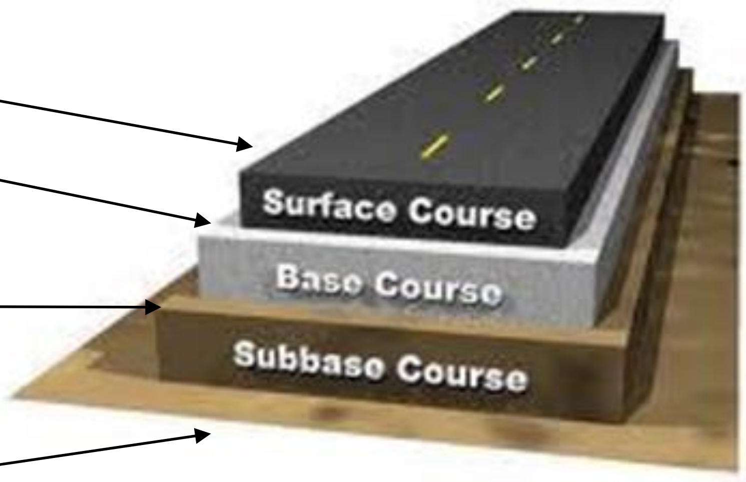
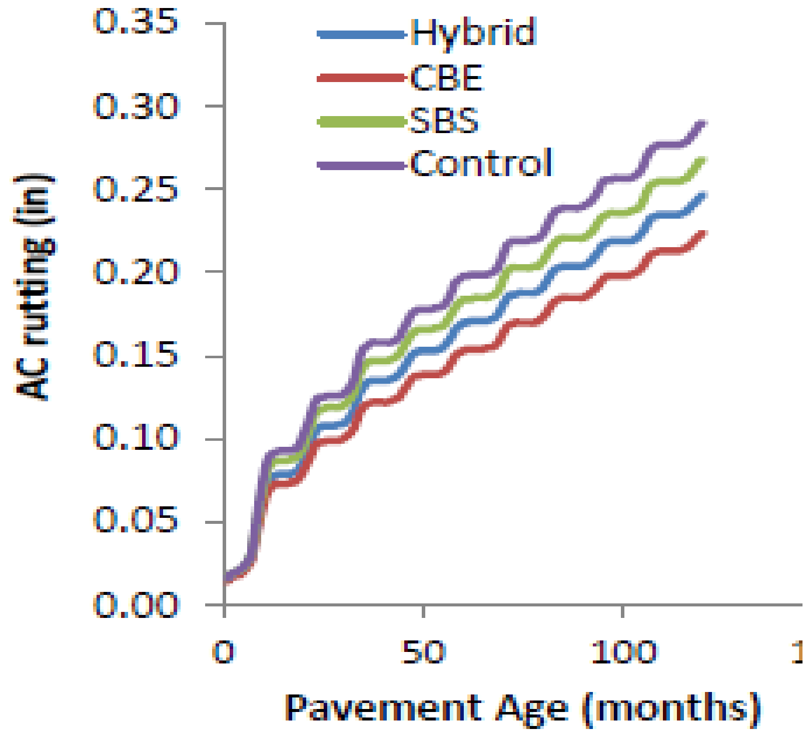
Pavement Structure Assumed

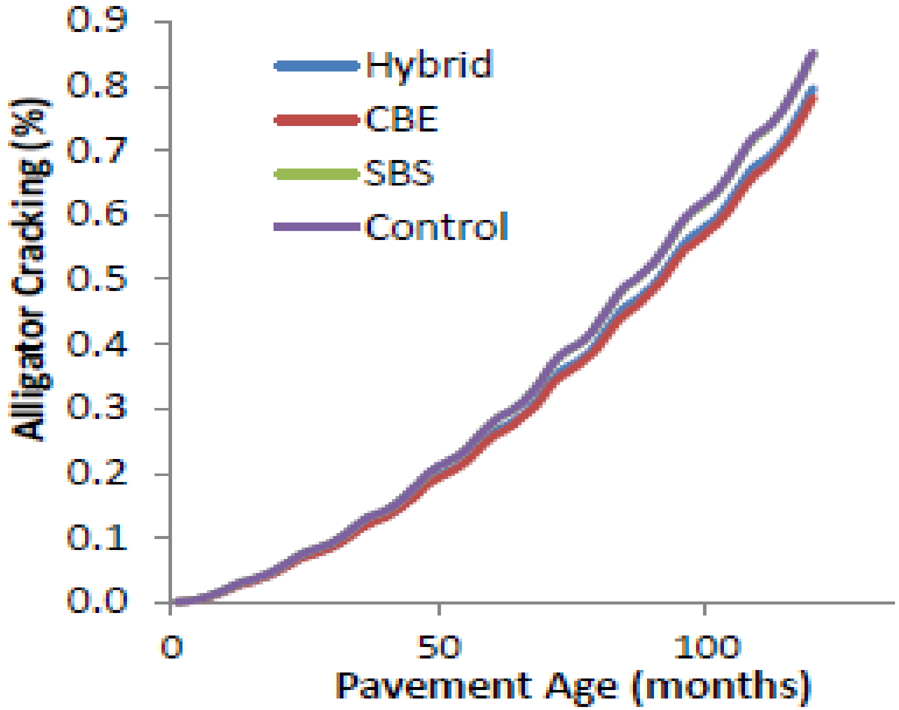
- Layer 1: AC=> h= 3.0, 4.0, 5
- Layer 2:
  - A-1-a, 6 in
  - Mr= 40000 psi.
- Layer 3:
  - A-2-5, 9 in
  - Mr= 28000 psi.
- Layer 4:
  - A-7-6, Last layer.
  - Mr= 10000 psi.



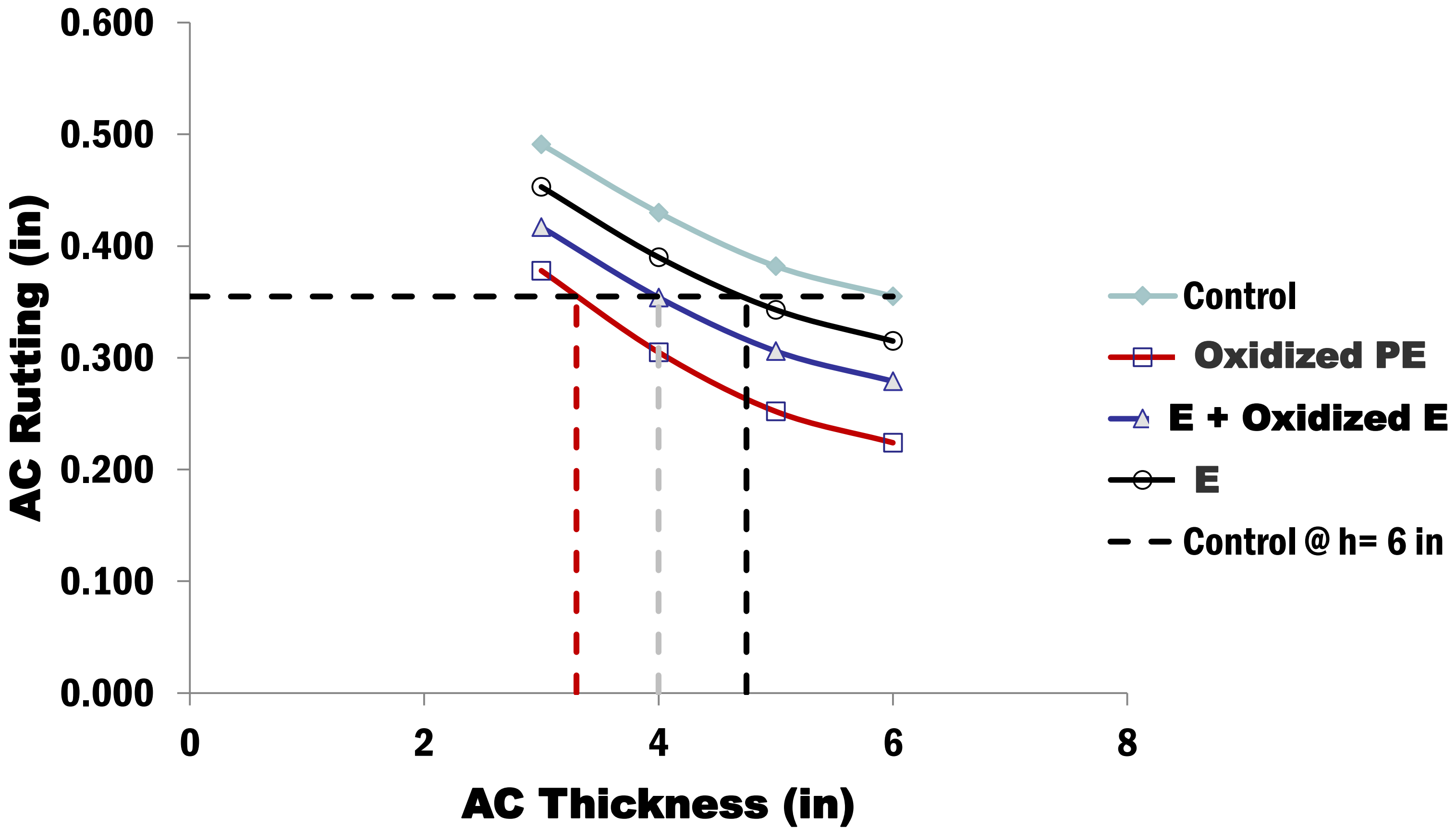
Results of Pavement Analysis

Distress	Control	CBE	SBS	Hybrid
AC Bottom Up Cracking (Alligator Cracking) (%of total area of lane cracked 12'x 500'=> 6000 ft²):	0.852	0.782	0.850	0.797
Permanent Deformation (AC Only) (in):	0.290	0.220	0.270	0.250





Rutting and Asphalt Layer Thickness



More Benefits Possible Today: Reduce Road Thickness up to 45% when Polymers are Selected Well

Road Performance Criteria

- 10-year design life
- Average annual daily truck traffic = 4500
- Pavement design thickness driven by material performance
- Road considered failed if
  - Rut depth reaches 0.35 inches

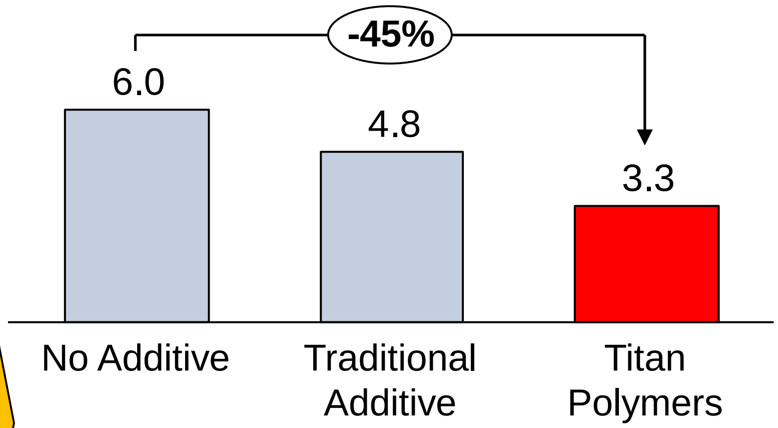
    or

  - Alligator cracking reaches 25%

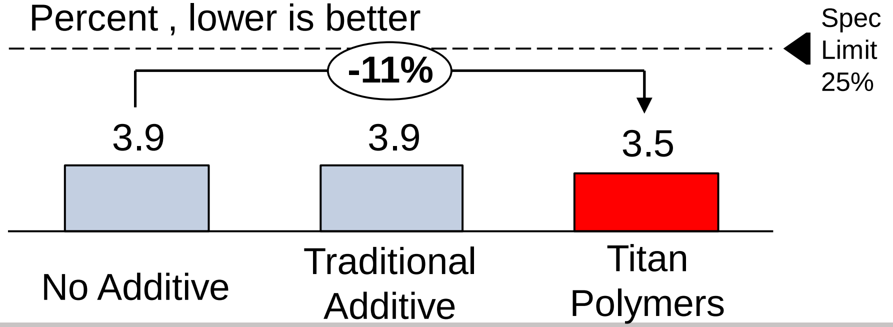
Rutting

Alligator Cracking

Pavement Thickness To Meet 10-Year Life*
Inches, lower is better



Alligator Cracking at 3.3 Inches Road Thickness
Percent , lower is better



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*Based on AASHTO MEPDG Design Method

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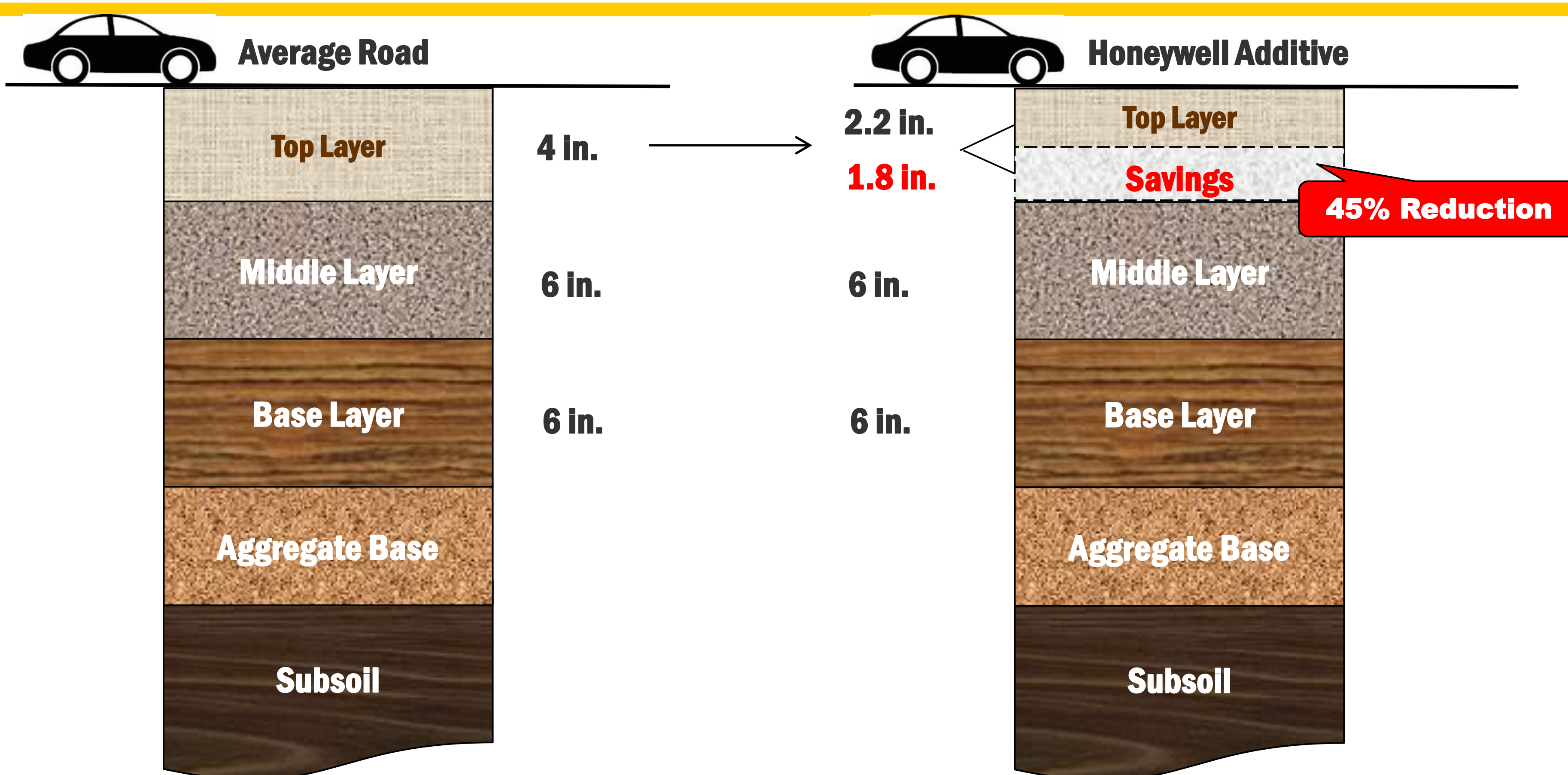
Potential Savings in pavement top layer



Better Internal Structure Enables Thinner Road Top Layer

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Sample for illustration purposes. Roads design varies depending on local conditions.

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Stretch Paving Cost with Specialty additives

Infrastructure dollars are extremely limited, while demands to build and improve roads continues to grow

Technologies like Oxidized Asphalt additives can help by:

1) <u>Build more roads</u> → Pave 40% more miles by reducing road thickness, while maintaining road performance

OR

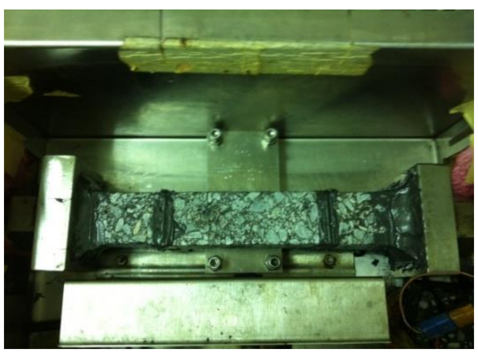
2) <u>Build better roads</u> → Extend the maintenance cycle by 5 yrs thereby reducing maintenance costs

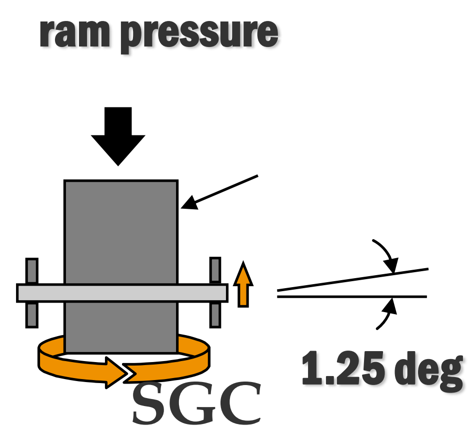
Integrating New Technologies Saves Money

Other Benefits of Specialty Polymers

Better Workability, less thermal Shrinkage

Thermal Cracking	Fatigue Cracking	Rutting	Workability (mix & compact)



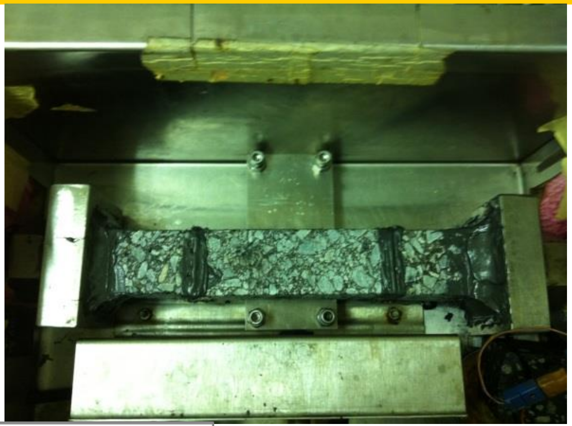


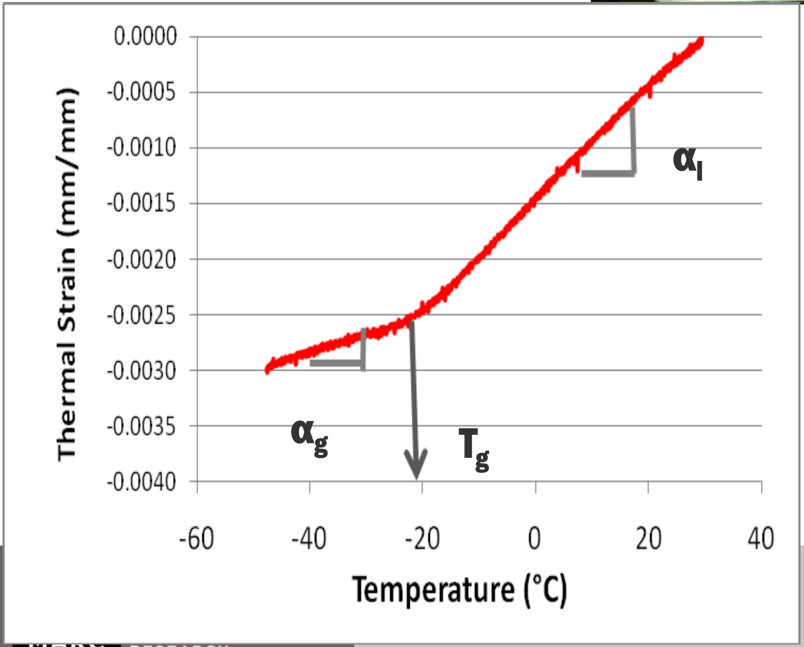
- 20 | 20 | 40 | 135

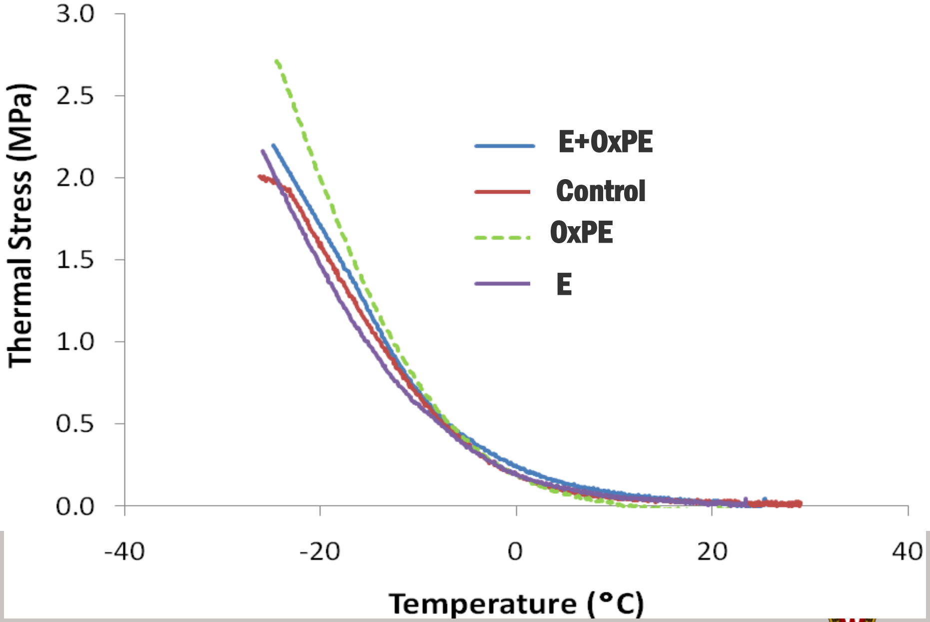
Pavement Temperature, °C

Thermal Stress Restrained Specimen Test (TSRST)

Ashalt Thermal Cracking Analyzer(ATCA)

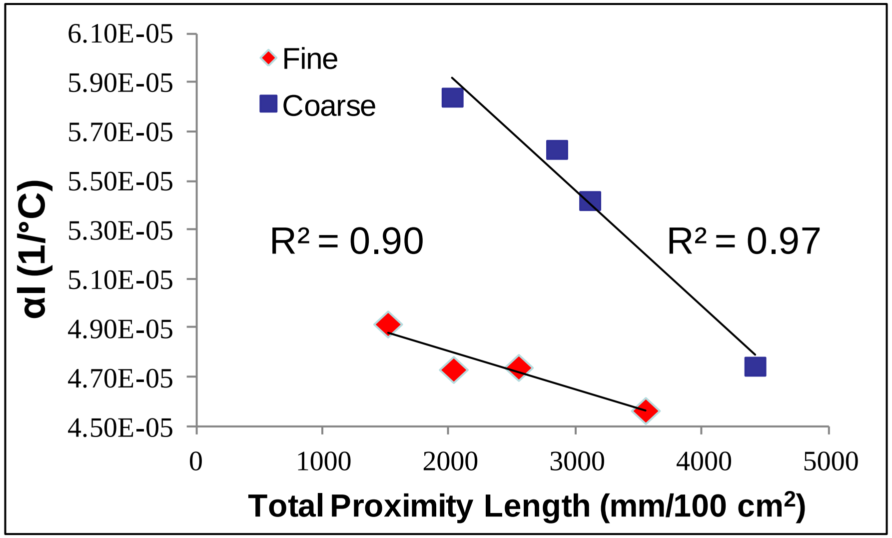






Effect of Aggregate Structure on CTC

Aggregate Structure Parameters



Good correlation between Internal Structure Parameters and Coefficient of Thermal Expansion.

Increase in Total Proximity Length → Higher Connectivity of Aggregate Skeleton → Higher Resistance to Thermal Strain

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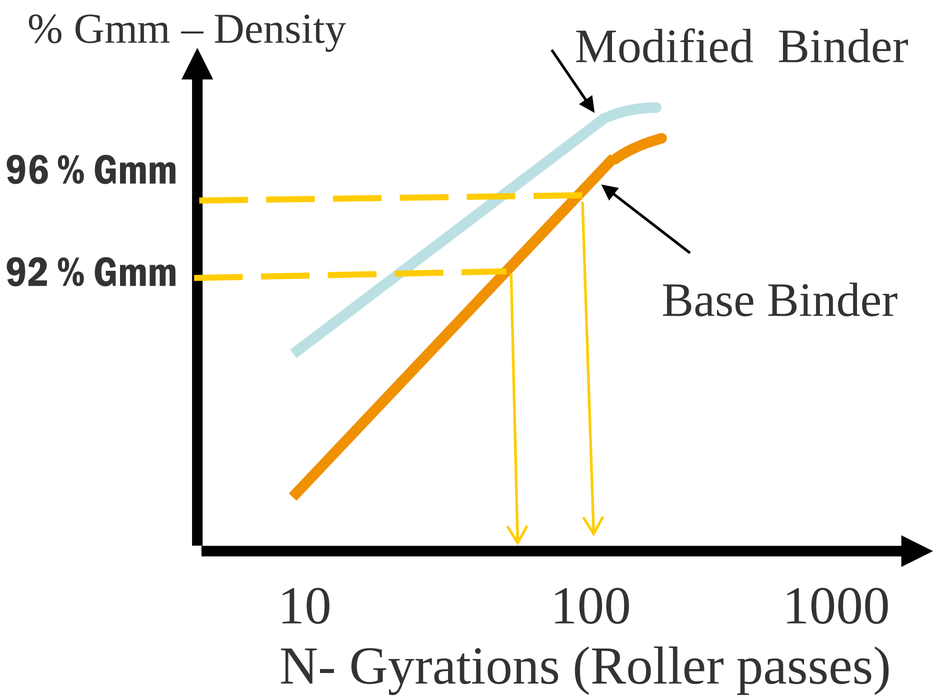
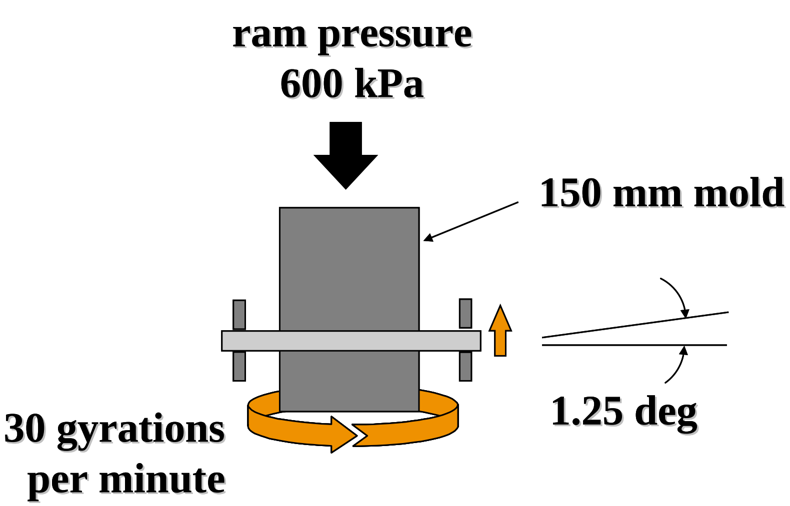
Workability: Measuring Required Compaction Effort
Superpave Gyratory Compactor

- Simulate field compaction with roller
- Also simulate traffic densification





Effect of Polymers on Compaction Effort of mixtures at 145 °C

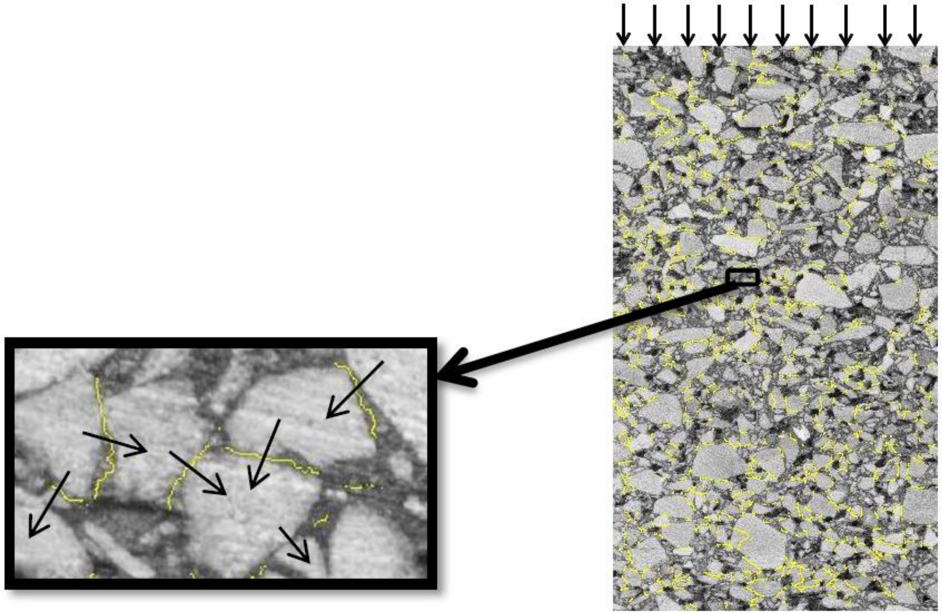
Sample	N92- 8 % air-voids	N96 – 4% air-voids	% Change in compaction effort
Control	36	111	0
Elastomer	32	100	-10
Plastomer	26	86	-23
Hybrid	24	76	-41

- Titan and Hybrid can reduce compaction effort (up to 40%)
- Or allow wider temperature range for compaction

Optimization of Asphalt Mixtures
More Cost effective materials and pavements

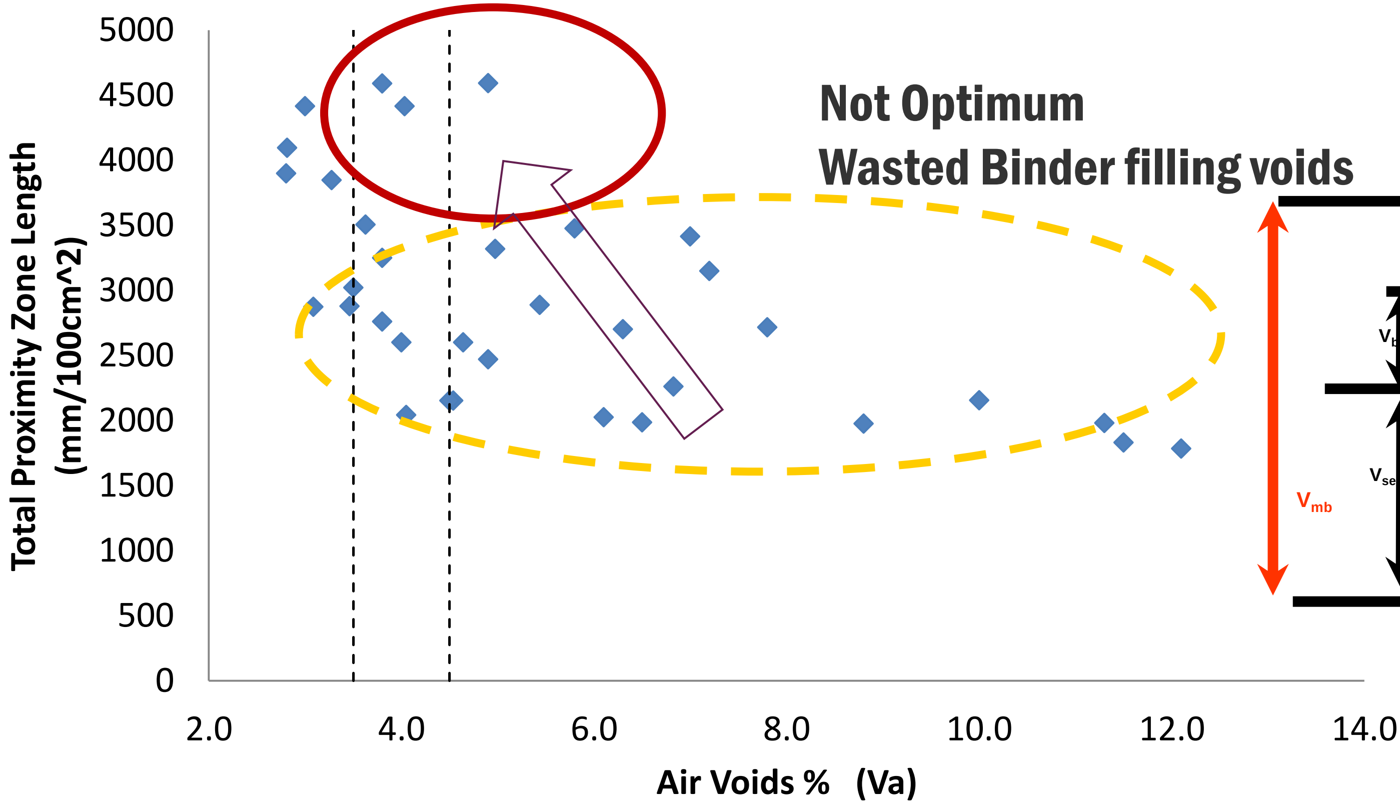
- **Micromechanical Characterization Using Imaging Analysis is Simple and Available**

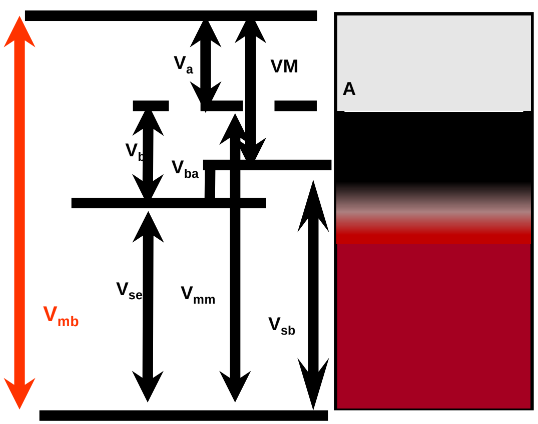
- Parameters calculated:
  - Number of contact zones
  - Contact length (area)
  - Contact orientation
  - Aggregate orientation
  - Aggregate skeleton



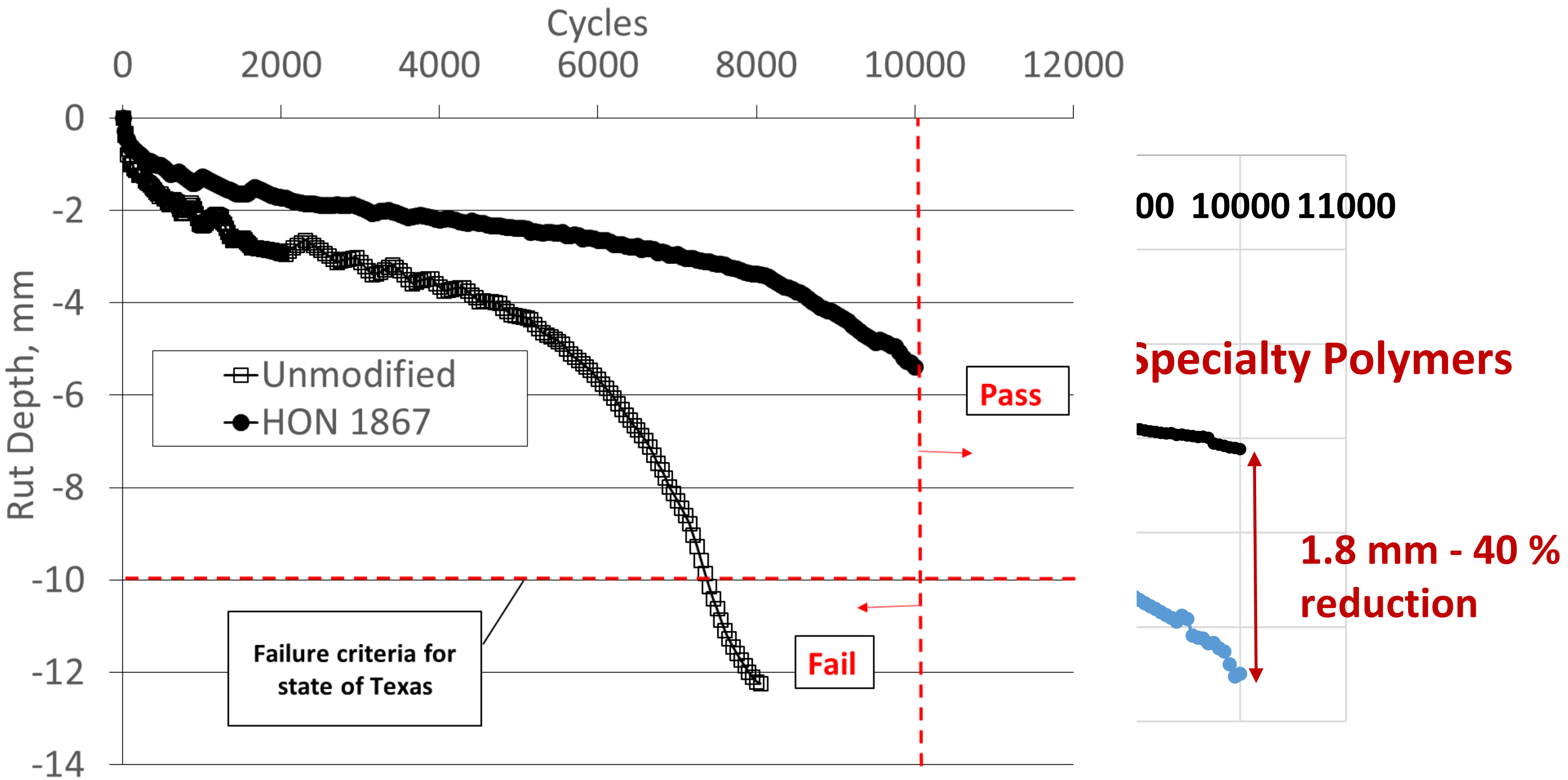
Titan ability to increase Contact Points (TPL) at optimum air voids

Optimum: Binder used effectively





Optimum Bitumen and Less Rutting



Concluding Results

- Roads are built with mixtures, not Binders!
- We need Modified Mixtures to impact pavement design
- Roads' Cracking & rutting are affected by:
  - aggregate structure and bitumen Properties.
- Road Thickness can be reduced
- Road service life can be improved
- There are specialty modifiers that can improve road performance and allow more economical pavement design
- Pavement ME is essential to all these developments

Thank You for the Opportunity

Questions?

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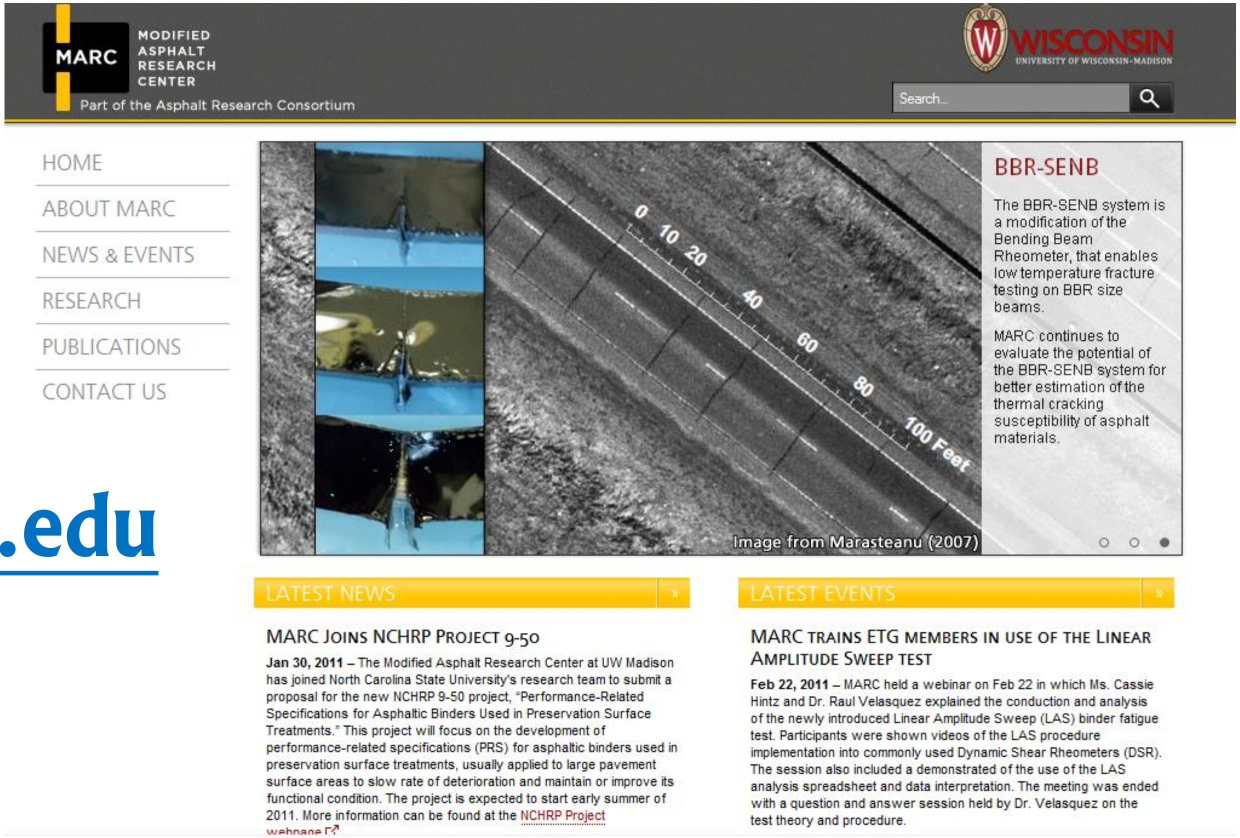

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