

# **21<sup>st</sup> Century Asphalt Pavements**

## **Challenges & Opportunities**

Minnesota Pavement Conference  
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## Topics

- Materials
- Testing
- Design
- Construction
- **THE BIGGEST CHALLENGE!**





# Materials:

## This is Not Your Granny's Asphalt!

Warm Mix  
Modifiers  
Recycling Agents  
Recycled Mixes  
Future

# How have asphalt materials changed?

- 1901 – 2000 **Age of Uncomplicated**
  - Almost all unmodified asphalt
  - Recycling in 1970s – 90s: Low amounts of RAP
  - Almost all dense-graded mixes
  - Marshall and Hveem become displaced
  - Volumetric design works OK

Reincarnated as Roads



# How have asphalt materials changed?

- 2000 – 2016
  - PG System in full swing
  - Refineries change – asphalt gets expensive
  - Warm mix
  - PPA to make high PG
  - REOB to make low PG
  - Polymers
  - More RAP and RAS
  - Smaller NMAS
  - SMAs



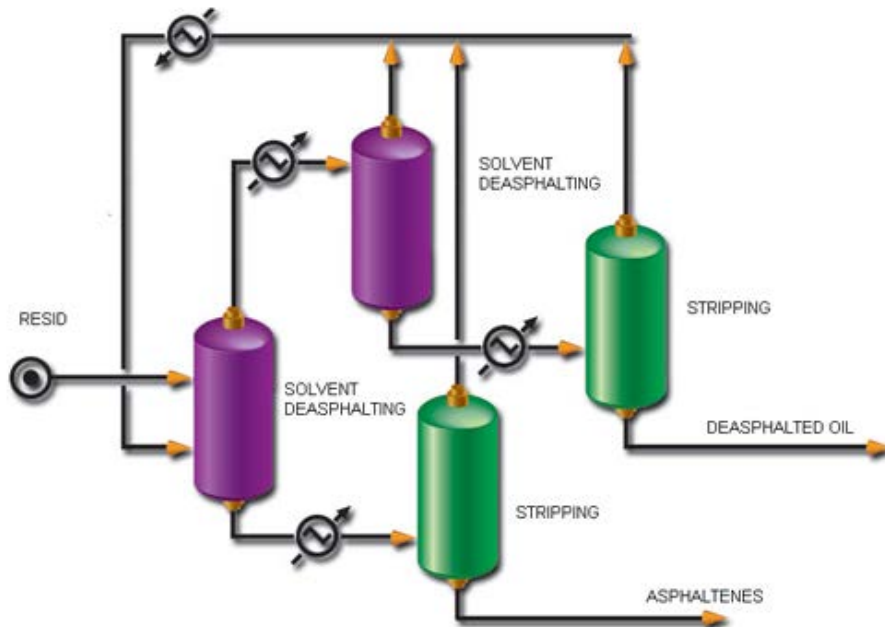
## PG System

- Much better asphalt specification
- Mix design needed some tweaking
  - Coarse gradations were not necessarily better
  - Aggregate-crushing compaction
  - Lift thickness vs NMAS
- All states except one or two



# Refinery Changes

- ROSE (Residuum Oil Supercritical Extraction)
- Cokers
- More terminal blenders

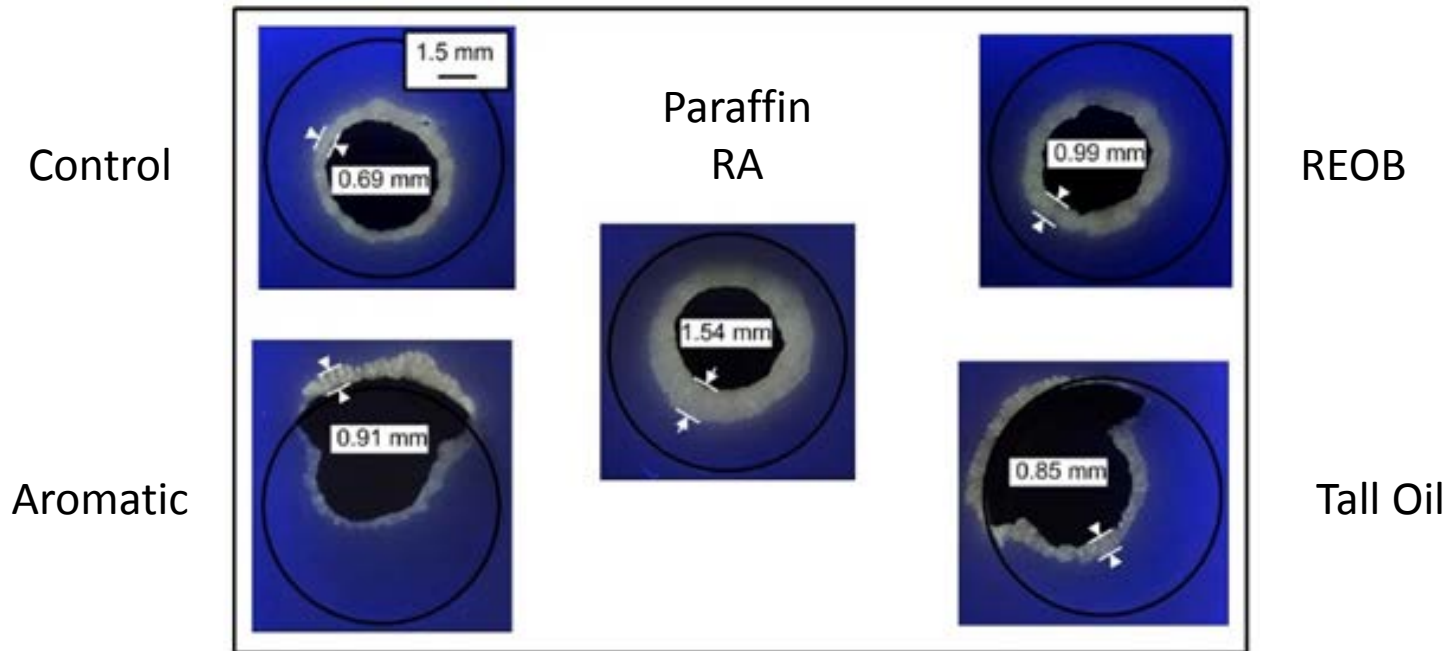


## REOB and PPA

- Recycled Engine Oil Bottoms (Steve Escobar)
  - Most common additive
  - High flash point, high visc. index, low wt. loss, low visc., etc.
  - Also paraffinic
- Polyphosphoric Acid (TRB Circular E-C160)
  - Commonly used additive
  - High visc., no free H<sub>2</sub>O, does not oxidize asphalt or lower m-value
  - May react with anti-strip
- Both are dependent upon asphalt chemistry!



## Blending Requires Attention



Compatibility is Important



## Warm Mix

- New, not radical, technology
  - Additives
  - Plant Foaming
- Lower production and placement temperature
  - Reduced emissions
  - Better compaction
  - Late season paving
  - Reduced energy consumption?
- 65% of Asphalt Mix in Minnesota!
- Future – Half Warm Mix?



# Yellowstone Paving

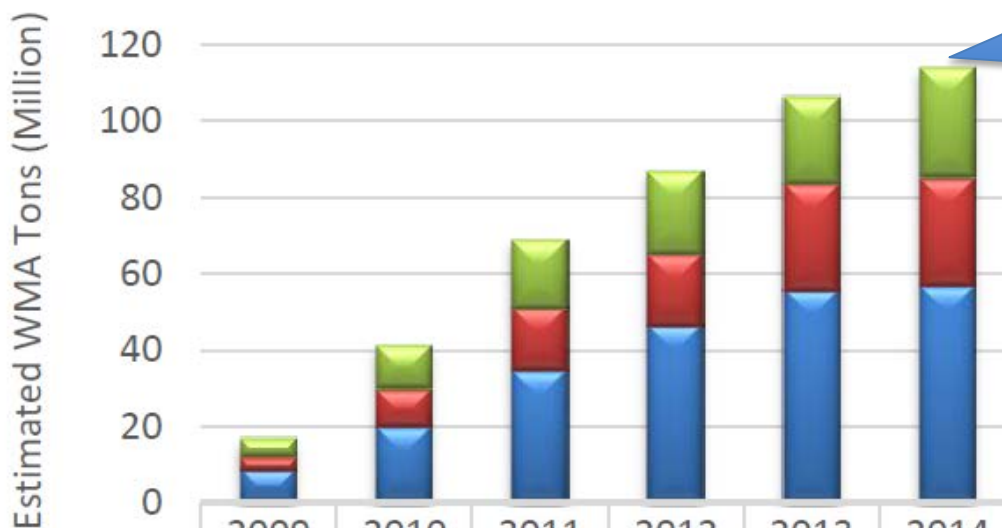
Control  
Temp = 320°F



Warm Mix  
Temp = 245°F

# 2009-2014

## Estimated WMA Tons

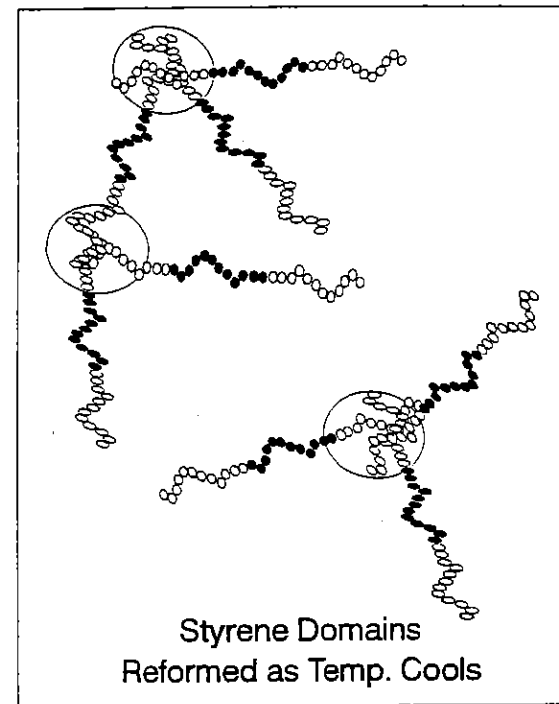
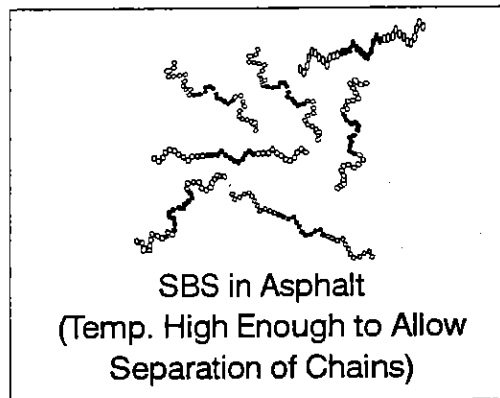
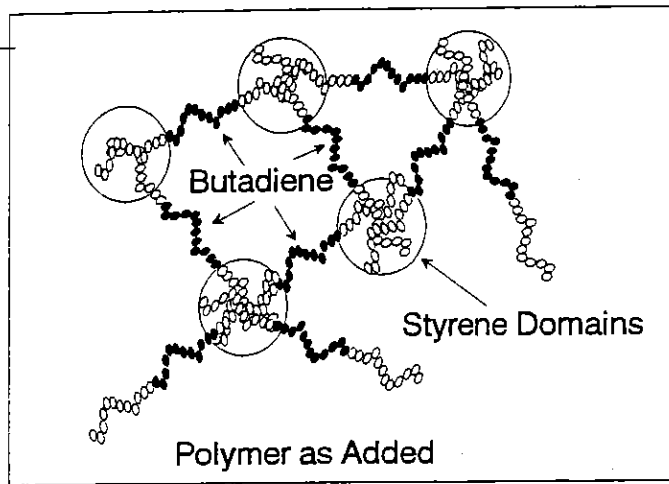


	2009	2010	2011	2012	2013	2014
Commercial & Residential	4.6	11.3	17.8	21.4	22.8	28.5
Other Agency	3.6	9.8	16.3	18.9	27.9	28.4
DOT	8.6	20	34.6	46.4	55.7	56.9

■ DOT    
 ■ Other Agency    
 ■ Commercial & Residential

>1/3  
Total  
Asphalt  
Tons!

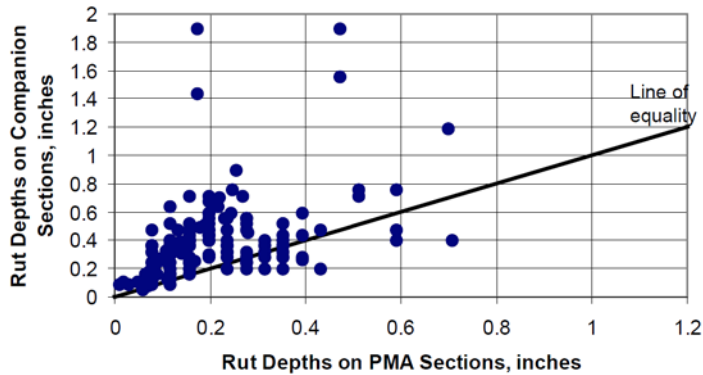
# Polymers



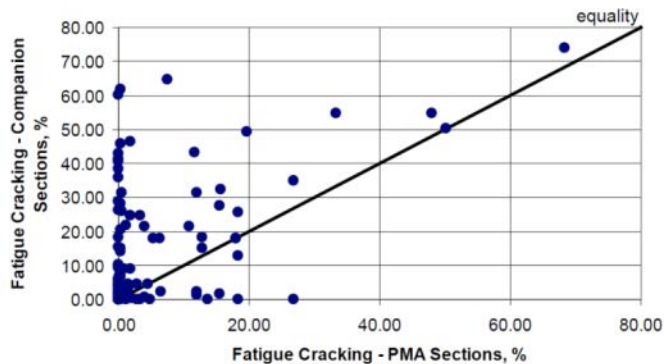
Stroup-Gardiner

# Polymer Modified Asphalt

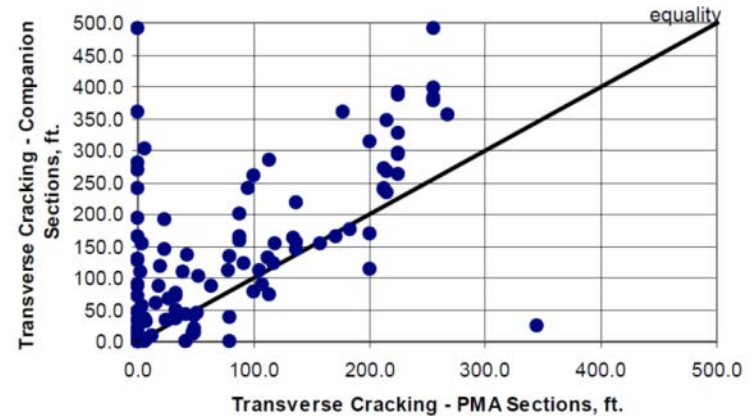
- Lower Rutting



- Lower Fatigue Cracking



- Lower Trans Cracking



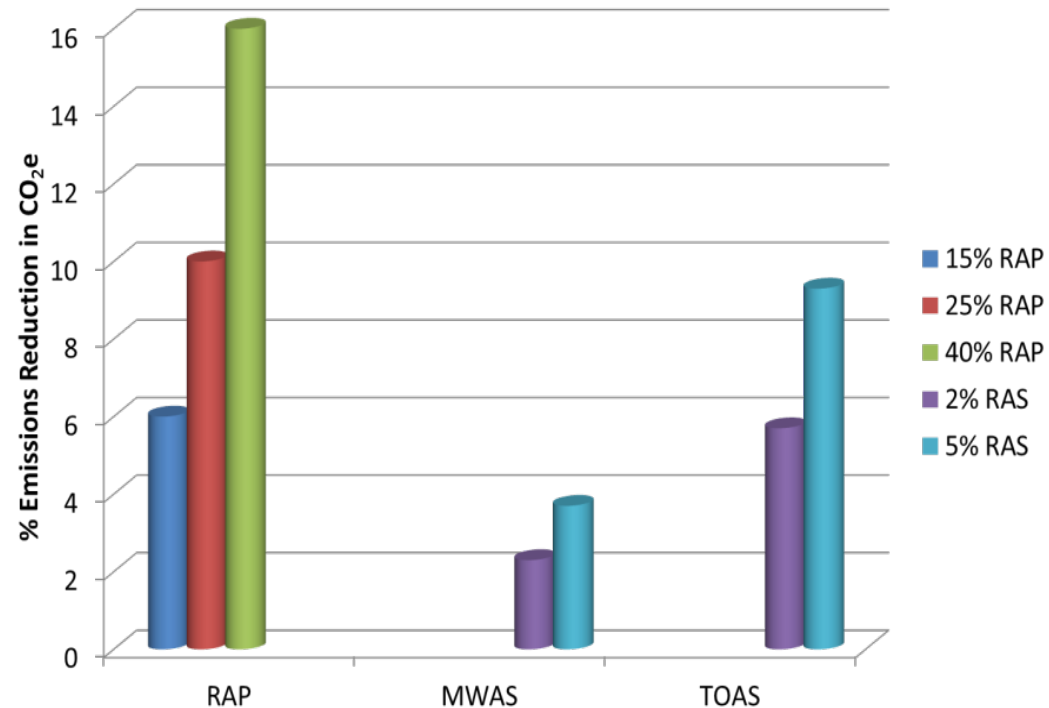
## RAP and RAS

- Resource Conservation
- Energy Conservation
- Price Stabilization



# Greenhouse Gases

- Using RAP/RAS reduces CO<sub>2</sub>e about the same amount as removing 270,000 vehicles





## Cost Savings

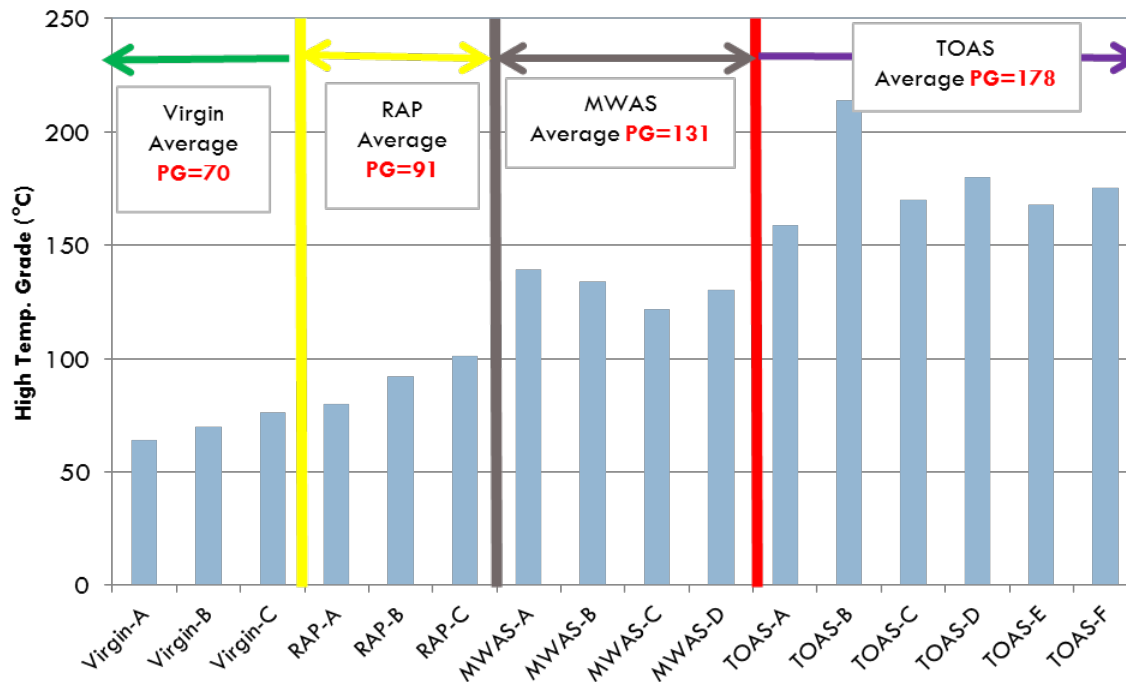
Reference	Material	Cost Savings
Zhou et al. (2006)	5% RAS	2 – 5%
Brock (2008)	20% RAP	>16%
	50% RAP	>40%
NCAT (Willis et al., 2012)*	25% RAP	14 – 20%
	50% RAP	29 – 35%

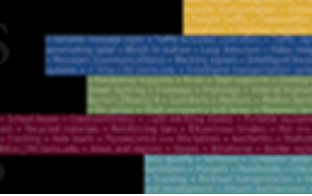
\* Used different amounts and stiffness of virgin binders used in mixtures.

# RAP/RAS and PG

- RAP/RAS binder too stiff

- Solution:
  - Balanced mix design for project-specific conditions





# Not What We're Looking For!





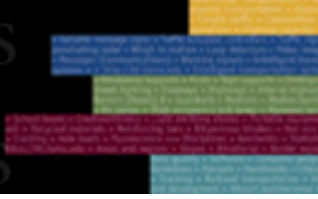
# **Testing: Macro and Nano**

Balanced Mix Design  
Microstructure



## Balanced Mix Design

- Current mix design methods
  - Volumetrics + Stability
    - Hveem
    - Marshall
  - Superpave method
    - Pure **volumetrics**; no mechanical testing
  - Superpave plus
    - **Volumetrics**+Hamburg/APA/...
- Control cracking in current methods
  - $V_{BE}$  (=VMA-AV) to control cracking; OK for virgin mixes
  - No simple cracking test



# Cracking Tests

Minnesota! →

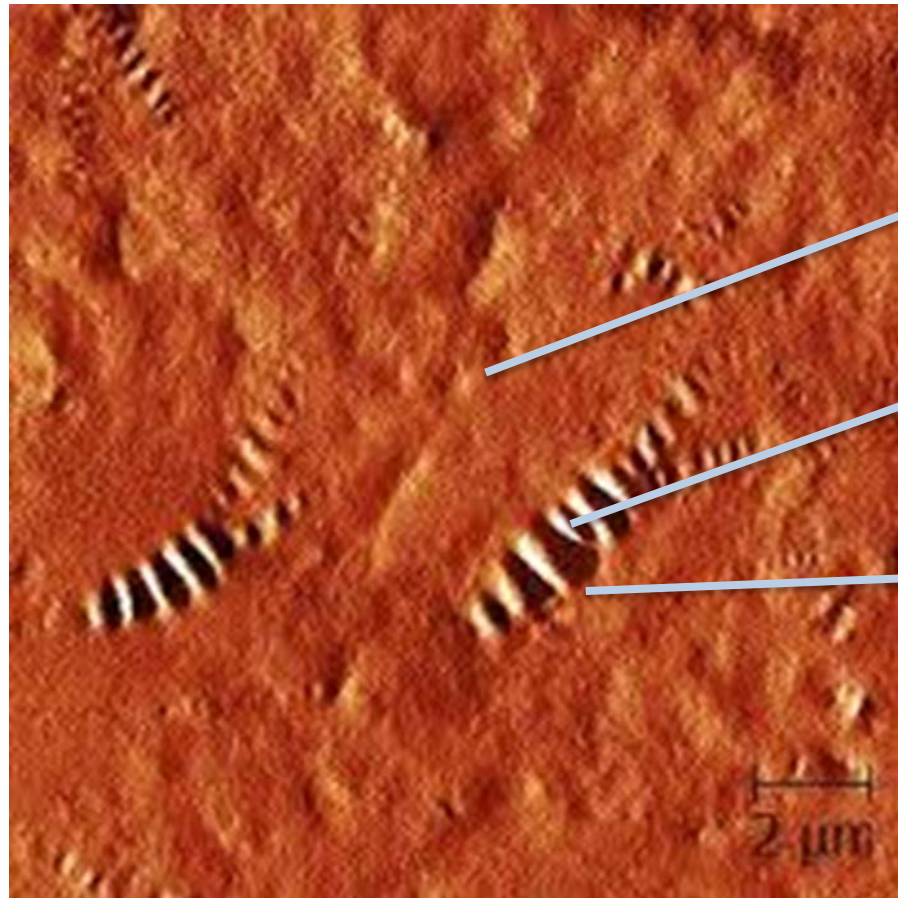


## RAP/RAS field test sections and performance

Test sections		Highway	Overlay/ new const.	Weather	Traffic MESAL	OT cycles	Performance
Amarillo	0%RAP	IH40 (severely cracked thick asphalt pavement)	4 inch/ overlay	Cold	30	95	3 yrs: 100% refl. cracking
	20%RAP					103	
	35%RAP					200	3 yrs: 57% refl. cracking
Pharr	0%RAP	FM1017-Very good support	1.5 inch/ new const.	Very hot	0.8	28	3yrs: overall - good conditions
	20%RAP					6	
	35%RAP					7	
Laredo	20%RAP	SH359-regular support	3 inch/ overlay	Very hot	1.5	3	3yrs: No cracking
Houston	15%RAP/ 5%RAS	SH146-Very good support	2 inch/new const.	hot	3.0	3	2.5yrs: No cracking
Dalhart	5%RAS	US87	3 inch/ Overlay	Cold	3.0	48/96	96 cycles-20% RCR; 48 cycles-50%RCR



# What Asphalt Looks Like at Nano Level



Interstitial  
Area

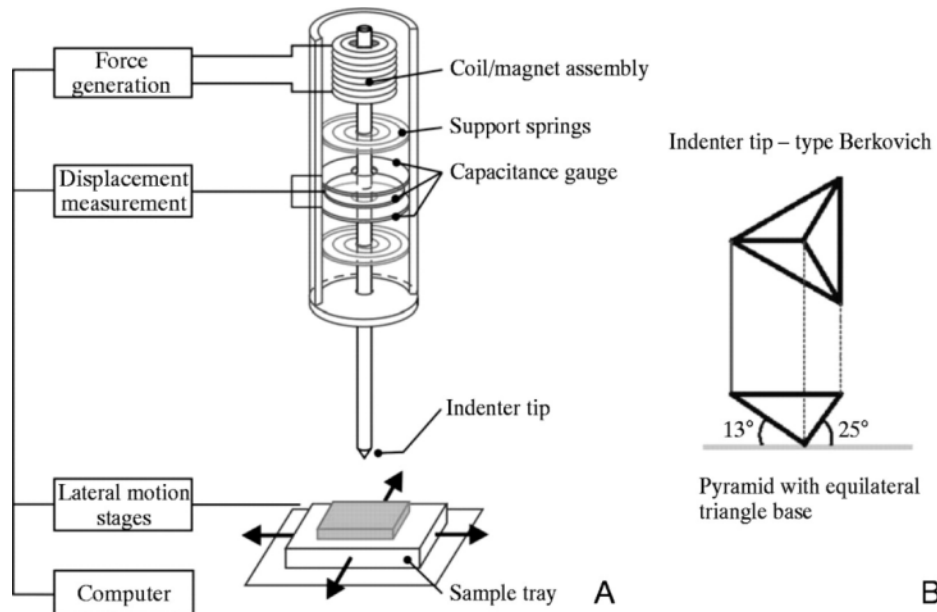
Bee

Bee  
Casing

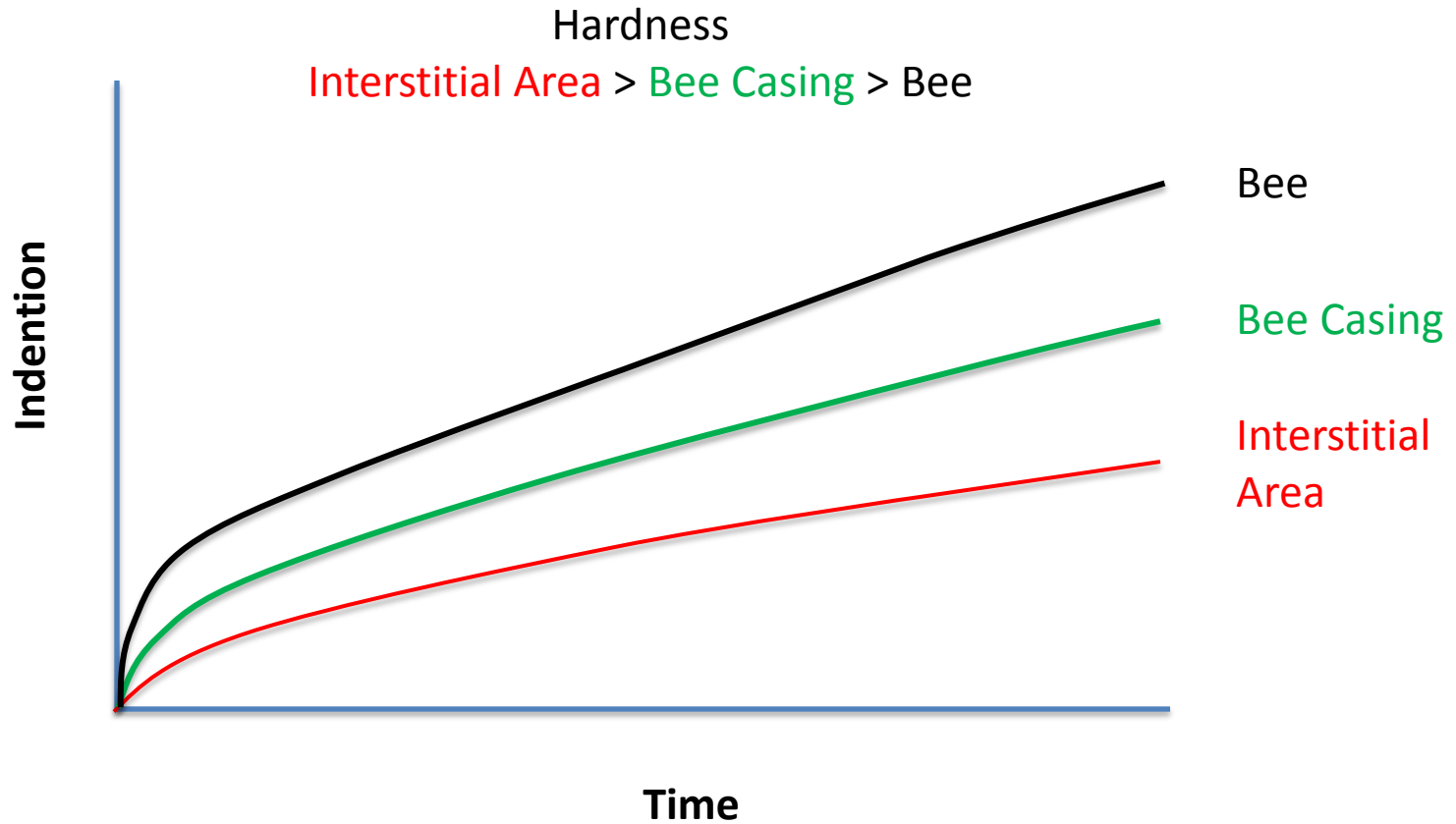


# Nano-Indentation Test

- Use conical or spherical indenter
- Apply constant load
- Measure penetration with time

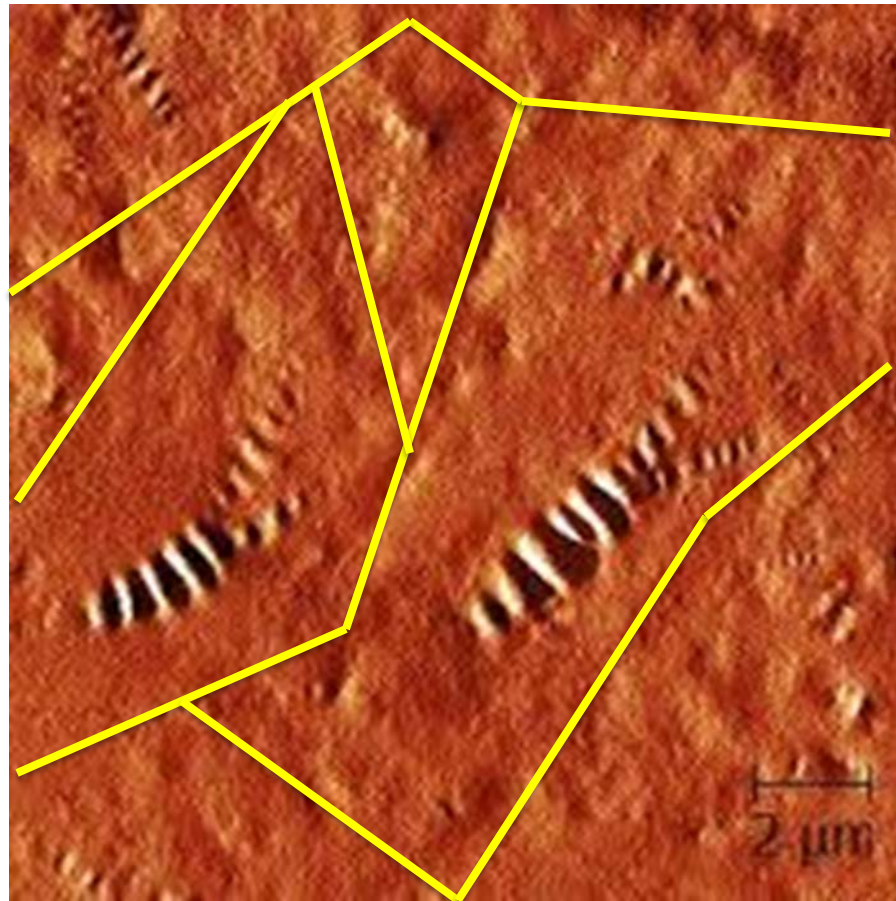


# AFM – Nano Scale Penetration Test



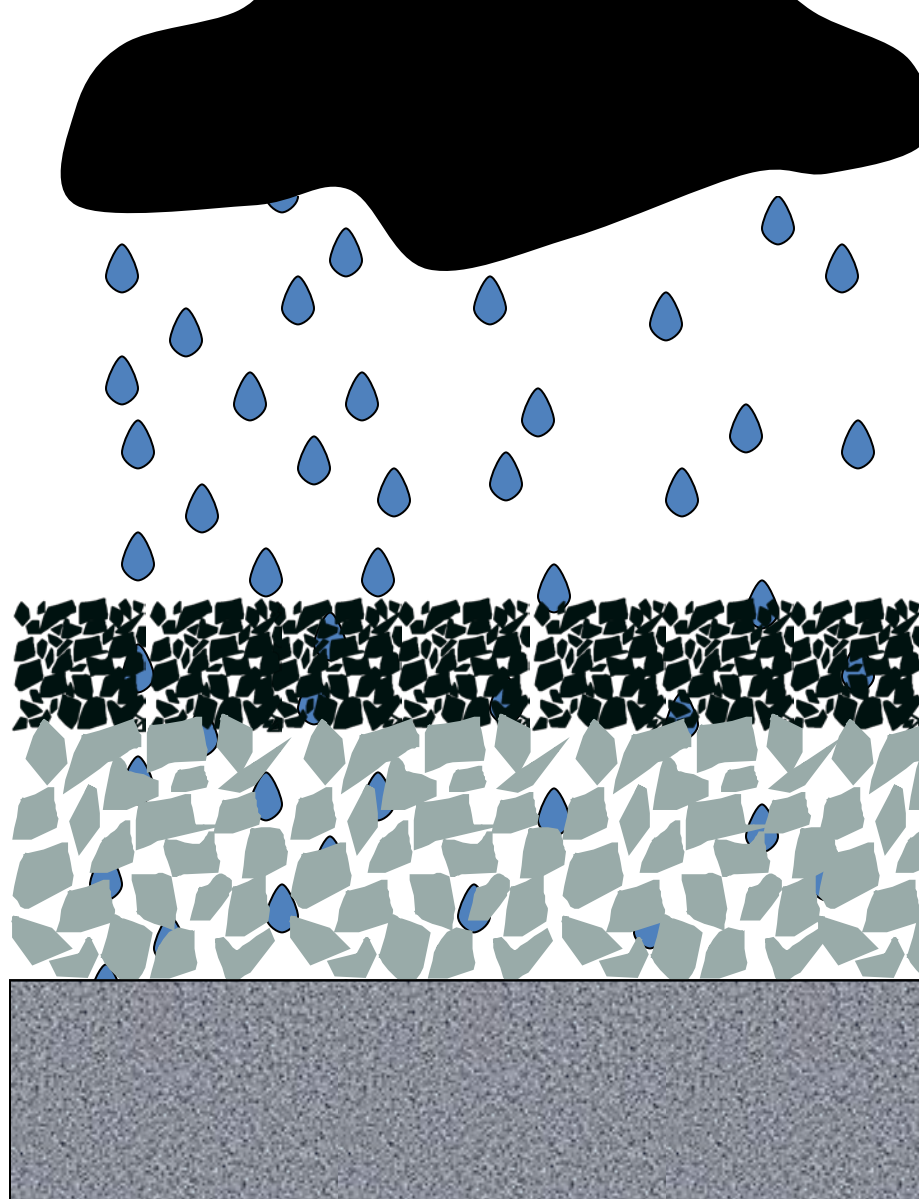


# Microstructure

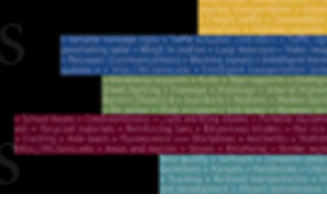




# **Design: Sustainable and Long-Lasting Perpetual Pavement**



Porous Pavement



# Demo



## Advantages

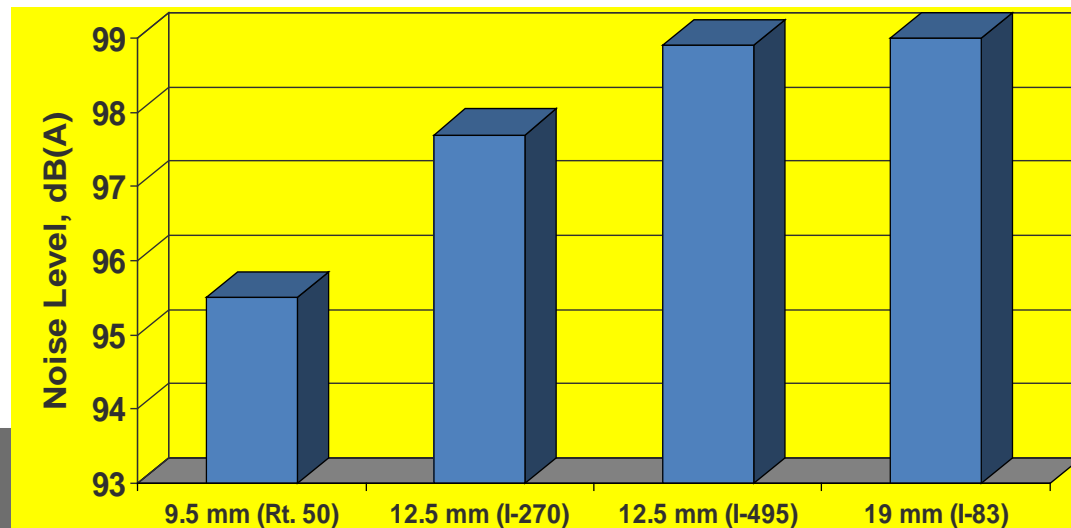
- Reduced surface runoff
- Better erosion control
- Better water quality
- Reduced storm sewer requirements
- Maintain natural drainage paths
- Reduced standing water nuisance
- Better GWT recharge
- Better skid resistance

## Surface Courses

- Safety
  - Skid resist. – low polish aggregate, microtexture important
  - Visibility – OGFC
- Noise Mitigation
  - Smaller micotexture
  - OGFC – 9.5 or 12.5 mm



NCAT Noise Trailer

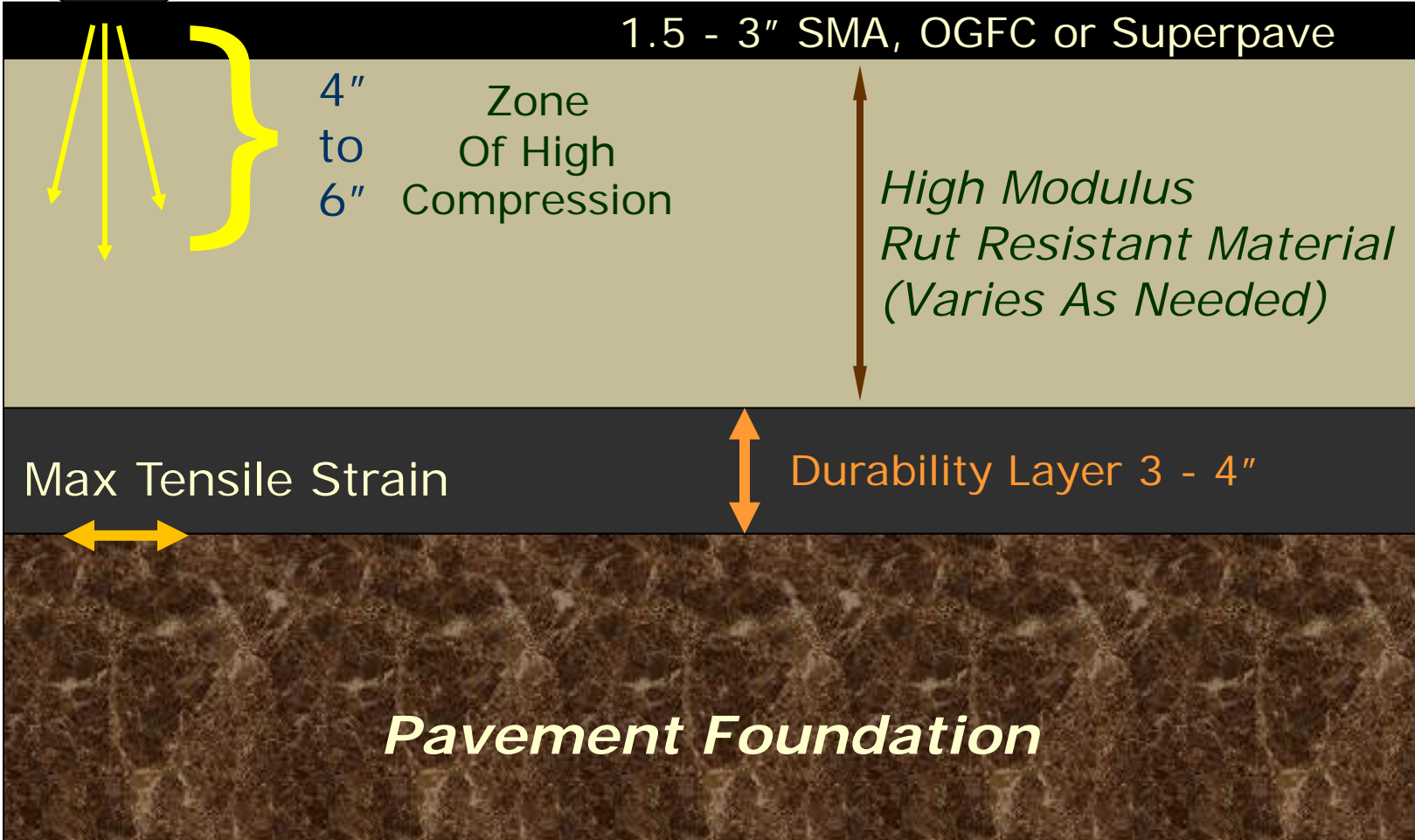
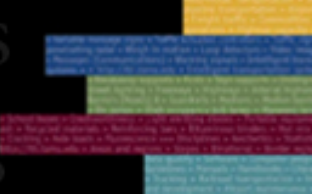




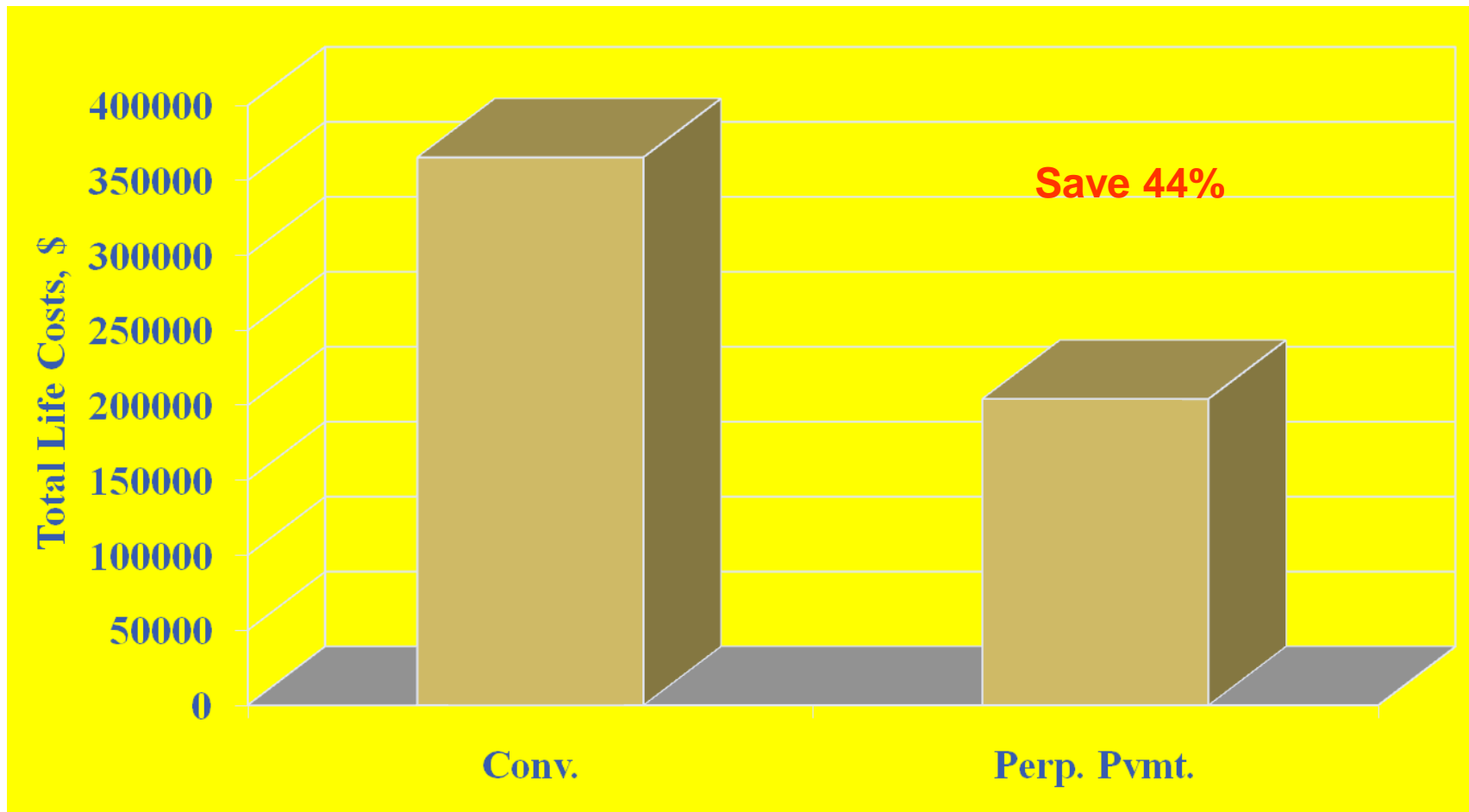


# Perpetual Pavement Design





## Costs





# Goal of Perpetual Pavement Design

- Design the structure such that there are no deep structural distresses
  - Bottom up fatigue cracking
  - Structural rutting
- All distresses can be quickly remedied from surface
- Result in a structure with ‘Perpetual’ or ‘Long Life’

## Avoid These!



**Bottom-Up Fatigue**

## Structural Rutting



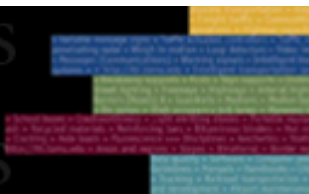


# **Rapid Construction: Our New Reality – Faster and Better!**



## FASTER! BETTER!

- Accelerated construction means “. . .minimizing time impacts to the public. . .” (Blanchard, 2009)
- Currently takes 10 to 15 years to get project from planning through construction.
- Project delivery:
  - Right attitudes and personalities
- Both contractor and agency:
  - Decision-making at lowest level
  - Remain customer focused
- Open to new approaches

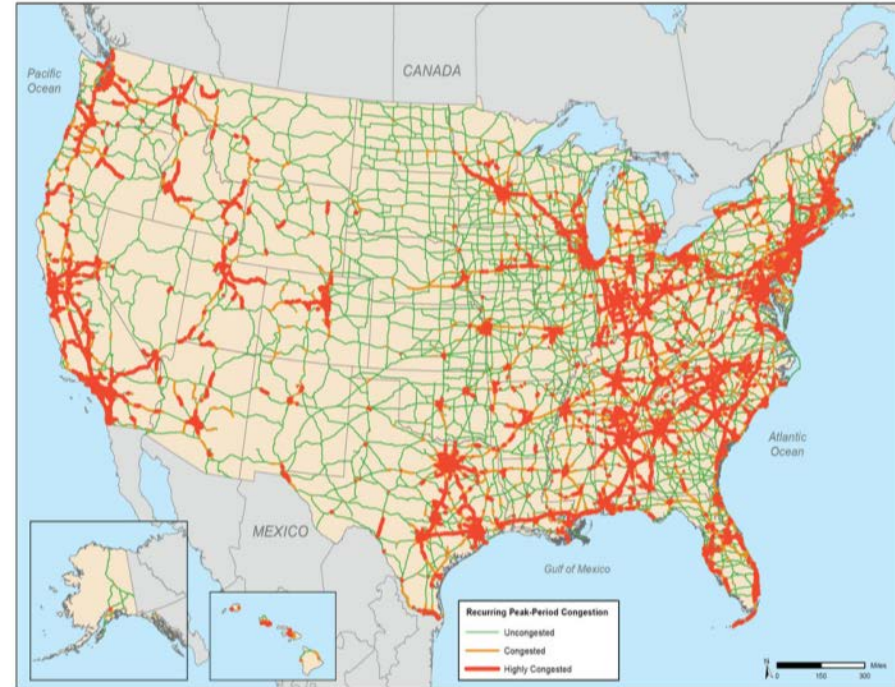


Peak-Period Congestion on the NHS: 2011



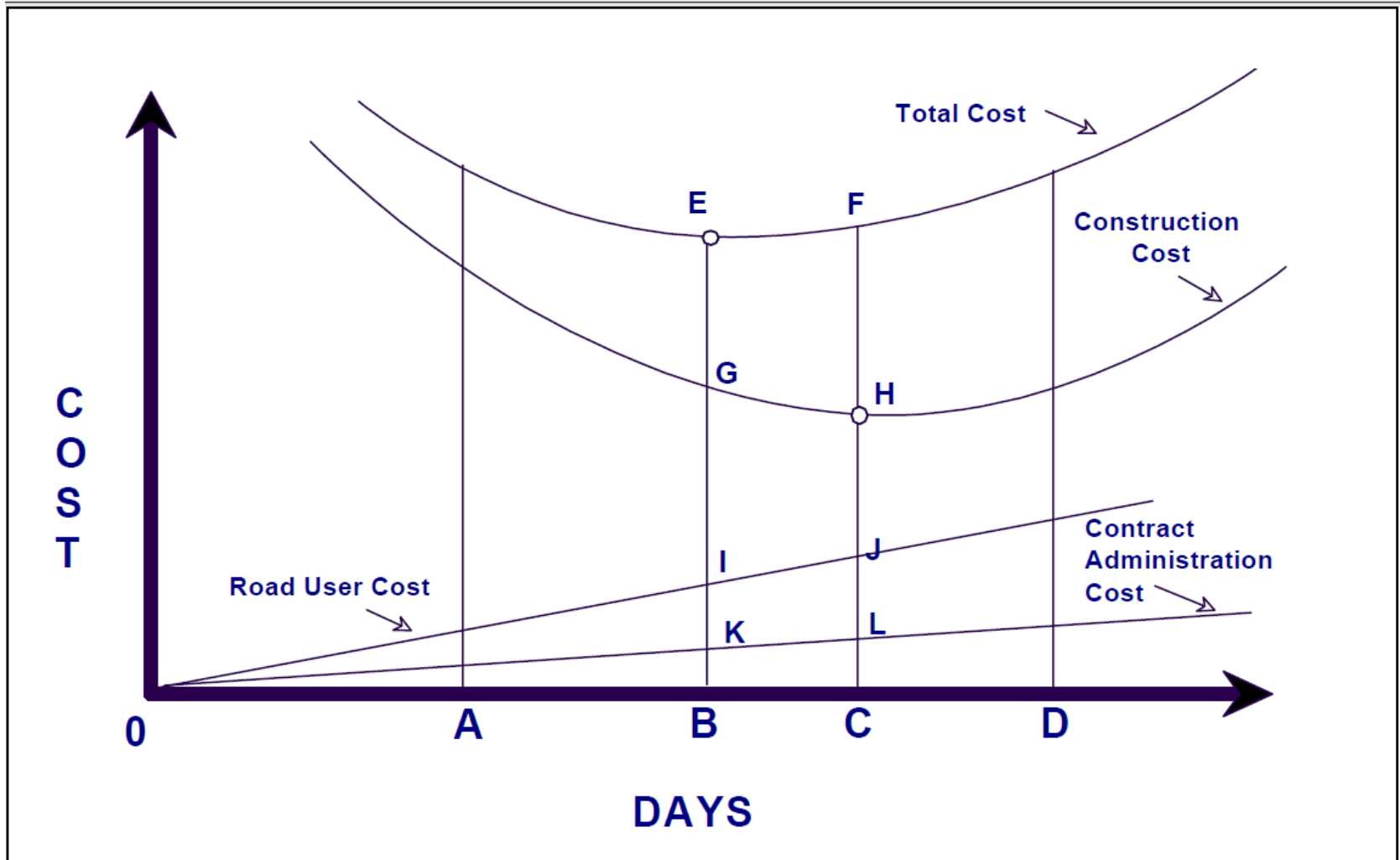
(a) Year 2011.

Peak-Period Congestion on the NHS: 2040



(b) Year 2040.





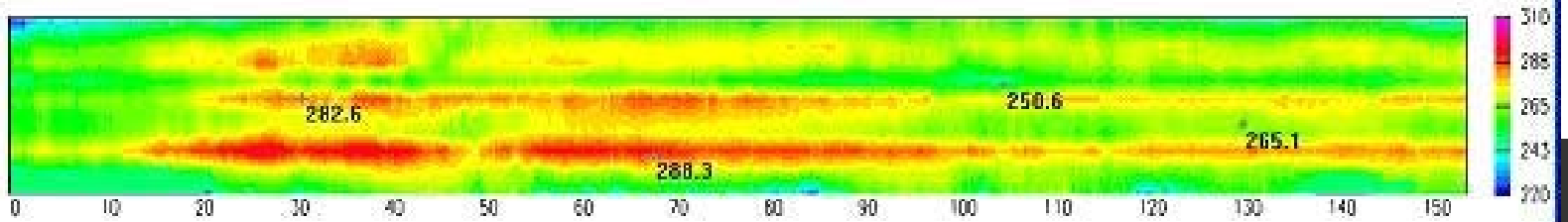
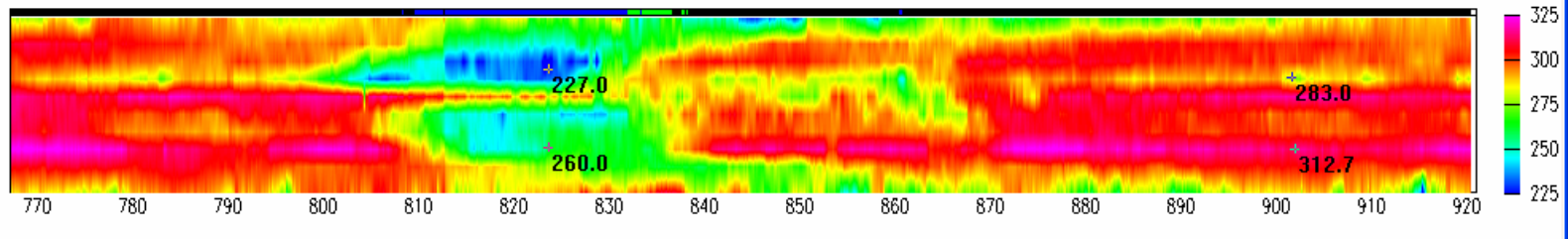
**Figure A. Project Costs by Type, Related to Duration**

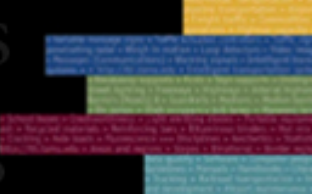


# Construction Productivity

- Allow contractor creativity
- Use existing in-place material
  - Demolition is slowest process
- Repetition of tasks
- Consider additional lanes to allow material removal/delivery
- Minimize mobilization/demob
- Evaluate variety of traffic control scenarios
- Real-time monitoring!

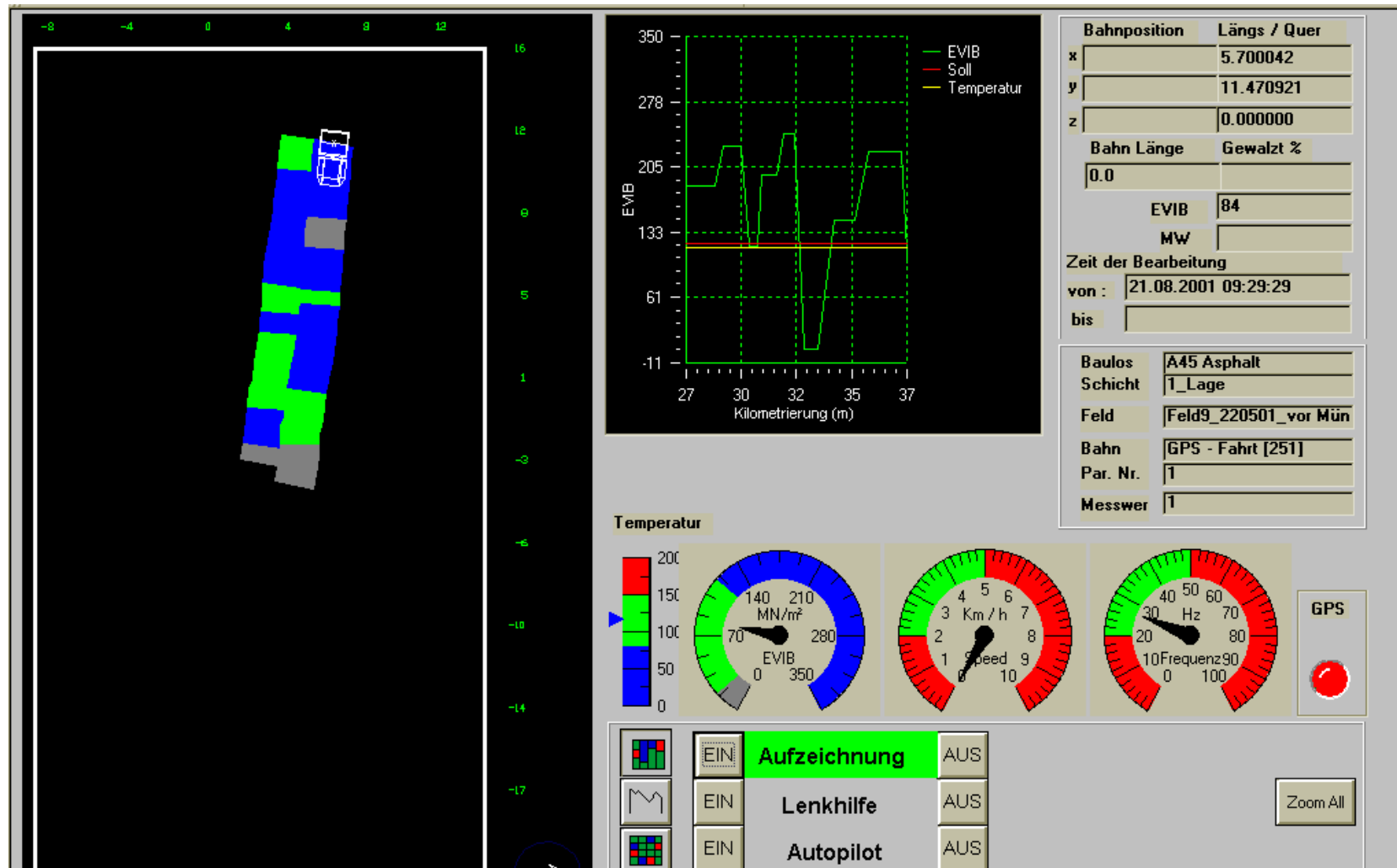
# Pave-IR Bar





# Intelligent Compaction Feedback







# Has this ever been you?



# MultiCool Program Window

CalCool 2.0 - Multilayer Pavement Cooling Program

File View Help

**Start Time**  
(24-hour clock)

Hour:   
Minutes:   
DATE  
Month:   
Day:   
Year:

**Environmental Conditions**

Ambient Air Temp:  F  
Average Wind Speed:  mph  
Sky Conditions:   
Latitude (Deg North):

**Mix Specifications**

Number of Lifts:   
Lift Number: 1  
  
Mix Type:   
PG Grade:    
Lift Thickness:  in.  
Delivery Temp:  F  
Stop Temp:  F

**Model Output**

Lift#	Thickness in.	Time, min		Temp(F)
		Lift	Total	
1	3.	47	47	174

**Existing Layer**

**Existing Surface**

Material Type:   
State of Moisture:

Moisture Content:   
Surface Temp.:  F

Units:  
 SI  English

Tabular Output
  Graphical Output

Ready NUM

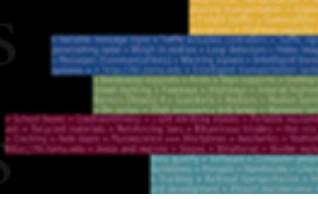
Place two layers at once!



↑  
Paves Upper Layer

↑  
Paves Lower Layer

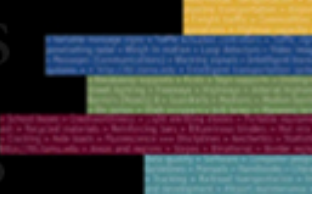




**THINK OUTSIDE THE PAVER!**

# The adhesive road by Dura - Vermeer

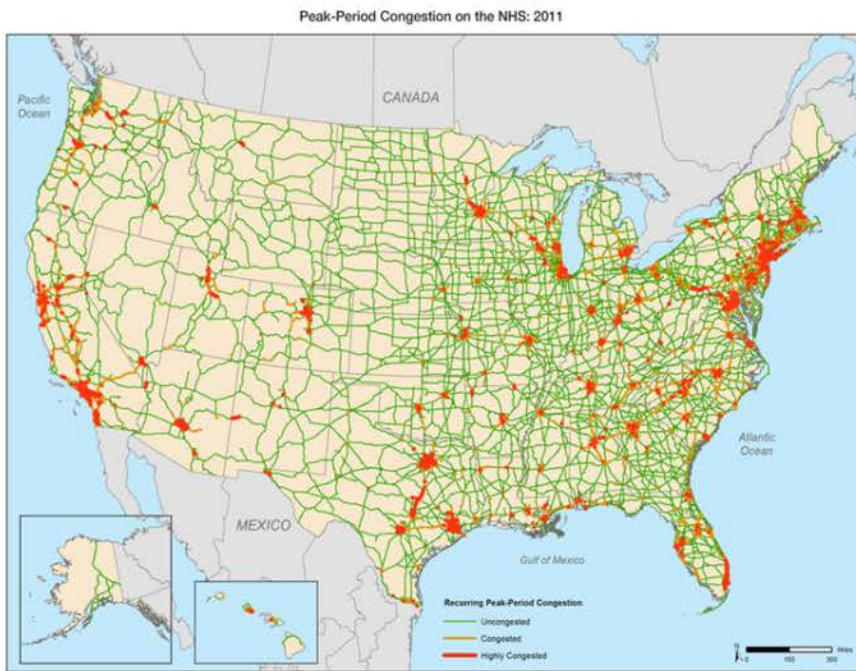
- A 30 mm asphalt layer rolled out as a carpet
- Can be attached and removed by using a switch on/off system using microwaves.







# Life Will Not Get Easier/Less Complicated



(a) Year 2011.



(b) Year 2040.



# **OUR BIGGEST CHALLENGE!**

## Education & Training

- Universities
  - Reduced emphasis on materials and pavements
- Trade Schools
  - Need material testing tracts
- Industry Efforts
  - Helps, but more is needed!







# Opportunities for Innovation

- All weather paving
  - Equipment
  - Quality
  - Materials
- Real time control/acceptance testing
- Nano-scale improvements
- Faster construction
  - Equipment
  - Scheduling



# Opportunities for Innovation

- Lower energy consumption
- Environmental/Safety improvements
  - Lower fumes/emissions
  - Increase recycling
  - Lower noise
- Quality improvements
  - Longer surface life
  - Long-life structures
  - Better durability predictions
- Improved Education