Evolution of Pavement Structural Design Systems

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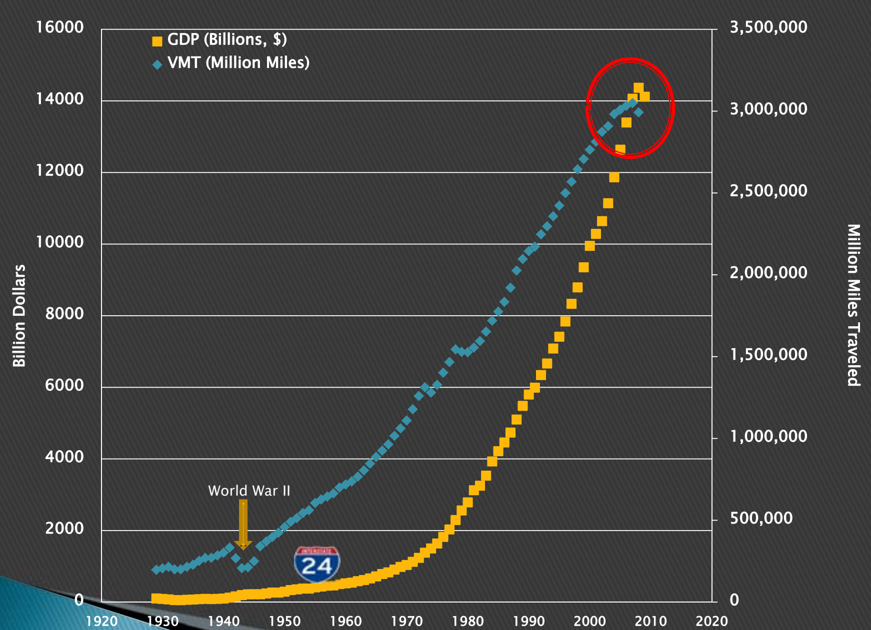
Why are pavements important ?

- Fundamental to economic growth and quality of life
- Pavement design is critical for long lasting and economical pavements



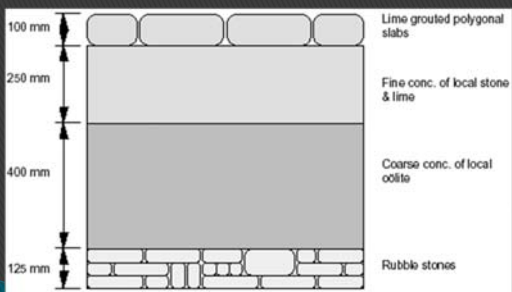
Major Advances in Pavement Design and Construction

- Roman Roads
- Telford Pavements
- Macadam Pavements
- German Autobahn
- US Interstate System
- China's highway expansion
- AASHTO Road Test
- Mechanistic Empirical Design
  - IlliSlab
  - Asphalt ME procedures
  - DARWin -ME

http://training.ce.washington.edu/wsdot/

Pavement Design History

- Roman Roads
  - 312 B.C.



Source: www.asphaltwa.com

Pavement Design History

- McAdam Pavements

John McAdam
1756 – 1836

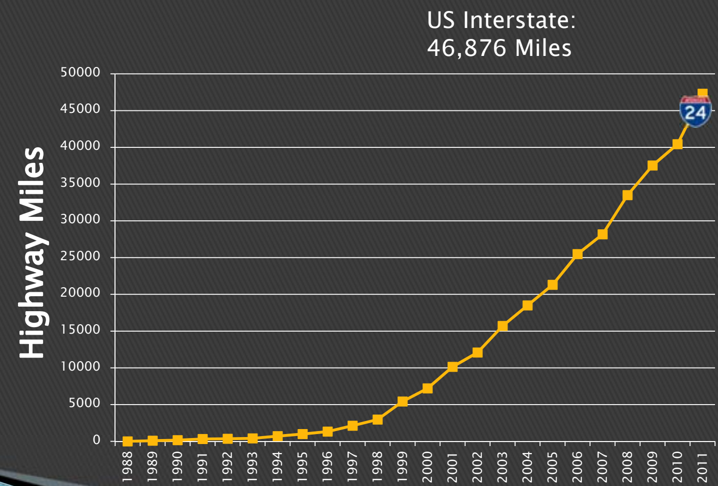
"Regardless of the thickness of the structure many of the roads in Great Britain deteriorated rapidly when the subgrade was saturated."

German Autobahn, 1936

China's National Trunk Highway System

Installation of Lean Concrete Base material

China's National Trunk Highway System



1919 Transcontinental Convoy – July 7 – September 7

Grand Island, Nebraska

US Roadway Expansion

- 1956
  - President Eisenhower
- Funded by Gas Taxes
  - ~ $38 Billion / Yr
- Responsible for NHS
  - Interstate
  - US Routes
  - 46,876 miles

The AASHO Road Test: A Look Back

Previous Road Test

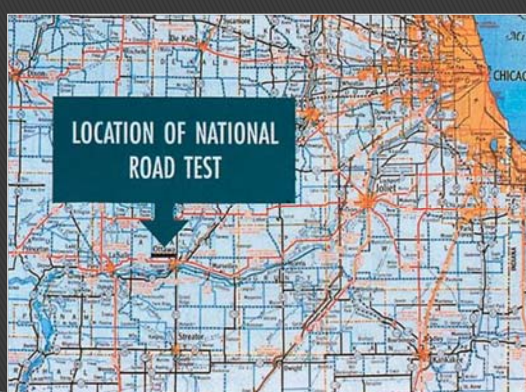
- Road Test one – MD 1950
  - Concrete Pavement
- WASHO Road Test, Idaho 1953-54
  - Flexible Pavements

AASHO Road Test

- "Grand-daddy" of major road tests
  - 1956-1960
  - Studied both pavements and bridges
  - $27 million (1956 $)
- Long lasting effects in pavement engineering
- Cornerstone of pavement design

Project Location

- Ottawa, IL on future I-80 alignment
- "Representative" soil and climate
- Cooperation of host state
- Flexible and pavements and bridges



Experimental Design

- Statistically based experimental design to isolate variables
- Flexible pavements
  - Surface, base, and thickness
  - 100 to 160 ft long
  - 468 total sections
- Rigid pavements
  - Reinforcing, slab and base thickness
  - 120 to 240 ft long (all doweled joints)
  - 368 total sections

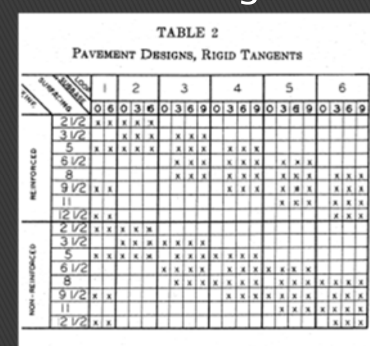


TABLE 2

PAVEMENT DESIGNS, RIGID TANGENTS

Type	Surfacing \ Subbase \ Loop	1		2			3				4				5				6			
		0	6	0	3	6	0	3	6	9	0	3	6	9	0	3	6	9	0	3	6	9
Reinforced	2 1/2	x	x	x	x	x																
	3 1/2			x	x	x		x	x	x												
	5	x	x	x	x	x		x	x	x		x	x	x								
	6 1/2							x	x	x		x	x	x		x	x	x				
	8							x	x	x		x	x	x		x	x	x		x	x	x
	9 1/2	x	x									x	x	x		x	x	x		x	x	x
	11															x	x	x		x	x	x
	12 1/2	x	x																	x	x	x
Non-Reinforced	2 1/2	x	x	x	x	x																
	3 1/2			x	x	x	x	x	x	x												
	5	x	x	x	x	x		x	x	x	x	x	x	x								
	6 1/2						x	x	x	x		x	x	x	x	x	x	x				
	8							x	x	x	x	x	x	x		x	x	x	x	x	x	x
	9 1/2	x	x									x	x	x	x	x	x	x		x	x	x
	11															x	x	x	x	x	x	x
	12 1/2	x	x																	x	x	x

Objectives

- To determine relationships between axle loads and pavement performance
- To determine effects of axle and vehicle loads on bridges
- To conduct special studies (base types, paved shoulders, fatigue, tire pressures, etc)
- To provide a record of the type and extent of effort/materials to maintain sections
- To develop test instrumentation, test procedures, graphs, charts, and formula helpful to highway design and evaluation

Construction

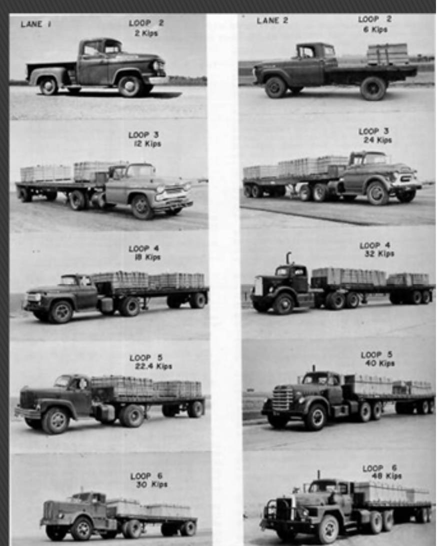
- 1956 to 1958
- Highly controlled
- Specifications based on prevailing SHA practices

Asphalt Paving

Concrete Paving

Truck Traffic

- Trucks driven by U.S. Army Transportation Corps
  - Initially 6 day schedule (18 hours, 40 minutes)
  - Later changed to 7 day (19 hours, 5 minutes)
  - Three rotating driving schedules (7.5 hours per driver each day)



Walt McKendrick

—Project Director—

"Take all the time you want as long as you are off the road when the trucks are back in service"

—to field staff inspecting pavement conditions

Performance Monitoring

- Flexible Pavements
  - Profile
  - Roughness
  - Cracking
  - Patching
  - Rut Depth
- Rigid Pavements
  - Profile
  - Cracking
  - Patching
  - Spalling
  - Joint/Crack Faulting

Monitoring Equipment

Serviceability

- Introduced as way of measuring pavement performance and defining “failure”
- Correlations developed to estimate panel rating serviceability based on observed distress, e.g. for flexible pavements:

$$PSI = 5.03 - 1.91\log(1+SV) - 1.38(RD)^2 - 0.01\sqrt{C_F + P_F}$$

Road Test Products

- Serviceability-performance concept
- Pavement design models
- Load equivalency factors
- Recognition of variability in construction and need for statistical sampling
- Demonstration of statistically based experimental designs and statistically based modeling
- Development and implementation of new performance monitoring equipment
- Framework for pavement and asset management

Limitations

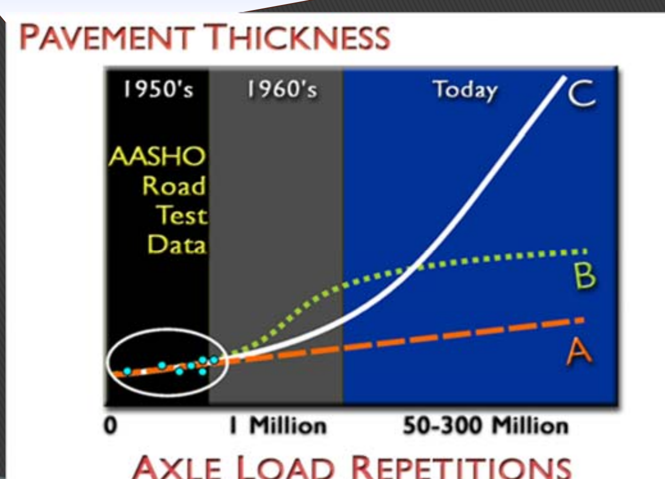
- One subgrade type
- One environment
- Only 2 years of service
  - Limited truck traffic
  - Limited environmental effects
- One HMA mix
- One PCC mix
- 1950s materials & paving technology

These factors limit the "inference space," not the validity of the results

One Subgrade Type…

(AASHO, 1961)

Low Traffic Levels…



Bill Carey

—Chief Engineer for Research—

"It was recognized that other models… could lead to correlation with subjective ratings just as good or perhaps even better than the correlation obtained with [the AASHO] model. "

—1962 AC Pavement Conference

Alvin C. Benkelman

—Flexible Pavement Research Engineer—

"This is my third road test and if I don't get it right this time they'll fire me"

—Having also served at Hybla Valley and WASHO Road Tests

Frank Scrivner

—Rigid Pavement Research Engineer—

"Well over half of the [rigid pavement] sections under traffic exhibited very little change in condition during the two years of traffic testing"

—1962 St. Louis Proceedings

Paul Irick

—Chief, Data Processing and Analysis—

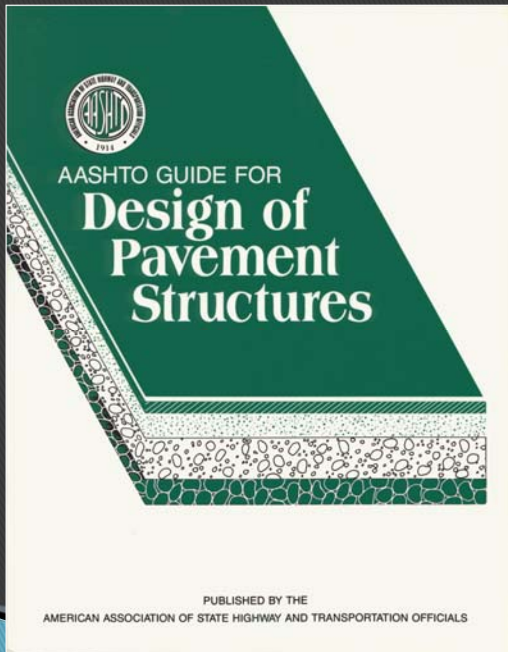
"…we aim to explore models for long time pavement performance that will bring in some of the physical parameters that are considered basic to the explanation of pavement performance."

—1962 AC Pavement Conference

Fred "Mickey" Finn

"The Asphalt Institute is fully aware of the significant contributions which have been made and, just as important, which will be made by this Project to the highway engineer."

—1962 St. Louis Proceedings



1993 Version

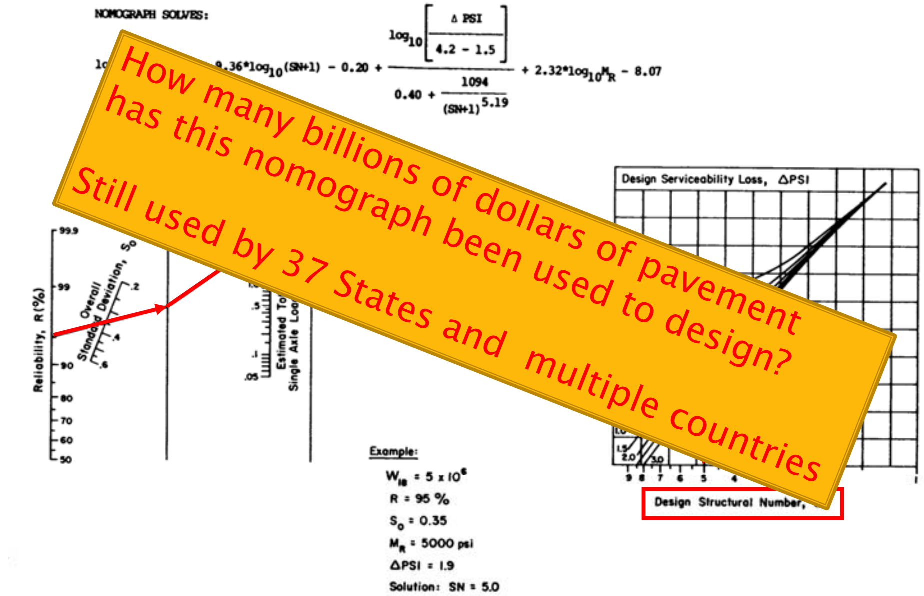
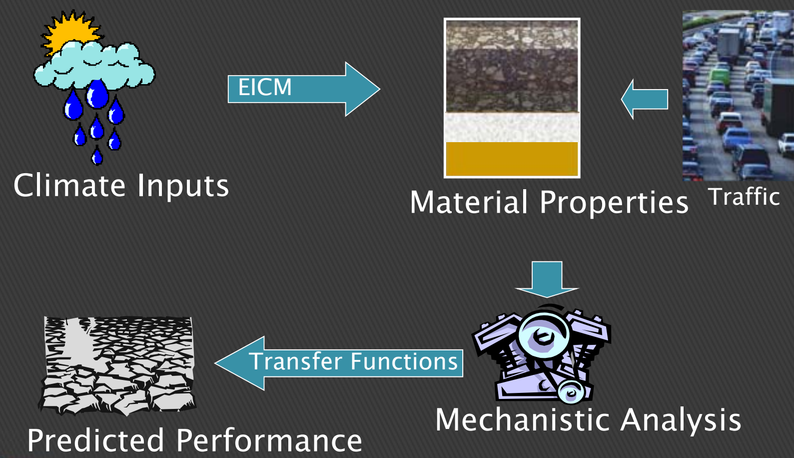


Figure 3.1. Design Chart for Flexible Pavements Based on Using Mean Values for Each Input

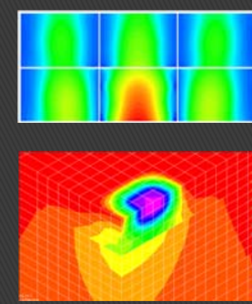
50 year step forward.....

- Fundamental Materials Inputs
- Traffic Loadings
- Climatic Considerations
- Calibrated to research grade pavement sections

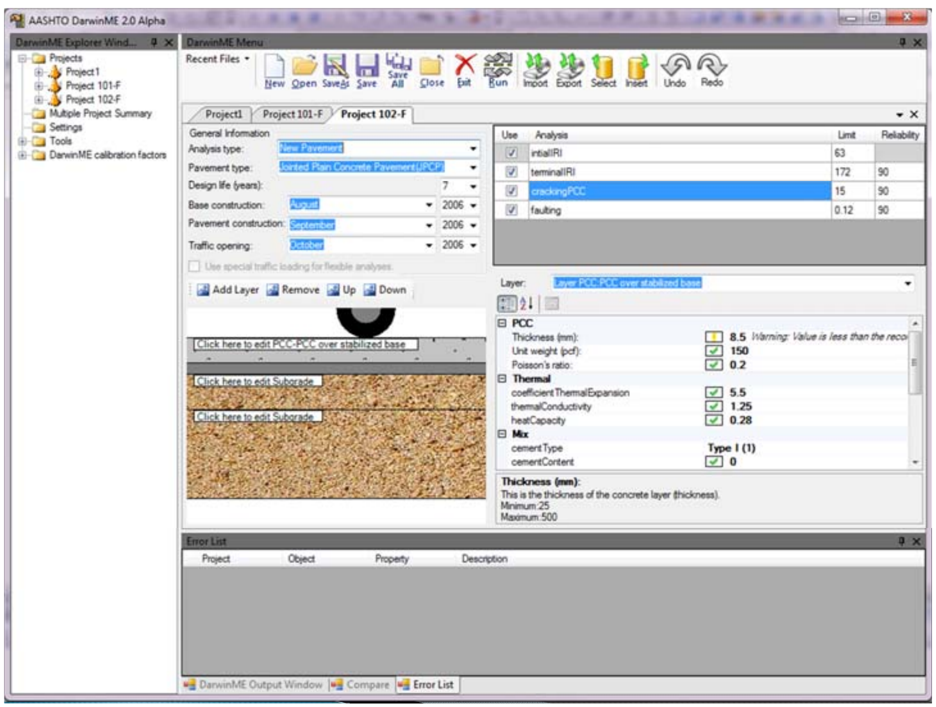
The Big Picture



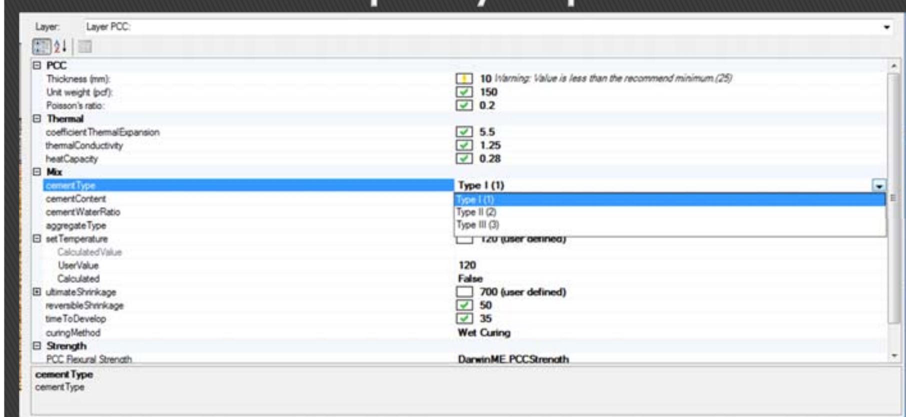
Structural Response Models – Elastic Layered and Finite Elements Tools



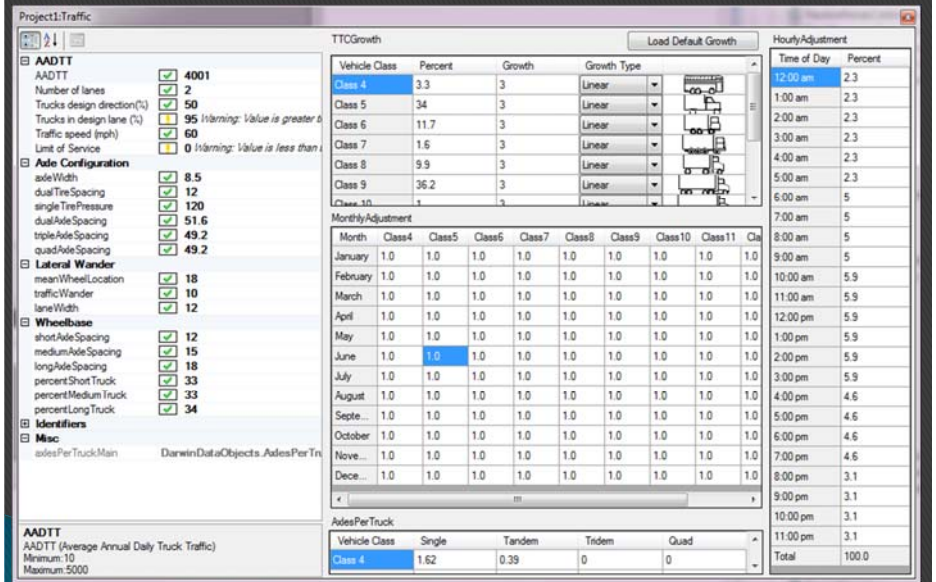
- For rigid pavements
  - ISLAB2000—Finite Element Model (FEM) program
- For flexible pavements
  - JULEA—Linear elastic layered analysis program



Material Property Inputs



Traffic

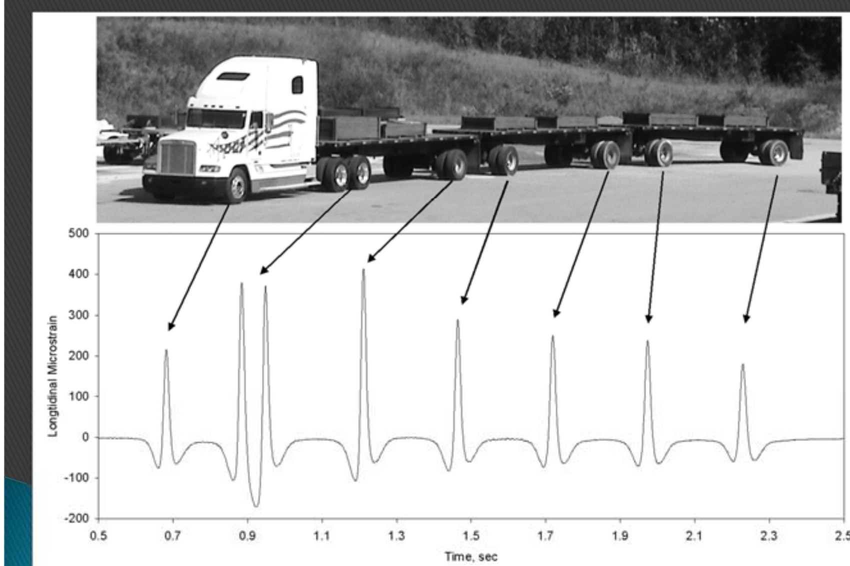


ARA, ASU and NCHRP 1-40

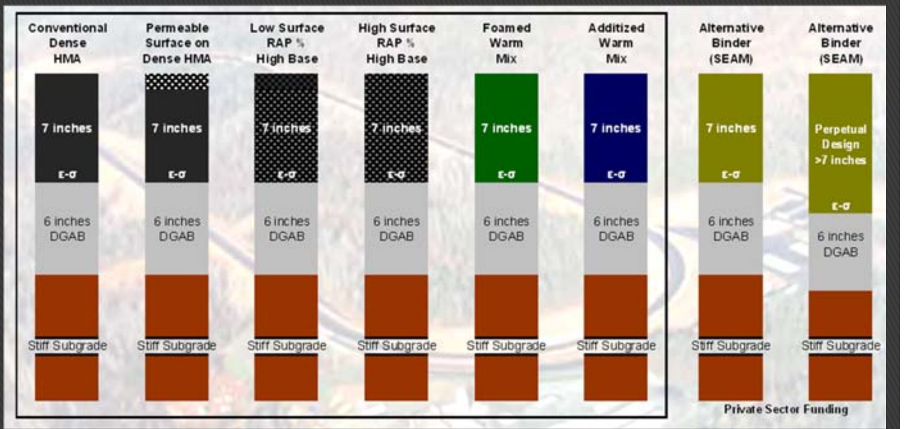
NCAT Test Track

National Center for Asphalt Technology NCAT at Auburn University

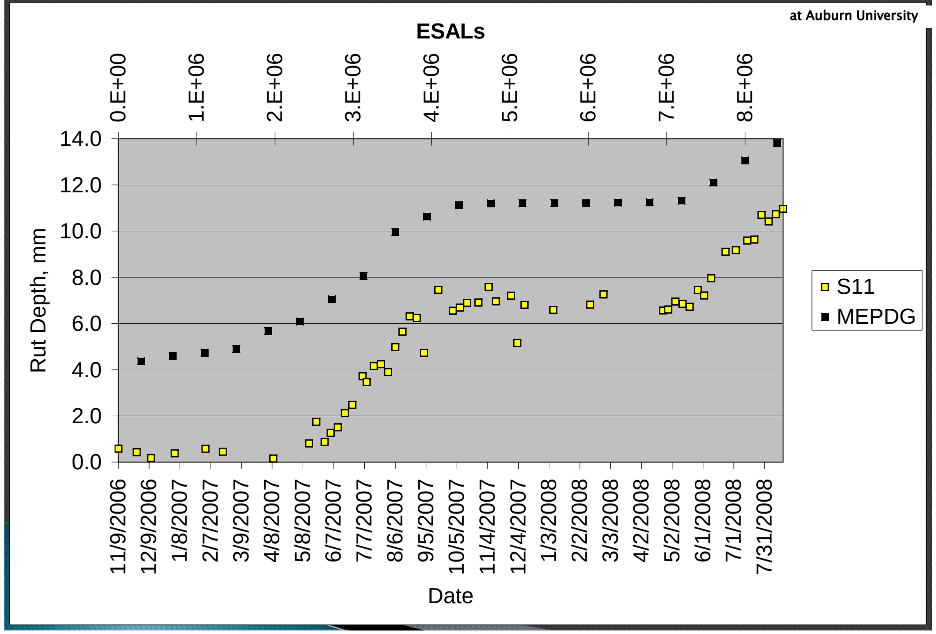
Strain Response



Continued Validation

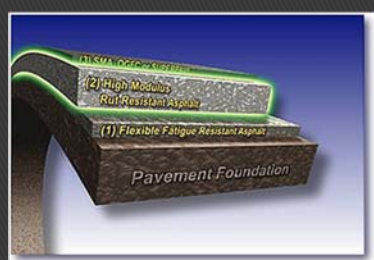


S11- As Built - Rut Depths



Other Pavement ME Design Procedures

- PerRoad3.5
  - Perpetual Pavement Design
  - Dr. Dave Timm and Newcomb
  - Asphalt Pavement Alliance
  - http://asphaltroads.org
- SW – 1
  - Asphalt Institute



Indiana DOT Experience

Road	AASHTO 93 Thickness Result	MEPDG Thickness Result	Estimated Contract Saving ($)	Actual Cont[illegible]	Total Savings ($)
I-465	16”-18’ PCCP	14”-18’ PCCP	[illegible]	[illegible]	
I-465 Ramps ( )	12.5”-18’ PCCP	11”-18’ PCCP	[illegible]	[illegible]	
I-465 Ramps (40/Wash. St)	12.5”-18’-PCCP	[illegible]	[illegible]	[illegible]	
I-80(mainline)	[illegible]	[illegible]	[illegible]	$775,170	
I-80(Ramp)	[illegible]	[illegible]	$520,000		
SR 14	[illegible]	[illegible]	$333,000	$155,440	
US 231	[illegible]	[illegible]	$333,000	$0	
US 231-Ramp	[illegible]	9.5”-18’-PCCP	$28,000		
US 231	15.5”-HMA	13”-HMA	$557,000	$0	
SR 62	16”-HMA	13”-HMA	$403,000	$420,548	
US 231	11”-18’-PCCP	10”-18’-PCCP	$178,000	$0	4,300,000

Total Estimated Savings = $10 Million

Evolution

- **Pavement design is not perfect…..BUT;**
- Were moving toward a more fundamental and structured platform for continuous improvement.