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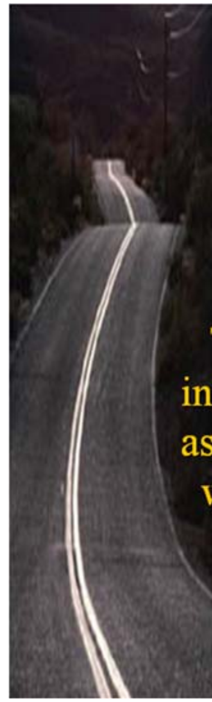
Evolution of Asphalt Mix Design Systems

Thomas Harman

Manager, Pavement & Materials TST

FHWA-OTS-Resource Center



CHANGE:

The dogmas of the quiet past are inadequate to the stormy present… as our case is new, so we must think anew and act anew.

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Our Visit Today

Part 1:	Part 2:	Part 3:	Part 4:
The GOAL of Mix Design	A Look Back at our Past	The Superpave Revolution	Hot Challenges because of Warm Mix

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Part 1: The GOAL of Mix Design

What is the GOAL?

- A Good mix provides?...
- A Bad mix does not provide?...

The GOAL is...

Getting this to → Carry this without → To much of This.

Professor Carl Monismith

excerpt ASCE Asphalt Mix Design an Construction © 2006

- Design of an asphalt-aggregate mixture consists of...

1. Select the *type* and *gradation* of mineral aggregate
2. Select the *type* and *grade* of asphalt binder, with or without modification
3. Select the *amount* of asphalt binder to satisfy the project-specific requirements...

Properties of a Good Asphalt-Aggregate Mixture

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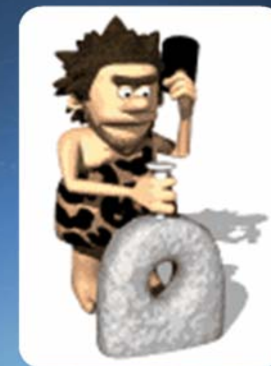
Part 2:

A Look Back at our Past

Early Design Methods

- T.L.A.R.
- W.A.G.
- S.W.A.G.



History

- Asphalt Paving in the United States
  - 1870 in Newark, New Jersey
  - 1871 in Washington, DC

Early Mix Design
(1940-1960)

- Dominated by World War II… Korean War
- 1950's Most Prevalent Systems, developed by:
  - Francis Hveem
  - Bruce Marshall
- Others:
  - Hubbard-Field, Smith Triaxial, & Texas Gyratory

Early Design Methods

- State of California DOT Method
  - Driver: Poor Performance
  - Key: lab *kneading* compaction
- Francis Hveem
  - Engineer CA Division of Highways
  - Hveem Method
    - Circa 1930's thru 1942, 1985

Early Design Methods

- 1939, Texas Highway Department
  - Philippi, Raines, and Love
- Texas Gyratory Press
  - Kneading compaction

Early Design Methods

- US Army Corps of Engineers Method
  - Driver: Poor Performance
    - 100 psi tires on WWII aircraft
    - Korean War introduced 200 psi tires
    - Impact Hammer (Compaction)
- Bruce Marshall
  - Vicksburg, Mississippi
  - Highway Research Board 1949

Early Design Methods

- 1950's, US Corps of Engineers
  - John McRae
- Gyratory Test Machine
  - Floating 2-point system
  - Kneading Compaction, w/ a measure of stability

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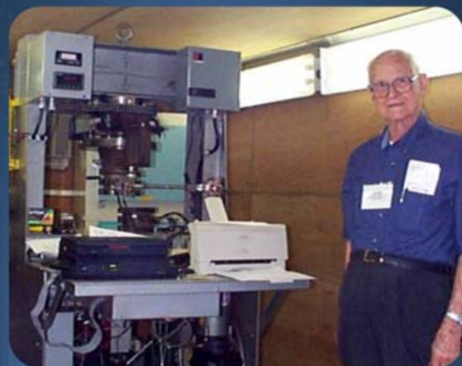
Early Design Methods

- 1950's, US Corps of Engineers
  - John McRae
- 1st NCAT Track



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European Methods

- Early 1960's, LCPC, France
  - Texas-type gyratory press
  - French rut tester

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LCPC Gyratory Compaction

- Early 1960's, LCPC, France
  - Texas-type press
  - 1968, 2nd prototype
  - 1973, PCG1
  - 1985, PCG2
  - 1997, PGC3

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LCPC Gyratory Compaction

Francis Moutier (LCPC)

- Early 1960's, LCPC, France
  - Texas-type press
  - 1968, 2nd prototype
  - 1973, PCG1
  - 1985, PCG2
  - 1997, PGC3

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LCPC Gyratory Compaction

- Early 1960's, LCPC, France
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Part 3:

The Superpave® Revolution

shrp

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SHRP
5 years to boldly go where…

- 1987, United States Congress authorized the Strategic Highway Research Program
- 1987, Focus on asphalt binder research
- 1990, Expanded to include research on mix

A rose by any other name…

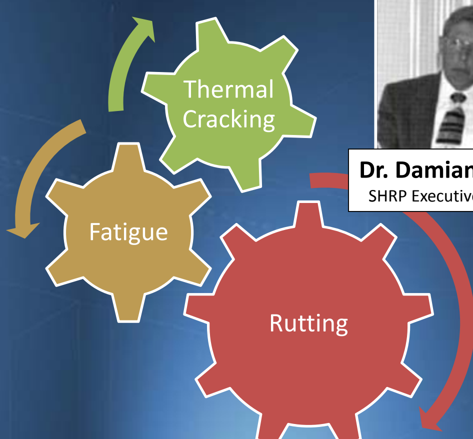
- But the Monk fish used to be called the Slime fish?
- And MiDAS became…

Frank Francois
Then Executive Director
AASHTO

Superpave® System

Performance-Based
Purchase Specification
Design and Analysis Tool

Focus on Limiting Distress (Failure Modes)



Dr. Damian Kulash
SHRP Executive Director

SHRP Researchers Working Hard

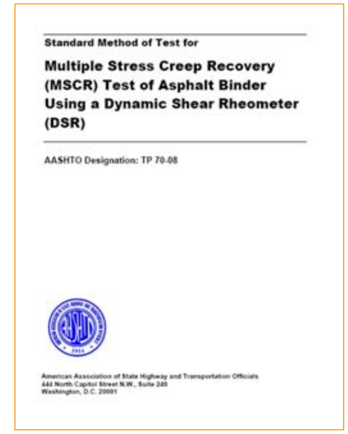
And many others…

Refinement, Jnr

Developed as Table 3 for AASHTO M 320-09

Original					
DSR G*/sinδ Min 1.0	64				
RTFOT					
64 Standard MSCR3.2 <4.0	[(MSCR3.2 – MSCR 0.1)/ MSCR 0.1] < .75	64			
64 Heavy MSCR 3.2<2.0		64			
64 Very heavy MSCR3.2 <1.0		64			
PAV					
S grade DSR G*sinδ Max 5000	28	25	22	19	16
H & V grade DSR G*sinδ Max 6000	28	25	22	19	16

AASHTO THE VOICE OF TRANSPORTATION


Standard Method of Test for
Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
AASHTO Designation: TP 70-08
American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

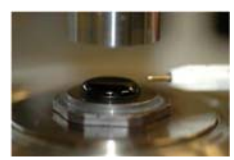
Matrix Approach, versions A-1

- The challenge is to develop a "purchase" specification…
- It has to be implement-able,
  - Both from a **Agency** and from a **Industry** standpoint

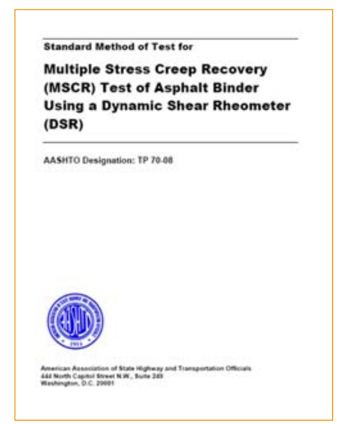

Dr. Dave Anderson
SHRP Researcher
Penn State

Refinement, Jnr

Standard Test Procedure developed for AASHTO TP70-09



AASHTO THE VOICE OF TRANSPORTATION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SHRP… Mix Design

- SHRP mixture research, building on:
  - –NCHRP 9-06, AAMAS
    - Report Number 338, published 1991
    - Von Quintus, Brent Rauhut Engineering
  - –LCPC in France

SHRP

- NCHRP 9-06, AAMAS
  Asphalt-Aggregate Mixture Analysis System
  - US Corps GTM
  - Texas gyratory shear test machine

SHRP Gyratory Compactor

- 1990, FHWA Demo Project No. 90
  "Innovative Asphalt Mix Laboratory Techniques"
- AAMAS
- SHRP (MiDAS)

FHWA Modified Gyratory Shear Test Machine

- Fixed Angle
  - Variable 0.5° to 3.0° at 0.25° increments
- 4" Specimens
- 30 rpm
- Height recordation

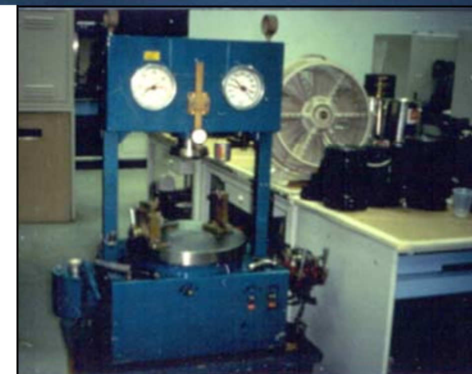
AAMAS Workshops

- April 1991 in Atlanta, Georgia
- FHWA proposed a hybrid gyratory

Harman & D'Angelo

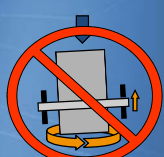
Asphalt Institute SHRP A-005 Contractor

- Fall of 1991
- Building on LCPC
- Mod. TX Gyratory
- 6" specimens
- 1° angle
- 30 rpm
- Height recordation



An Alternative Path

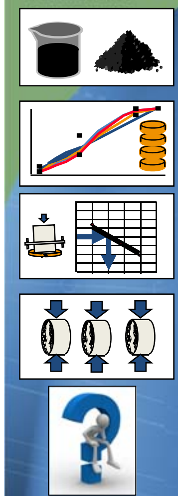
- SHRP Intense Debate
- University of California – Berkeley
  - Promoted Rolling Wheel compaction



Superpave Gyratory Compactor Calibration

Making Superpave Mixtures Consistent

Superpave® Mix Design



1. • Selection of Materials
2. • Selection of a Design Aggregate Structure
3. • Selection of the Design Binder Content
4. • Evaluation of Moisture Sensitivity
   • Modified Lotman, AASHTO T 283
5. • Asphalt Mixture Performance Test(s)

~~A Simple~~ Performance Test(s)

NCHRP 9-19

- E*
- Flow Number, Fn
- Flow Time

TP-62 Determination of Dynamic Modulus, E*

- 9-29: HMA Performance Tester
- TP 62 Dynamic Modulus E*
  - Accommodate HMA Performance Tester
  - Separate Std for sample preparation
  - Separate Std. for master curve

Asphalt Mix Performance Tester

- ✓ NCHRP 9-29
- ✓ Evaluate mixture fatigue and response (E*) rutting (Fn)
- ✓ Published as TP 79 also PP 60, PP 61, and PP 62
- ✓ Relatively inexpensive and ease of use
- ✓ **Provides key MEPDG input**

Asphalt Mix Performance Tester Flow Number (Fn)

- Developed as indicator of rutting potential
- 9-33 relationship flow number/maximum traffic with lab mixes (field mix issue-age)
- Issues
  - High temperature 50% reliability PG LTPPBind 3.1
  - Confined/unconfined
  - Load: various levels have been used

Asphalt Mix Performance Tester *(2009/2010)*

- Develop pooled fund for training and equipment purchase of the equipment
- Technician training for operation of the equipment (AAT contractor/NCAT Lab)
- Remaining issue with determination Flow Number, Fn

Home

Part 4:

Hot Challenge because of Warm Mix

Warm Mix Asphalt

- WMA encompasses a wide range of enabling technologies that enhance asphalt production and/or lay-down properties…

Q. Which project is which?

A: Hot-Mix Asphalt (HMA)?

B: Warm Mix Asphalt (WMA)?

Project No. 1

Project No. 2

What is WMA?

Relative Production Temperature (ºF)	Zone	Driver	WMA Technology Category…
HMA	Total Project	Extend Paving Season	
- 40º	Production	Improve Aggregate Co[…]	
		Reduce Fuel Usage (F)	
- 60º		Reduce Emissions (E)	
		Enhance Worker (W[…]rt	
- 80º	Transport	Extend Effective Ha[…]ce	
	Lay-Down	Improve Compaction (I.C.=[…])	
- 100º		Reduce Emissions (E)	
		Enhance Worker (W) Comfo[…]	

Yes

May-be

No

n/a

Un-likely

A little

A lot

Q. From an Agency perceptive, what Driver is most important?

Relative Production Temperature (ºF)	Zone	Driver	WMA Technology Category…
HMA	Total Project	Extend Paving Season	?
- 40º	Production	Improve Aggregate Coating	?
		Reduce Fuel Usage (F)	?
- 60º		Reduce Emissions (E)	?
		Enhance Worker (W) Comfort	?
- 80º	Transport	Extend Effective Haul Distance	?
	Lay-Down	**Improve Compaction (I.C.=I.P.)**	?
- 100º		Reduce Emissions (E)	?
		Enhance Worker (W) Comfort	?

I.C. = I.P.

- The BAD mix with GOOD density out-performed the GOOD mix with POOR density

Nevada Automotive Test Center

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Memorable Message

- **I.C. = I.P.**
  Improved Compaction = Improved Performance
- **F.E.W. key benefits…**
  – Fuel
  – Emissions
  – Worker Comfort

**Advantages will only be realized by optimizing production operations and utilizing best practices

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Mathy Tech. & Eng. Services and Paragon Technical Services, Inc

Currently Twenty Two (22) Technologies Marketed and Available in the US.

Lake Asphalt of Trinidad and Tobago

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Economics of WMA Start Up to Operating

- Foaming Systems…
  – $35 to $100k + Start Up
  – Water is basically free.
  – If a liquid antistrip is needed, ~ $1 to $2 / ton

- Additive Systems…
  – $7 to $60k Start Up
  – $1.75 to 2.50 / ton of mix

- Factor in fuel savings
  Net cost ~ Zero to $1.50 / ton

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Mike Acott

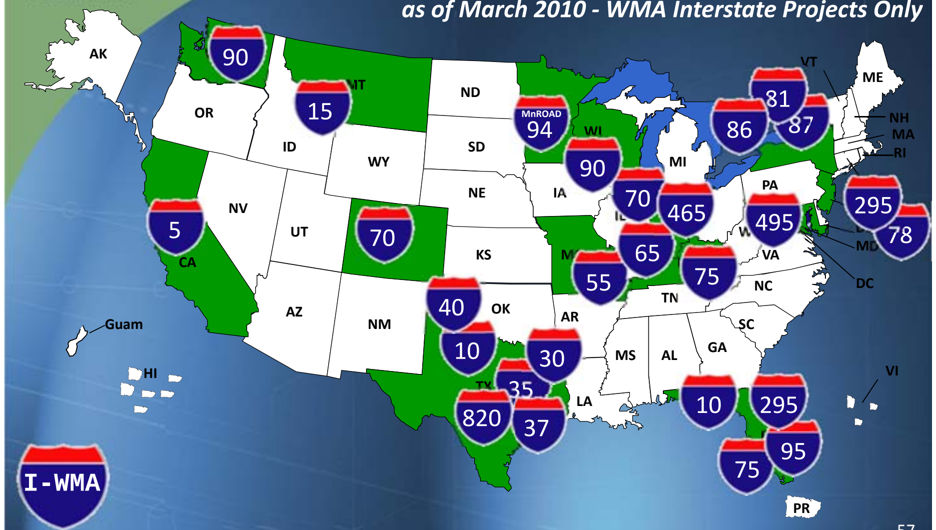
President, National Asphalt Pavement Association

"WMA is the future of flexible pavements in the U.S. … lowering our production and paving temperatures promises improved energy consumption, operations, and quality."

NAPA
NATIONAL ASPHALT PAVEMENT ASSOCIATION

Interstate Highway WMA Usage

as of March 2010 - WMA Interstate Projects Only



What will Laboratory Mix Design Require for WMA?

DRAFT R35

- Simulate the WMA technology…
  - Blending of additive
  - Foaming unit, $30k
  - Etc.

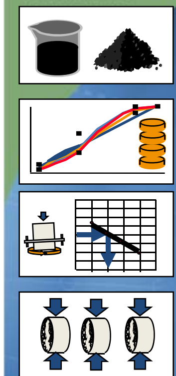
Q. What if we treat WMA Different?

- GOAL should be to have a performance-based mixture design process with criteria that applies to plant mix asphalt –
- Regardless of the temperature it is produced!

Evolution of Mix Design Recipe

Recipe – TLAR → Empirical → Volumetric – Strength Tests → Volumetric – Performance Tests → Performance Indicators & Tests ?

Where are we headed?



1. • Selection
2. • Selection ... te Structure
3. • Selection ... r Content
4. • Evaluation
   • Modified ... 3
5. • Asphalt Mixture Performance Test(s)

Performance-Driven Asphalt Mixture Design

Property	Concern	Available Tools	State-of-the-Practice
Work-ability	Segregation		
Low-Skid	Safety		
Permeability	Moisture Damage		
Durability	Premature Failure		
Stability	Rutting		
Fatigue Resistance	Cracking		
Facture Resistance	Cracking		
Tied to Structural Design	Right Mix – Right Application		

Performance-Driven Asphalt Mixture Design

Property	Concern	Available Tools	State-of-the-Practice
Work-ability	Segregation	Uniformity / Density / IR Camera	?
Low-Skid	Safety	Polish Factor / AIMS…	PF
Permeability	Moisture Damage	FH Permeometer / Volumetrics / Lotman / Hamburg…	Va, VMA, T-283
Durability	Premature Failure	LA Abrasion / Micro Duval / VMA / MSCR-binder…	LA, VMA
Stability	Rutting	Volumetrics / Hamburg / APA / AMPT (FN) / MSCR	Va + ???
Fatigue Resistance	Cracking	Volumetrics, CP Beam, TP Beam, Semi-circular Notched Specimen	VMA
Facture Resistance	Cracking	BBR-binder…	PG-grade
Tied to Structural Design	Right Mix – Right Application	AMPT (E*) + MEPDG	???

However…

- Mix Design provides… LTMF
- Mix Verification, during production, provides… JMF

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Thank You!