



Evolution of Mix Design


Marshall, Superpave and
Balanced Mix Design



November 21, 2024

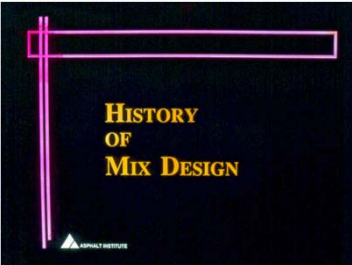
Washington D.C.

Pennsylvania Ave,
Paved 1876

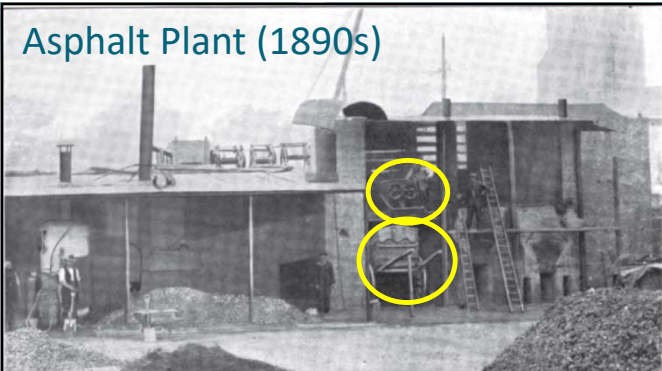


Recycling

- Opening slide
- 1989
Asphalt Institute
Building
Dedication
- State of the art
35-mm slide



Asphalt Plant (1890s)



Rule of Thumb

- Based on
Experience



"Recipe" Mix Design

- 200 lb fine sand
- 300 lb coarse sand
- 400 lb crushed gravel
- 50 lb penetration asphalt

Mix @ 300 F and lay on road

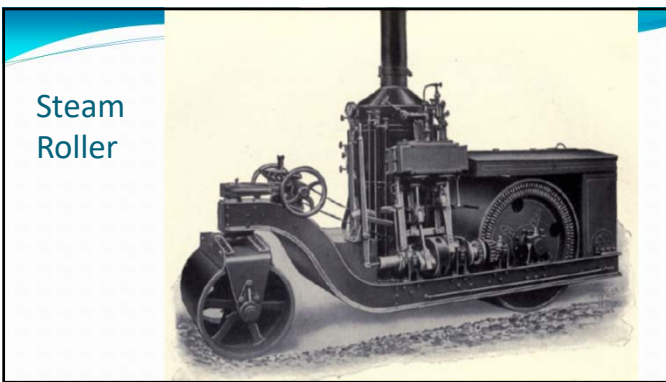
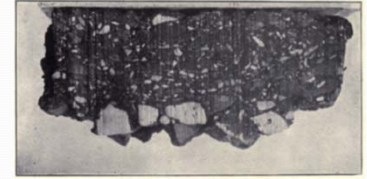
Transport





Surfacing Mix Design (Cushion Coat)

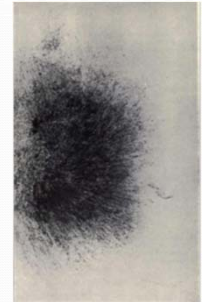
- Recipe Design
 - 70 to 83% sand
 - 5 to 15% lime
 - 10% asphalt
- Sand heated to 300°F
 - Add Lime (cold)
 - Adjust visually
 - Add asphalt



Steam Roller

Pat-Paper Test

- Brown paper (from grocery store)
- Mixture in pan dumped on to paper
- Asphalt fluidity judged visually



Typical 1900s Pavement

- Surfacing Mix
- Asphaltic Concrete
- Hydraulic Cement Stabilized Aggregate

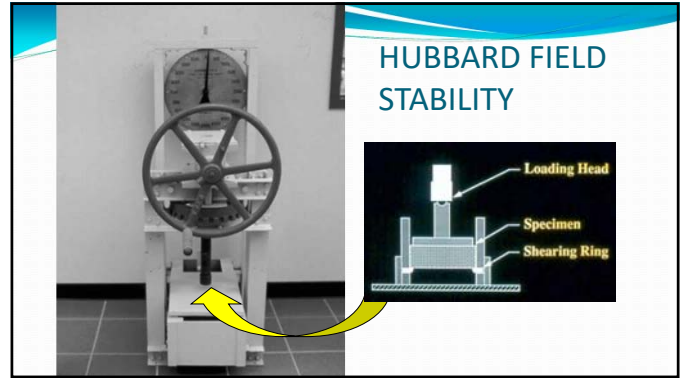
Asphaltic Concrete Mixture

- 7.4% asphalt
- 0(?)% air voids
- 13.2% VMA

1.5 inch nominal maximum size

Asphalt Concrete as Surface

- First used in 1872 in Washington, DC
 - Not successful
 - Moved around and disintegrated
- Surface Asphalt Concrete
 - Developed by Barber Company 1890s
 - 1902, first large use in Muskegon, MI



Hubbard Field Mix Design

- Developed in 1920s by the Asphalt Association
- Provost Hubbard
- Fredrick Field



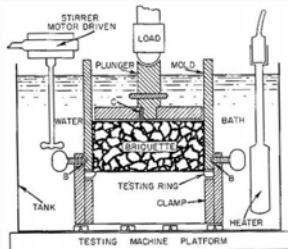
Marshall Method of Mix Design

- Developed in 1930s
- Adopted by Corps of Engineers
 - WW II
- 1943 joined Corps to "civilianize"



Hubbard Field Mix Design

- Compact Mixture with rammer
- Specifications
 - Air voids
 - Voids in compacted aggregate
 - Hubbard Field Stability



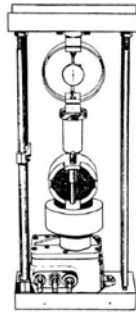
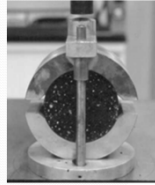
Marshall Mix Design

- Used drop hammer instead of hand rammer
 - Calculated air voids
 - Similar stability test
 - Different geometry
 - No VMA
 - No absorption
- Added in 1960s (Norman McLeod)



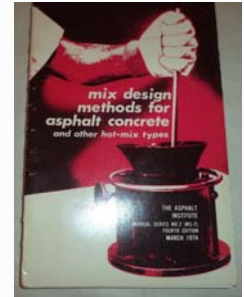
Marshall Mix Design

- Similar stability test to Hubbard Field
- Different geometry



MS-2 (1974 edition)

- MS-2 becomes defacto standard



World War II

- Airfield asphalt design
- Portable



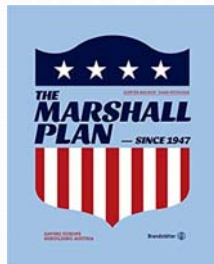
Oil Embargo

- October 1973 to March 1974



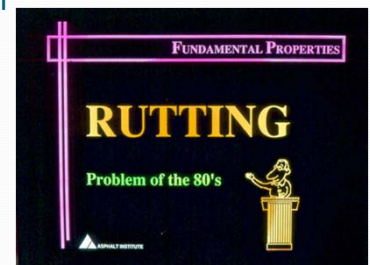
Post World War II

- Marshall Plan
 - Rebuild Europe
 - \$12 billion
- Supreme Command of Allied Powers
 - Rebuild Japan



National Problem

- After 1973 Oil Embargo



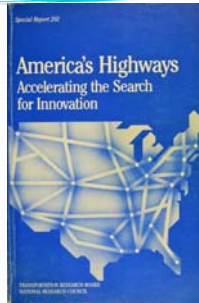


SHRP Comes to Life

- SHRP part of National Academy of Sciences
- Oversight committees created
- Research Plans re-worked into RFPs
- Funding approved by Congress, April 2, 1987
- First contracts signed in October, 1987

Strategic Transportation Research Study

- Strategic Transportation Research Study
 - Commissioned by FHWA (1982)
- TRB expert committee chaired by Dr. Thomas D. Larson, Secretary of PennDOT
- Special Report 202, 1984
- Recommended a 5-year, \$150 million, program of strategically focused research



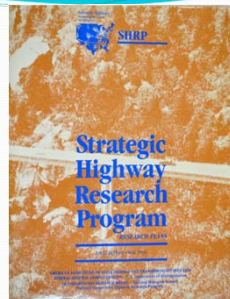
SHRP PROGRAM

- Asphalt Binder Properties
 - (\$22 million)
- Performance Based Testing Systems
 - (\$15 million)
- Pavement Performance Studies
 - (\$4.5 million)
- Performance Based Specifications
 - (\$5 million)
- Coordination
 - (\$3.5 million)



STRS to SHRP Planning the Research

- Collaborative effort among AASHTO, FHWA and TRB
- Carried out as NCHRP 20-20 (University of Maryland)
- May 1986 Report



Asphalt Advisory Committee



A-001 Contract

- Technical guidance for research contracts
- Use results from research contracts
- Develop specifications and mix design system



Asphalt Mixture Performance-Based Vision

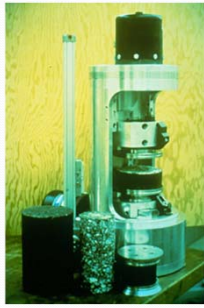
- Rutting
- Fatigue
- Low Temperature

- Include
 - Short Term Aging
 - Long Term aging



Performance Based Vision

- Measure Engineering Properties
 - Modulus
 - Compliance
- Predict
 - Stress
 - Strain
 - Performance




Result of SHRP Research

- Performance Based Asphalt Binder Specification ✓
- Performance Based Asphalt Mixture Specification ✓ ✗
- Performance Based Mix Design System ✗

Asphalt Binder Performance-Based Vision

- Rutting
- Fatigue
- Low Temperature

- Include
 - Short Term Aging
 - Long Term aging



What's in a Name?

- Asphalt Aggregate Mixture Analysis System **AAMAS**
- Mixture Design and Analysis System **MIDAS**
- SUPERior PERforming AsPHALT **Superphalt**

What's in a Name?

Superpave

- **SU**perior **PER**forming Asphalt **PAVE**ment

Restricted Zone

- Related to Natural Sand
- Excess Natural Sand
- Prevents Excess Percent

Tiered Approach

- Level 1
 - Empirical Properties
- Level 2
 - Simplified Performance-Based Testing
- Level 3
 - Complete Performance-Based Testing

Not Ready for Implementation

Empirical Properties

- Which Properties
- What Value

Superpave Volumetric Mix Design

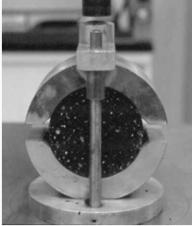
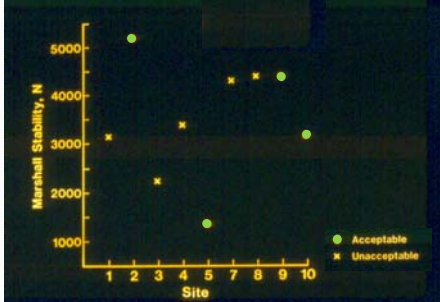
- WHAT'S IN?
- WHAT'S NOT?

SHRP Delphi Group

FHWA Volumetric Design Expert Task Group

Marshall Stability and Flow

Marshall Stability

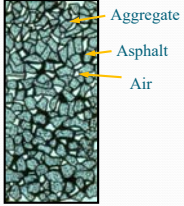
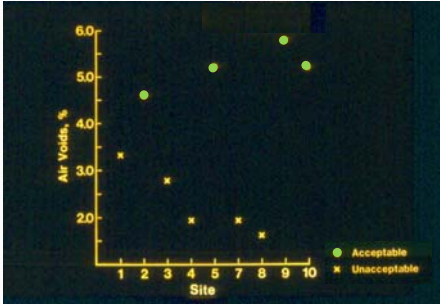



Site	Marshall Stability, N	Status
1	3100	Unacceptable
2	5100	Acceptable
3	2200	Unacceptable
4	3400	Unacceptable
5	1400	Unacceptable
7	4300	Unacceptable
8	4400	Unacceptable
9	4400	Unacceptable
10	3200	Unacceptable

NCHRP Research

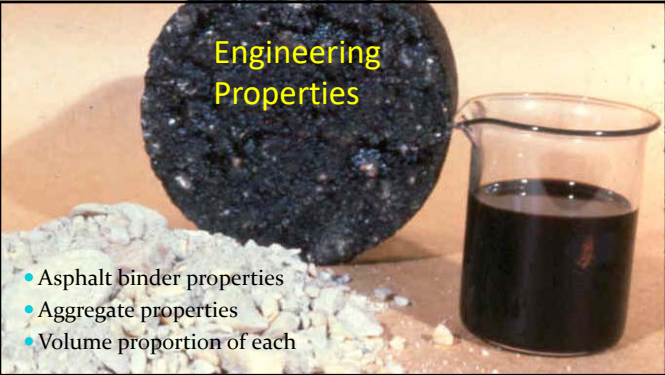
- 9-09 Refinement of N-design Inconclusive
- 9-13 Water Sensitivity tests Use AASHTO T-283
- 9-14 Restricted Zone Delete, use FAA
- 9-16 Gyratory compaction as rutting test Negative
- 9-25 Superpave VMA Use criteria from MS-2
- 9-31 Superpave Air voids Use four percent

Air Voids

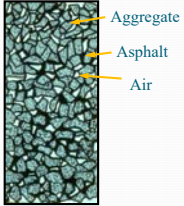
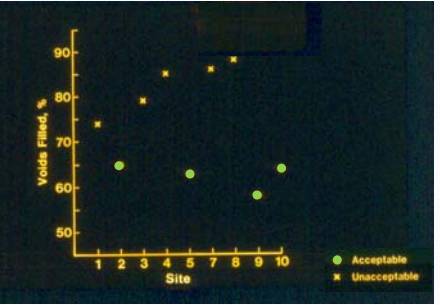
Site	Air Voids, %	Status
1	3.3	Unacceptable
2	4.6	Unacceptable
3	2.8	Unacceptable
4	1.9	Unacceptable
5	5.2	Unacceptable
7	1.9	Unacceptable
8	1.6	Unacceptable
9	5.8	Unacceptable
10	5.2	Unacceptable

Engineering Properties



- Asphalt binder properties
- Aggregate properties
- Volume proportion of each

Voids Filled with Asphalt

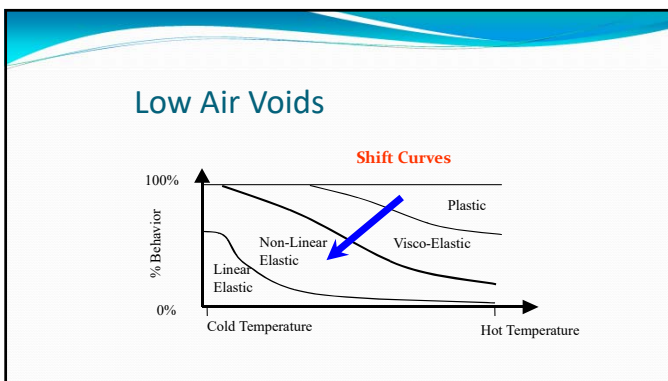
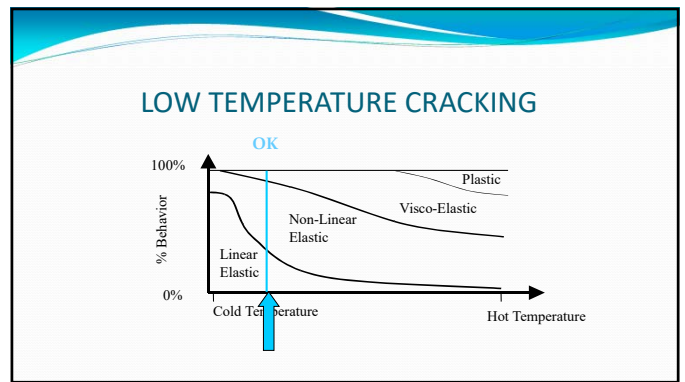
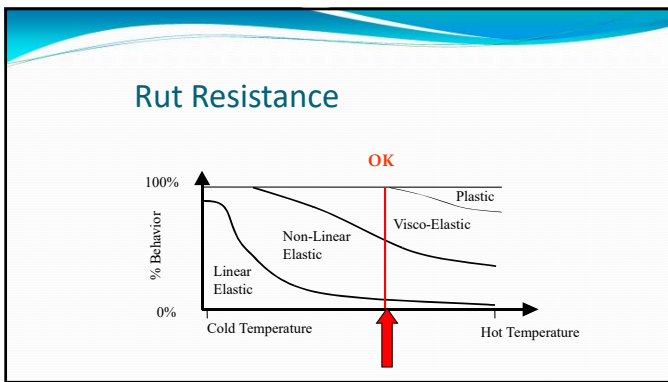
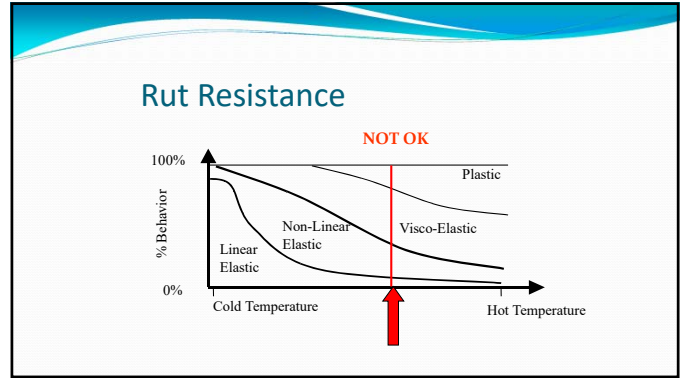
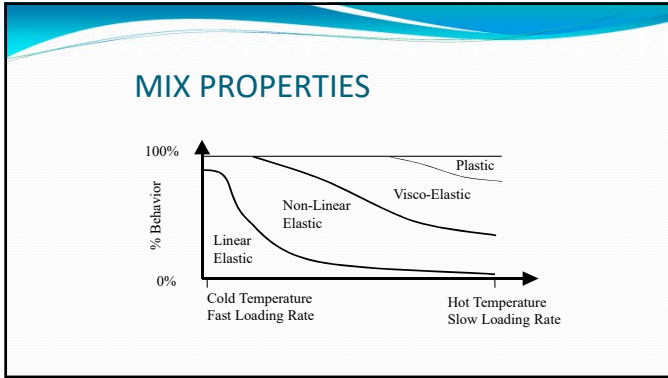



Site	Voids Filled, %	Status
1	74	Unacceptable
2	65	Unacceptable
3	79	Unacceptable
4	84	Unacceptable
5	63	Unacceptable
7	86	Unacceptable
8	87	Unacceptable
9	58	Unacceptable
10	64	Unacceptable

Asphalt Mixture Properties

- Linear Elastic
- Non-linear Elastic
- Visco-elastic
- Plastic






Rutting Empirical Properties

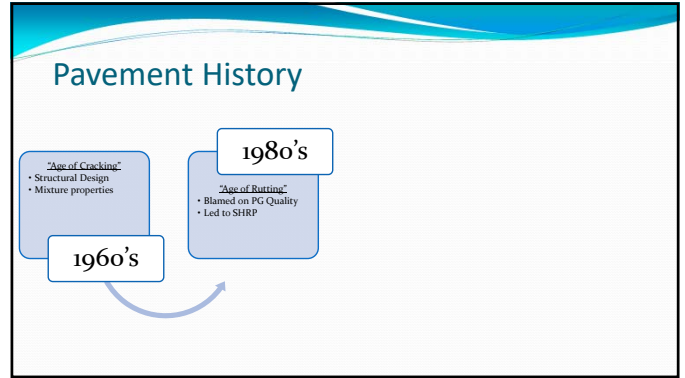
A photograph of a road surface showing significant rutting. Yellow arrows point from the rutted area to a list of empirical properties.

- Materials
 - Aggregate
 - Crushed faces
 - Fine Aggregate Angularity
 - Surface chemistry
 - Asphalt binder
 - High temperature PG
 - Low temperature PG
- Proportions
 - Air voids
 - Volume effective asphalt
 - Voids filled with Asphalt


Fatigue Empirical Properties



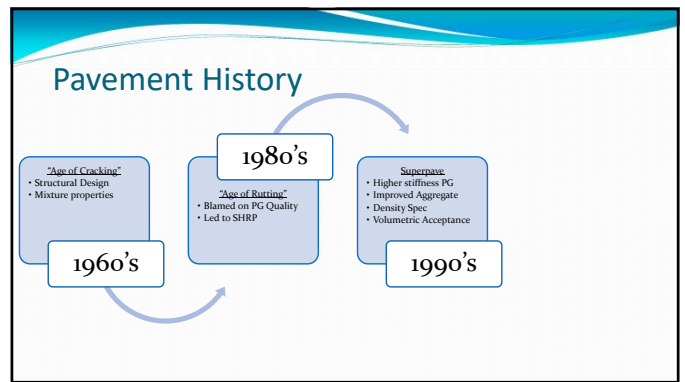
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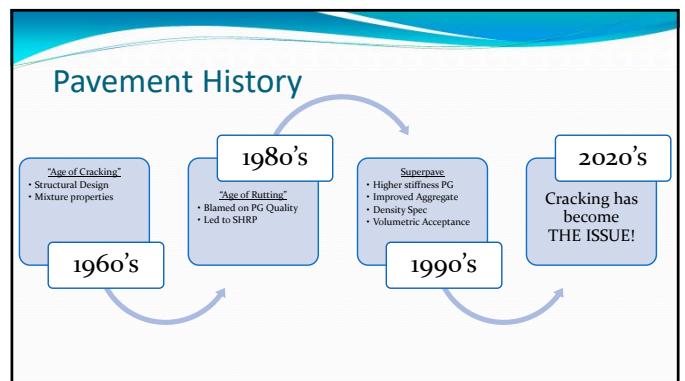
Low Temperature Cracking Empirical Properties

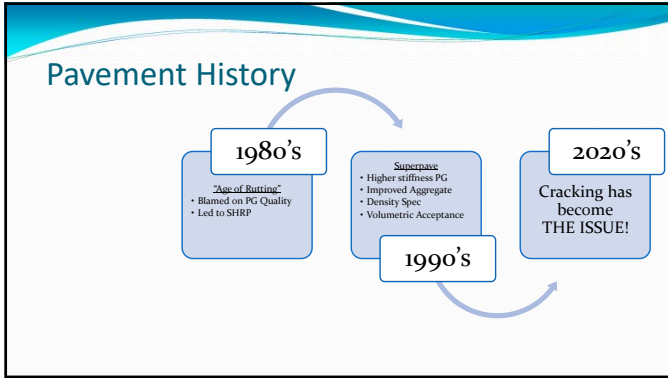


- Materials
 - Aggregate
 - Crushed faces
 - Fine Aggregate Angularity
 - Surface chemistry
 - Asphalt binder
 - High temperature PG
 - Low temperature PG
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Balanced Mix Design



SHRP (Superpave) History NCHRP 9-41

NCHRP
The National Cooperative Highway Research Program

The Superpave Mix Design System: Anatomy of a Research Program
(2012)

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TRB's National Cooperative Highway Research Program (NCHRP) was established in 1967 to support the original Strategic Highway Research Program managed by the National Academies of Sciences, Engineering, and Medicine.

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Contributor(s): National Academies of Sciences, Engineering, and Medicine; Transportation Research Board; National Cooperative Highway Research Program

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