Hot Mix Asphalt 101

Definition of HMA

In simple terms…:

A mixture of asphalt binder and graded mineral aggregate, mixed at an elevated temperature and compacted to form a relatively dense pavement layer

(≈ 5% binder and ≈ 95% aggregate)

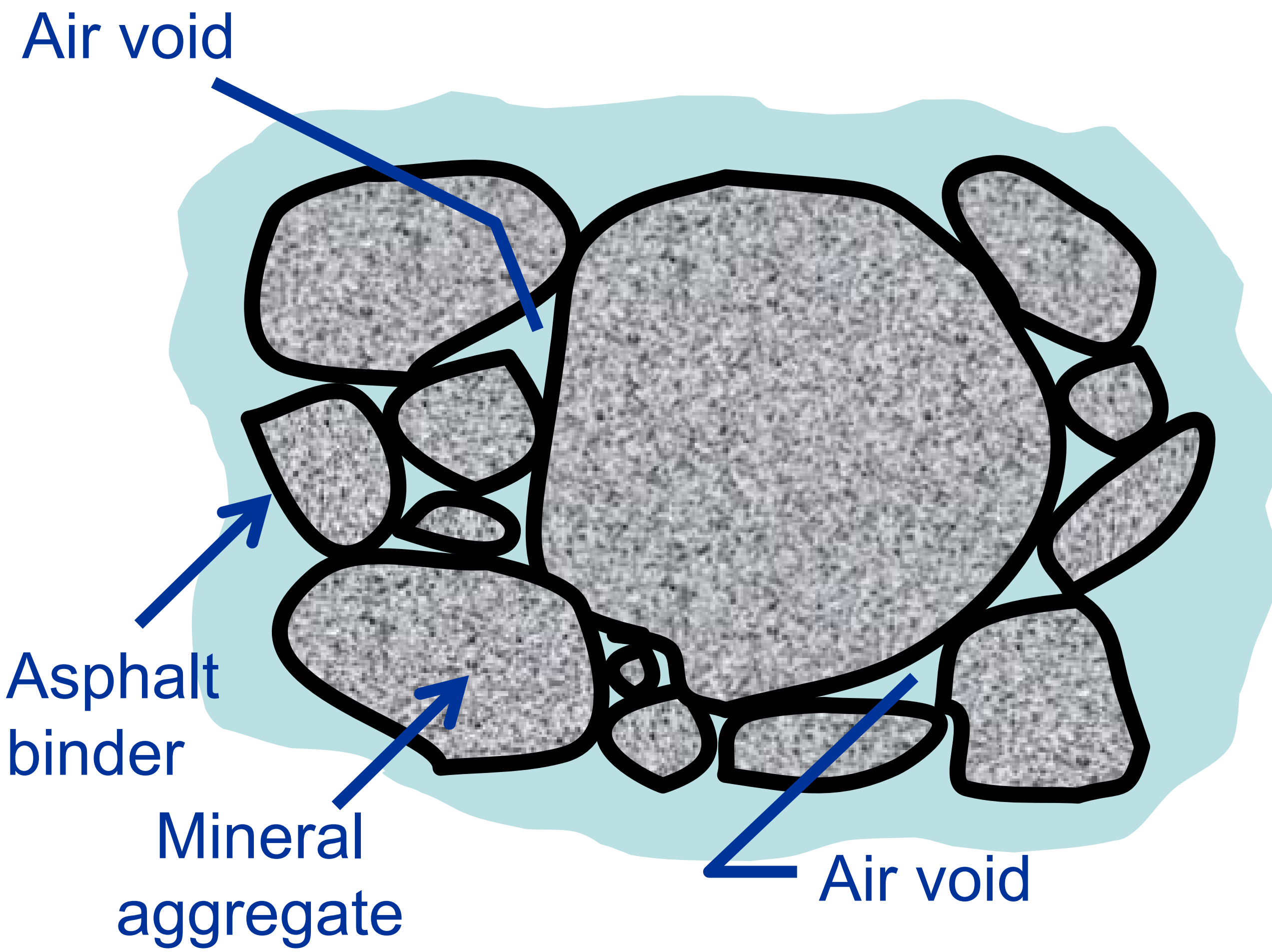
HMA Uses

- Highways
- Airfields
- Port Facilities
- Parking Lots
- Recreational (Bikeways, Tennis Courts, Tracks)
- Hydraulic Structures
- Recycled Material

Components

- Asphalt Binder
- Mineral Aggregate
- Air
- Optional Modifiers/Additives:
  - Binder Modifiers/Additives (e.g., polymers, elastomers, fibers, rubber)
  - Aggregate Modifiers/Additives (e.g., lime, granulated rubber, anti-strip agents)

Components (cont.)

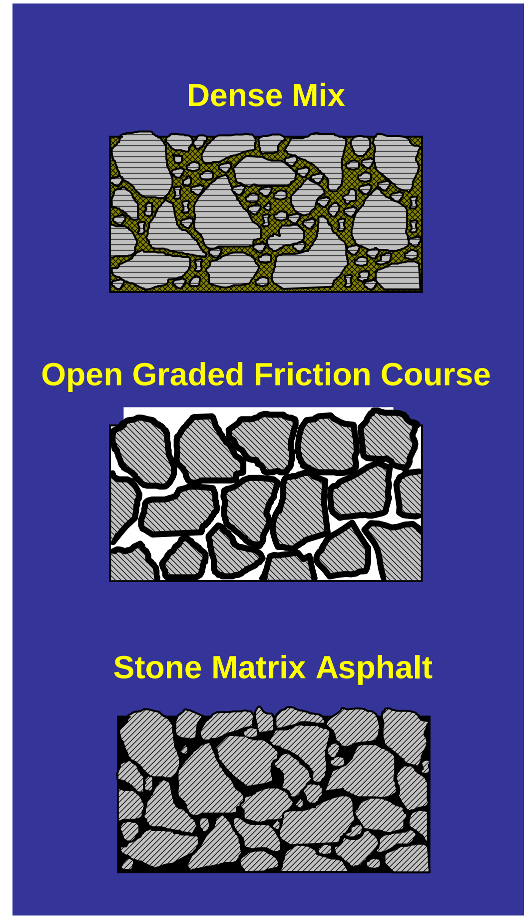


Components (cont.)

NOTE: relative size of rectangles indicate approximate proportions of components in the mix.

Types of HMA Mixtures

- Dense-Graded (DGA)
  - Size evenly distributed from smallest to largest size (well-graded)
- Open-Graded (or Uniformly-Graded) Friction Course (OGFC)
  - Primarily coarse aggregate with few fines
- Stone Mastic (Matrix) Asphalt (SMA)
  - Mid-size aggregate missing or reduced



Hot Mix Asphalt

Mixture Design Objectives

Specific Mix Design Objectives

- Stability (permanent deformation resistance)
- Durability
  - Moisture damage and aging
- Fatigue cracking resistance
- Safety (adequate skid resistance)
- Resistance to thermal cracking
- Permeability
- Flexibility

Mix Design Considerations

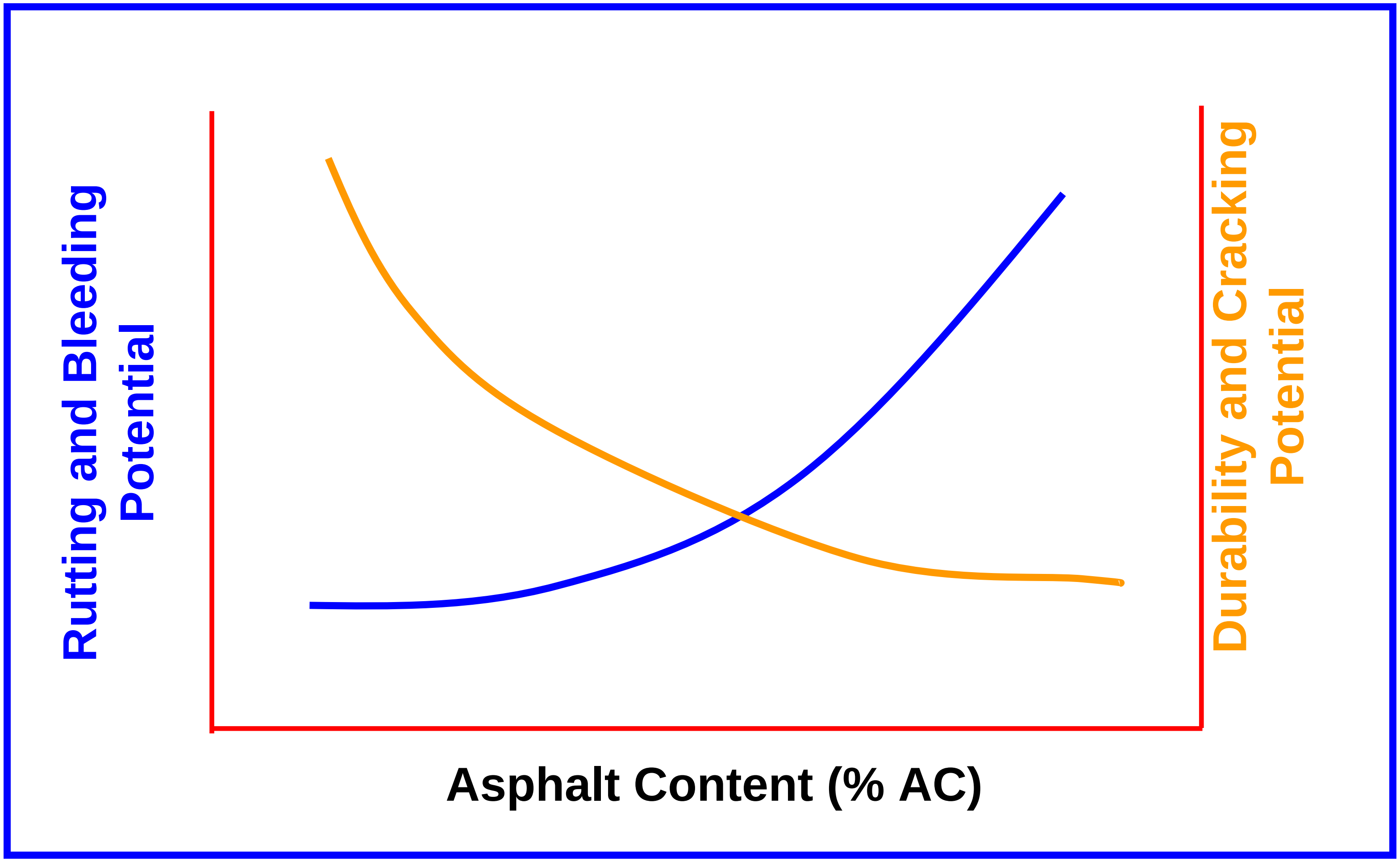
Mixture Property	Component and Construction Effects on Mixture Properties						
	Asphalt Stiffness		Aggregate Gradation		Asphalt Content		Degree of Compaction
	Hard	Soft	Dense	Open	High	Low	High
Stability	X		X			X	High
Durability	-	-	X		X		High
Fatigue Resistance	X		X		X		High
Skid Resistance	X			-		X	-
Fracture Strength	X		X		X		High
Imperviousness	-	-	X		X		High

Basic Mix Design Philosophy

Asphalt binder content

- As much asphalt as possible for
  - Durability
  - Fatigue resistance
  - Flexibility
- Not so much asphalt to affect
  - Stability
  - Friction

Asphalt Content Impact on HMA Performance – Balancing Act



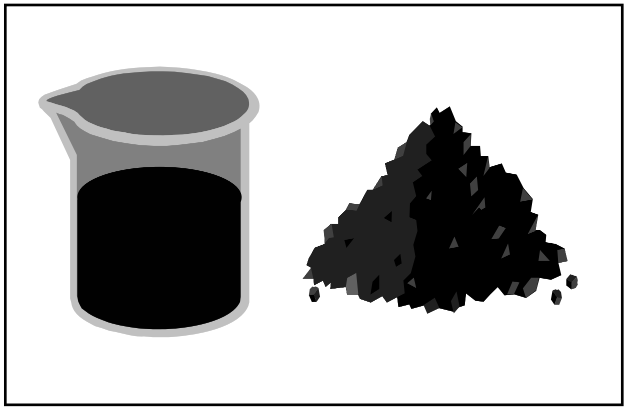
Consideration of Structural Composition on Mix Design

Top 1/3	**1 Stability** **2 Skid Resistance** **3 Durability** **4 Tensile Strength -Thermal Cracking**
Middle 1/3	**1 Stability** **2 Durability**
Bottom 1/3	**1 Fatigue Resistance** **2 Durability**

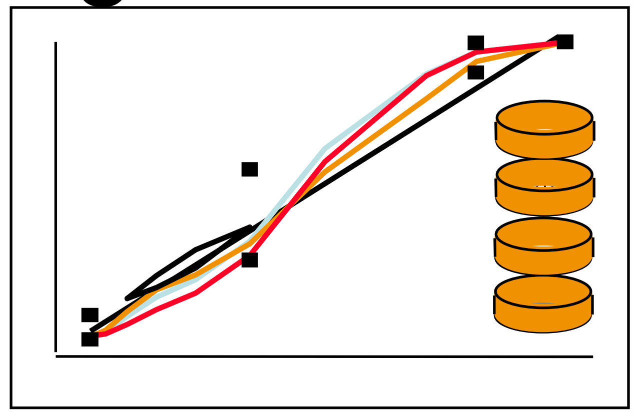
Superpave Mixture Design

Superior Performing Asphalt Pavements

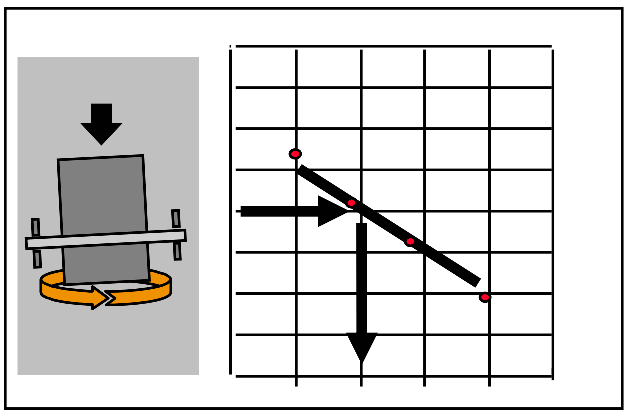
4 Steps of Superpave Mix Design



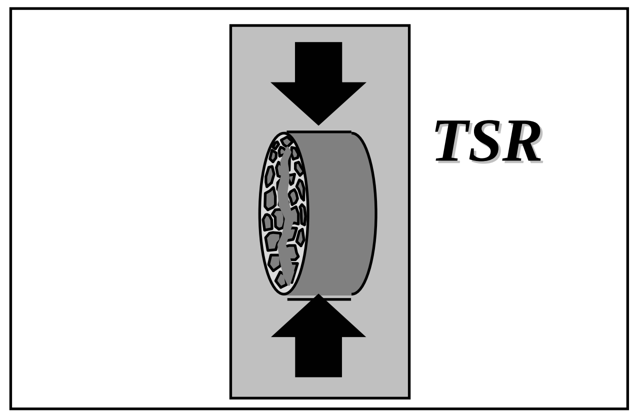
1. Materials Selection



2. Design Aggregate Structure



3. Design Binder Content



4. Moisture Sensitivity

Aggregate Properties

- Consensus Properties - *required*
  - coarse aggregate angularity (CAA)
  - fine aggregate angularity (FAA)
  - flat, elongated particles
  - clay content
- Source Properties - *agency option*
  - toughness
  - soundness
  - deleterious materials

Asphalt Binders

Polymer Modified Binders

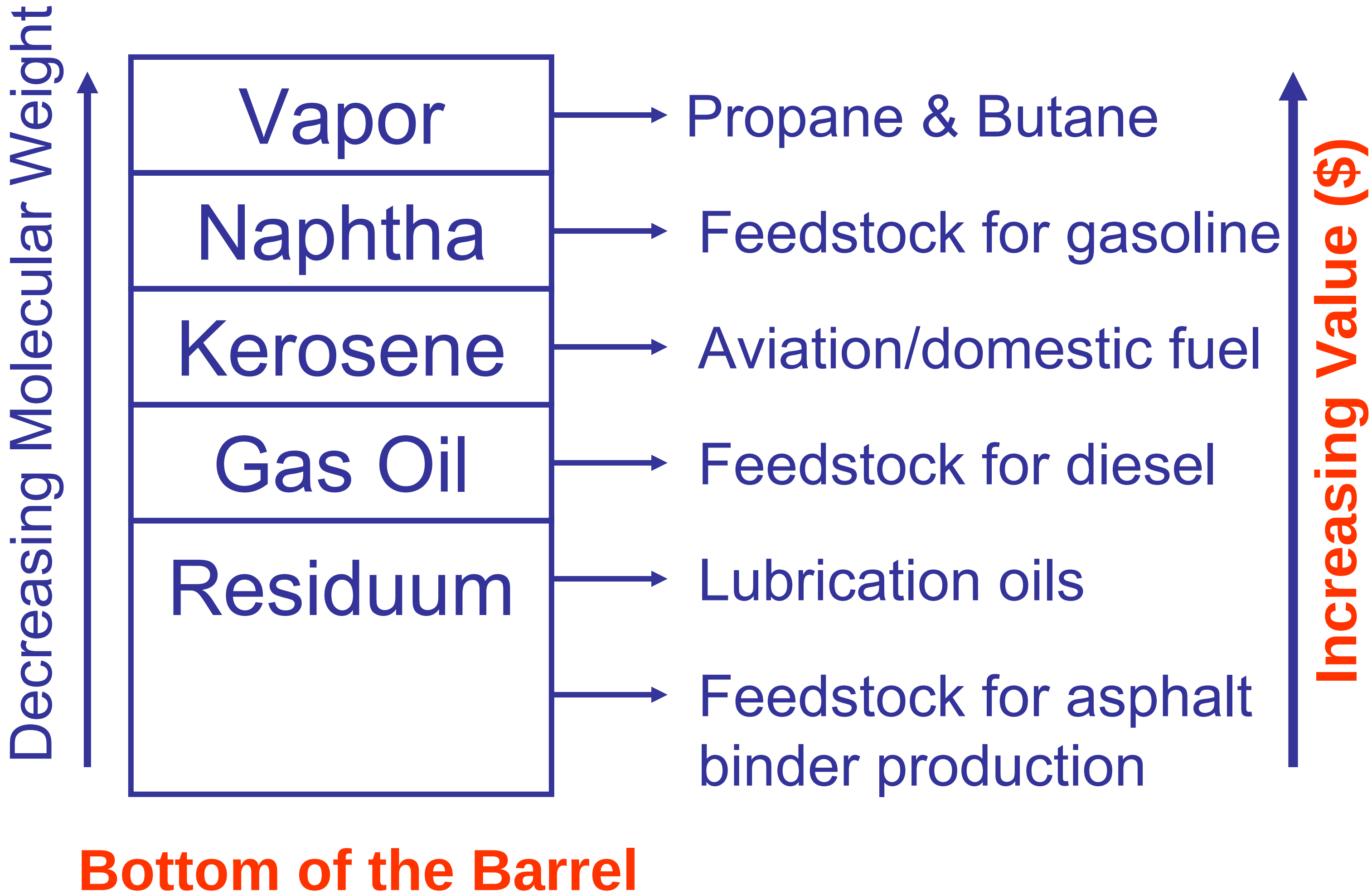
“Ideal” Asphalt Binder

- Low stiffness at construction temperature
- High stiffness at high in-service temperature
- Low stiffness at low in-service temperature
- Excellent long-term durability

Sources of Asphalt Binder

- Asphalt occurs naturally or is obtained through distillation of petroleum crude oil.
- Examples of natural asphalt include the binder in rock asphalt and Trinidad Lake asphalt.
- More commonly, asphalt is obtained through distillation of crude oil.

Refinery Atmospheric Distillation

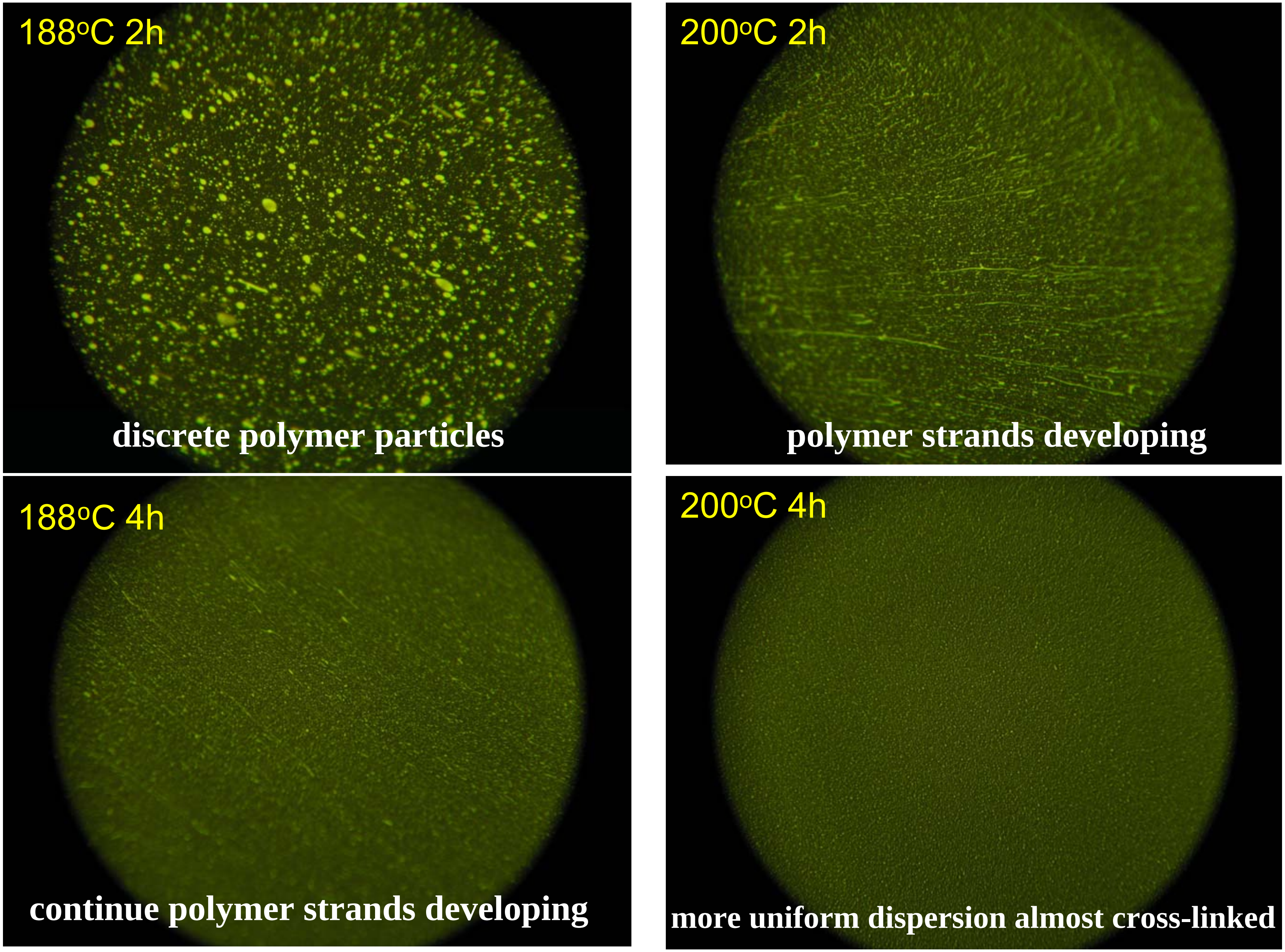


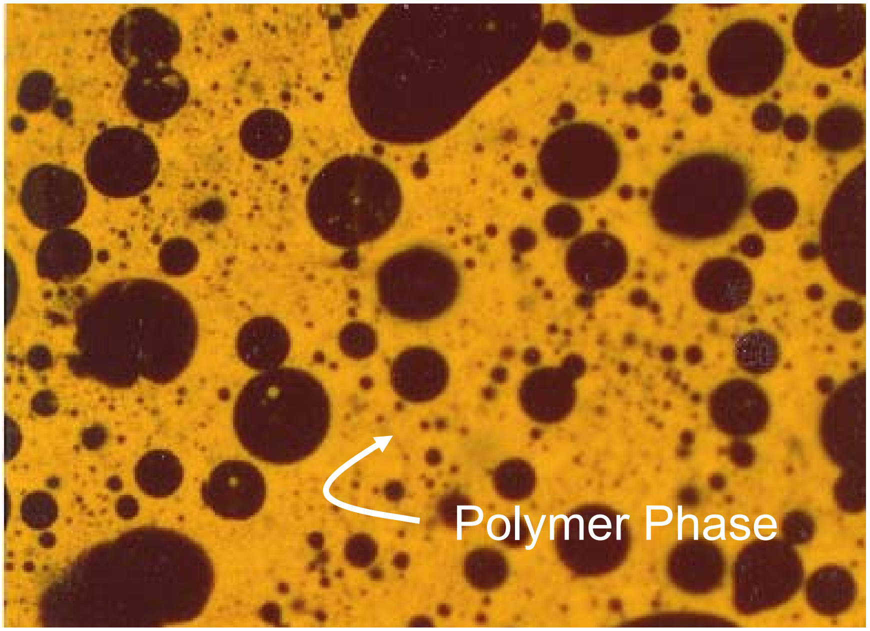
Polymer-Modified Binders

- The term "polymer" refers to a large molecule formed by chemically reacting many ("poly") smaller molecules (monomers) to one another in long chains or clusters.
- Physical properties of a specific polymer are determined by the sequence and chemical structure of the monomers from which it is made.

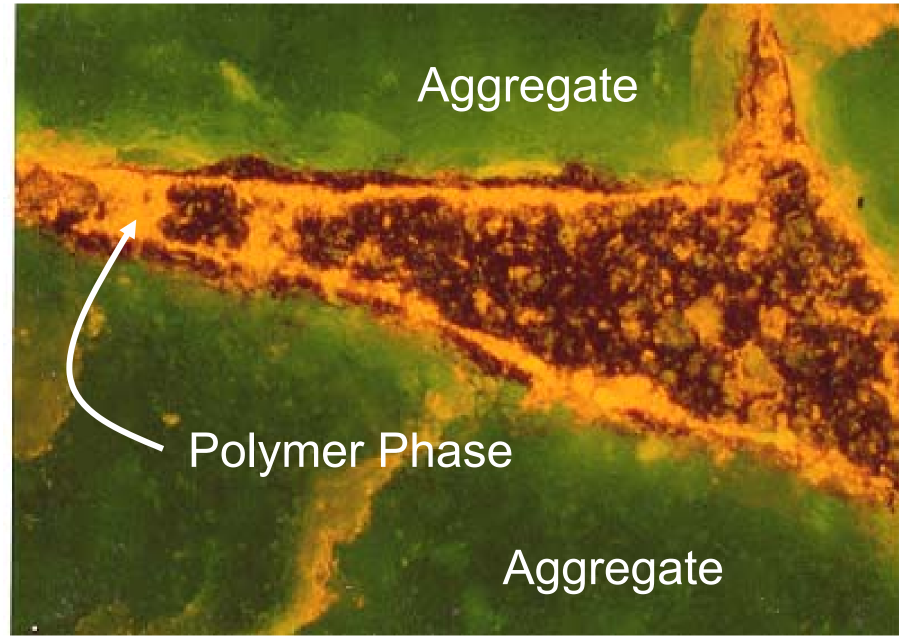
Why Polymer-Modified Asphalt?

Site Feature	Condition Description	Estimated Increase in Service Life, Years[a]
Foundation soils	Nonexpansive soils; coarse-grained soils	5–10
	Expansive soils; moderately to highly plastic soils (PI>35)	2–5
	Frost susceptible soils in cold climates; moderately to highly frost susceptible (Class 3 and 4)[b]	2–5
Water table depth	Deep	5–10
	Shallow; adequate drainage	5–8
	Shallow; inadequate drainage	0–2
Traffic	Low	
	Stop and go–intersections	5–10
	Thoroughfares	3–6
	Heavy loads–special containers	5–10
	Moderate volumes	5–10
	High volumes	5–10
Climate	Hot	5–10
	Mild	2–5
	Cold	3–6
Existing pavement condition	HMA	
	Good condition	5–10
	Poor condition; extensive cracking[c]	1–3
	PCC–jointed plain concrete pavement	
	Good condition[c]	3–6
	Poor condition; faulting and midpanel cracking[c]	0–2

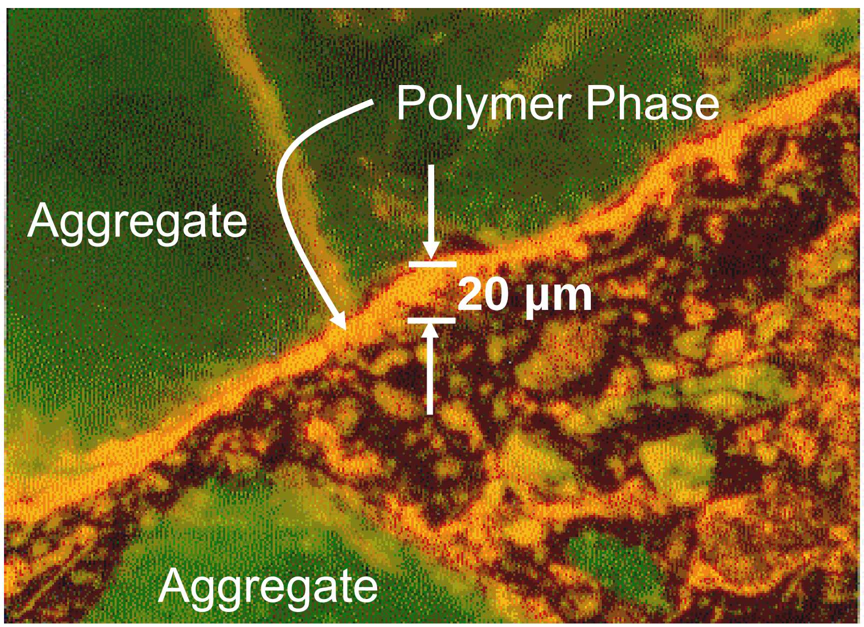

188oC 2h
discrete polymer particles
200oC 2h
polymer strands developing
188oC 4h
continue polymer strands developing
200oC 4h
more uniform dispersion almost cross-linked



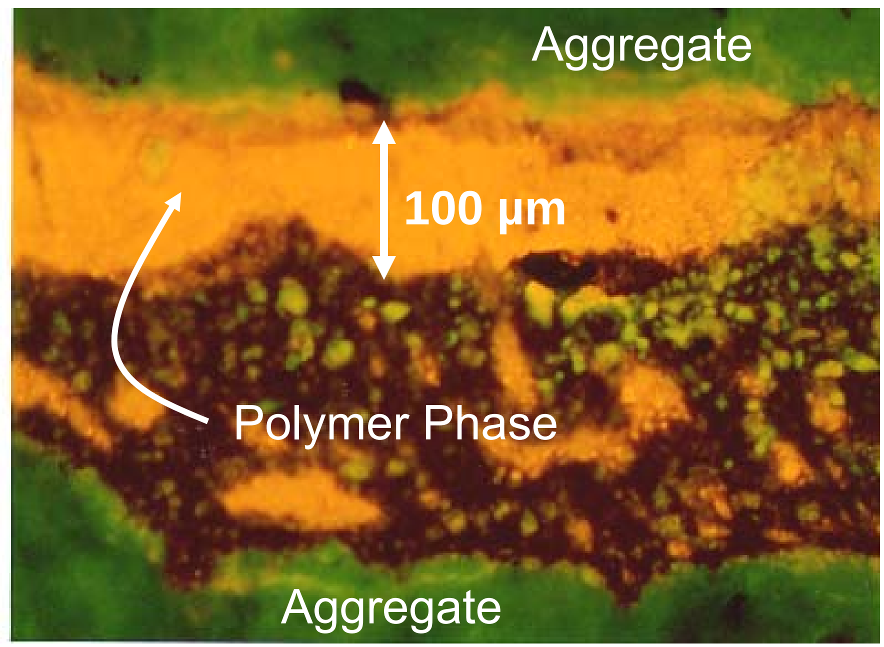
Venezuelan binder modified with 7% EVA, cracked surface, 0.5 x 0.7 mm. Wegan and Brulé, AAPT, 1999.



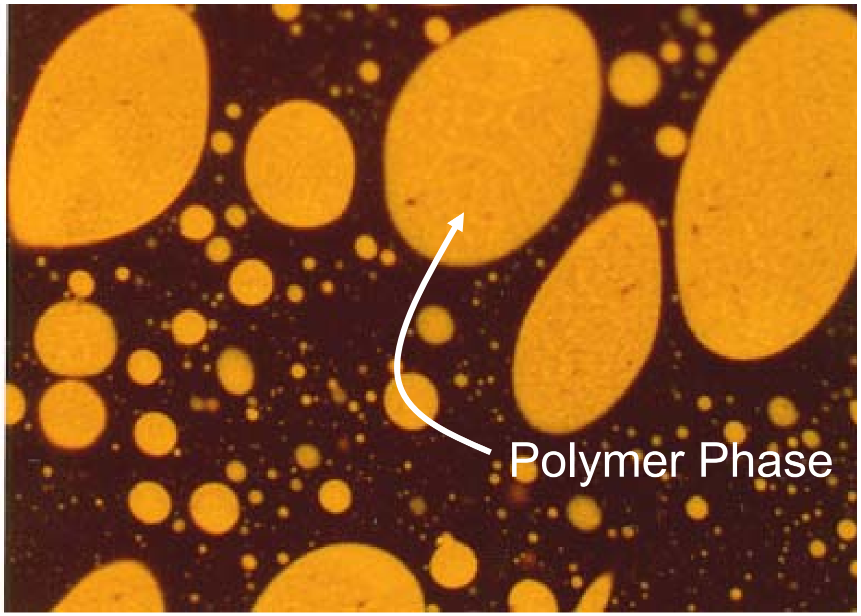
SMA produced from the modified Venezuelan binder, 0.5 x 0.7 mm. Wegan and Brulé, AAPT, 1999.



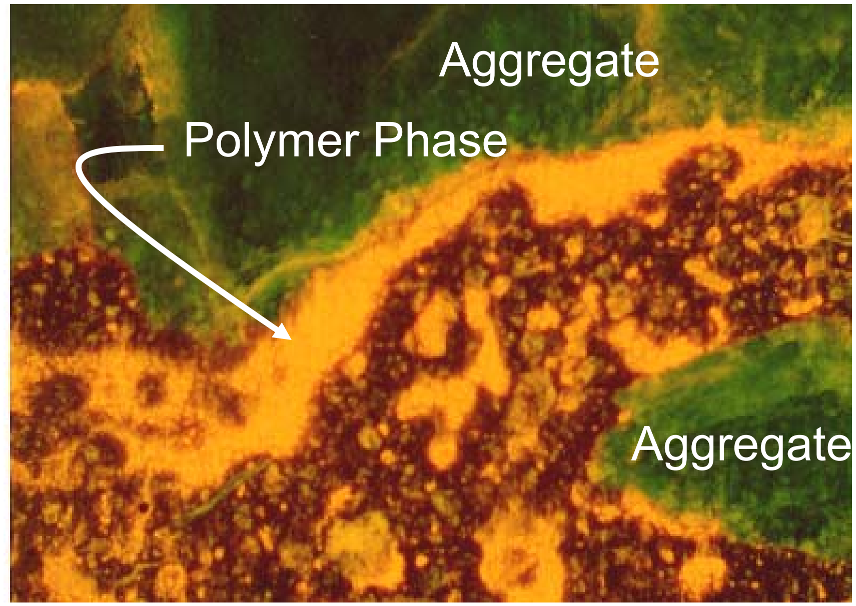
SMA produced from the modified Venezuelan binder, 0.5 x 0.7 mm. Wegan and Brulé, AAPT, 1999.



Gap-graded HMA produced from the modified Venezuelan binder, 0.5 x 0.7 mm. Wegan and Brulé, AAPT, 1999.



Middle East binder modified with 7% EVA, cracked surface, 0.5 x 0.7 mm. Wegan and Brulé, AAPT, 1999.



SMA produced from the modified Middle East binder, 0.5 x 0.7 mm. Wegan and Brulé, AAPT, 1999.

Rubbers and Plastics

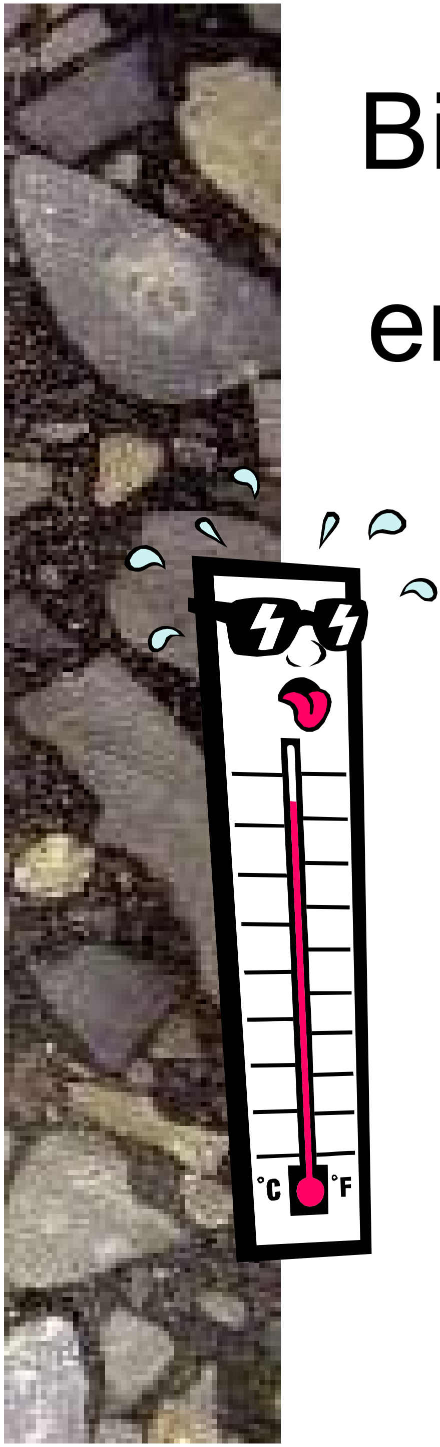
Rubbers (Elastomers) ⇒ Thermoplastic

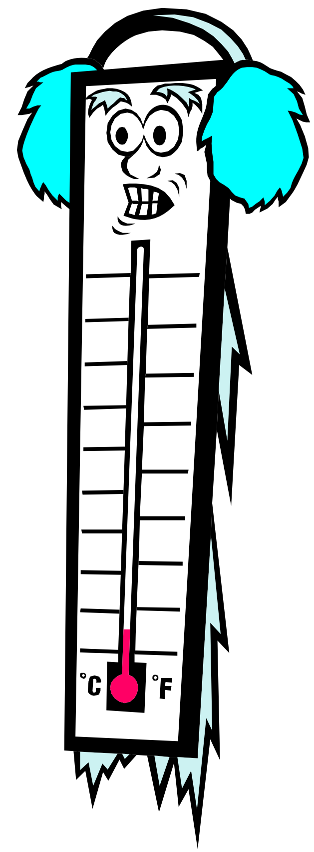
Plastics (Plastomers) ⇒ Thermosetting

Definitions

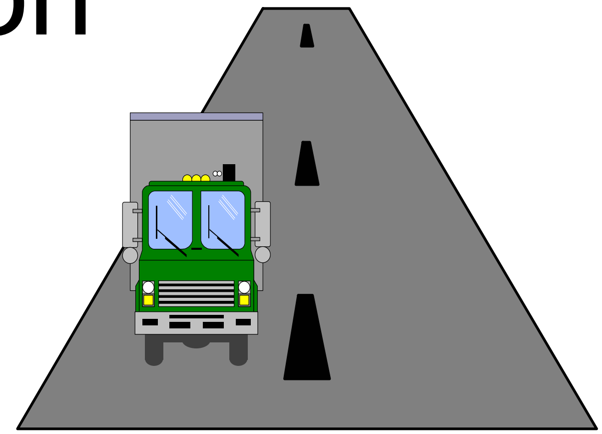
- Thermoplastic materials soften and become plastic-like when heated but return to their hardened state upon cooling.
- Thermosetting materials flow under stress when heated but, once cooled, cannot be re-softened by heat.

Binder Grade is a function of environment and traffic level





Effect of Loading Rate on Binder Selection



- Example
  - for 55 mph highway
    PG 64-22
  - for 30 mph highway
    PG 70-22
  - for intersections
    PG 76-22

NJ Standard Grade

Slow - Bump one grade

Stopped - Bump two grades

Grading System for Asphalt Binders

- Grading System Based on Climate

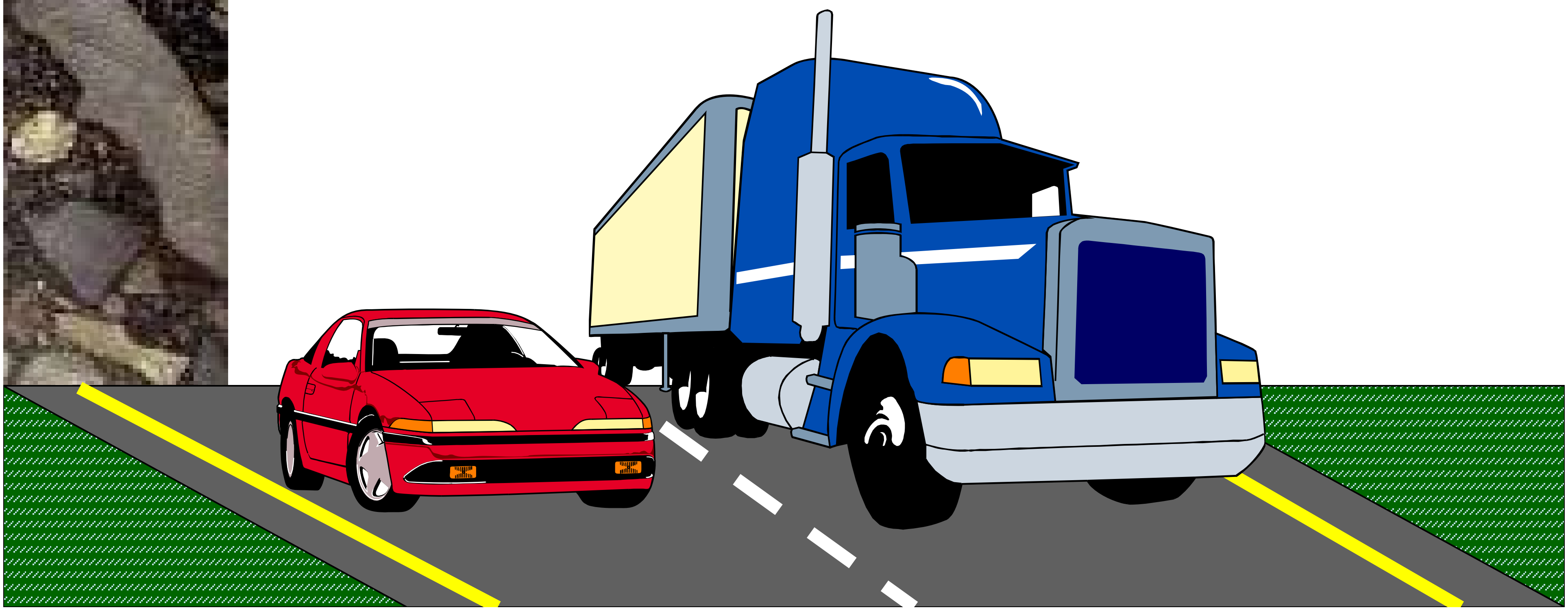
PG 64-22

Performance Grade

Average 7-day max pavement design temp

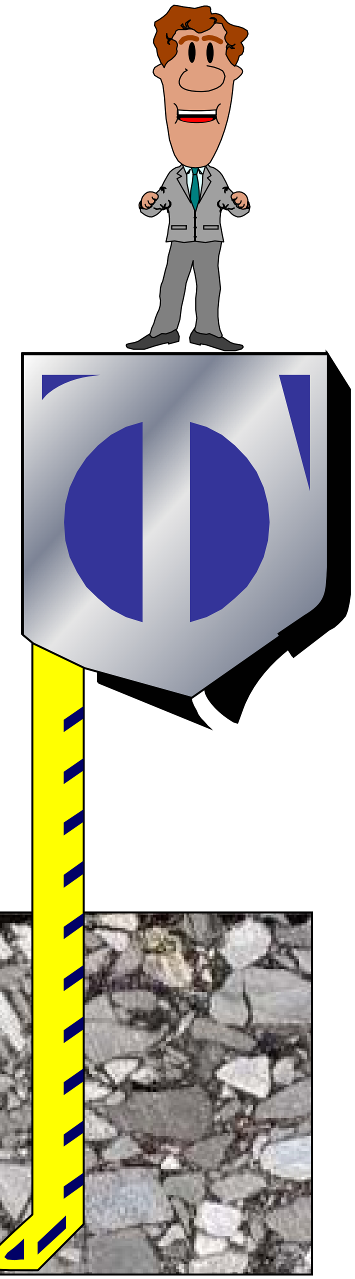
Min pavement design temp

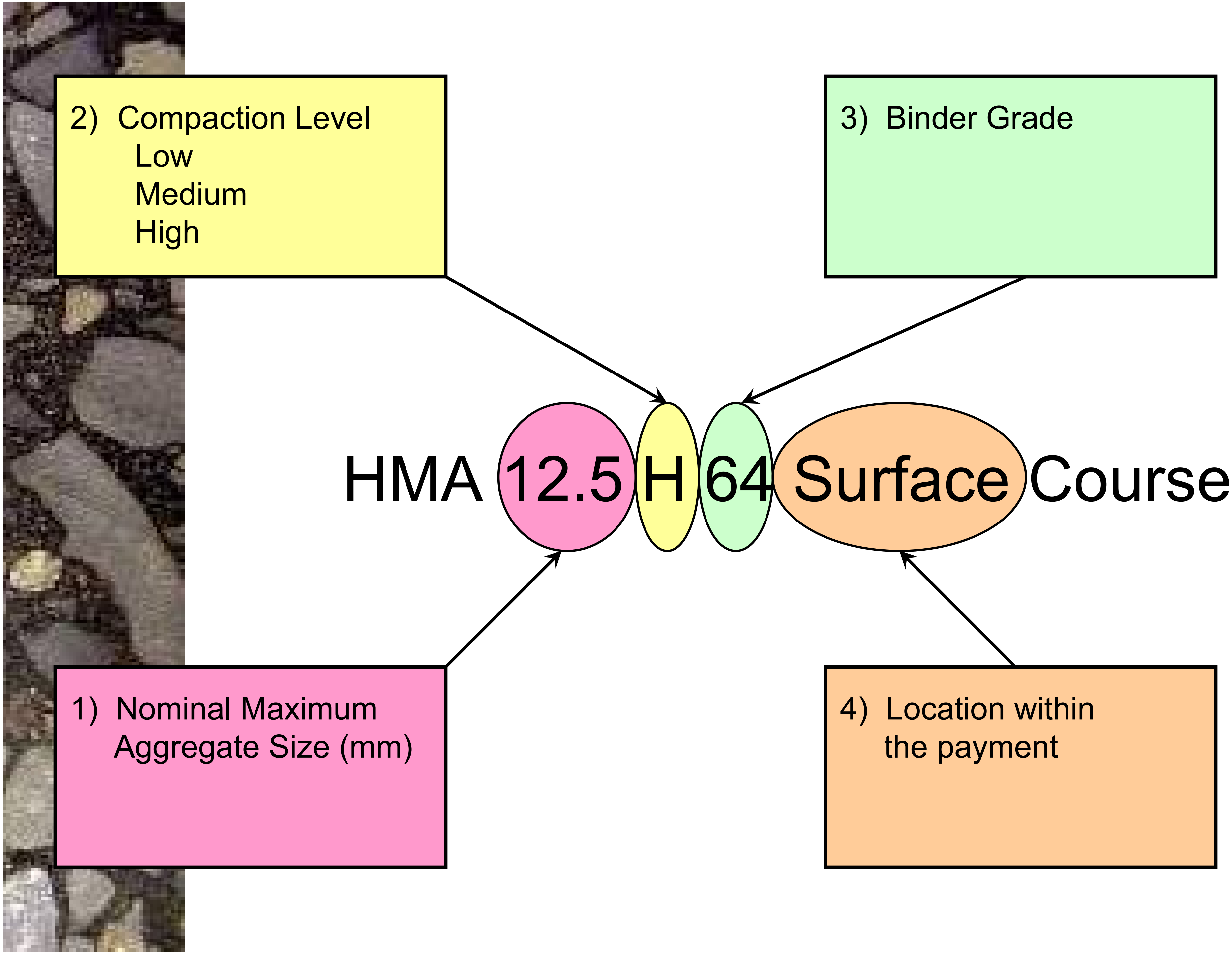
Compaction level is a function of traffic and depth of layer

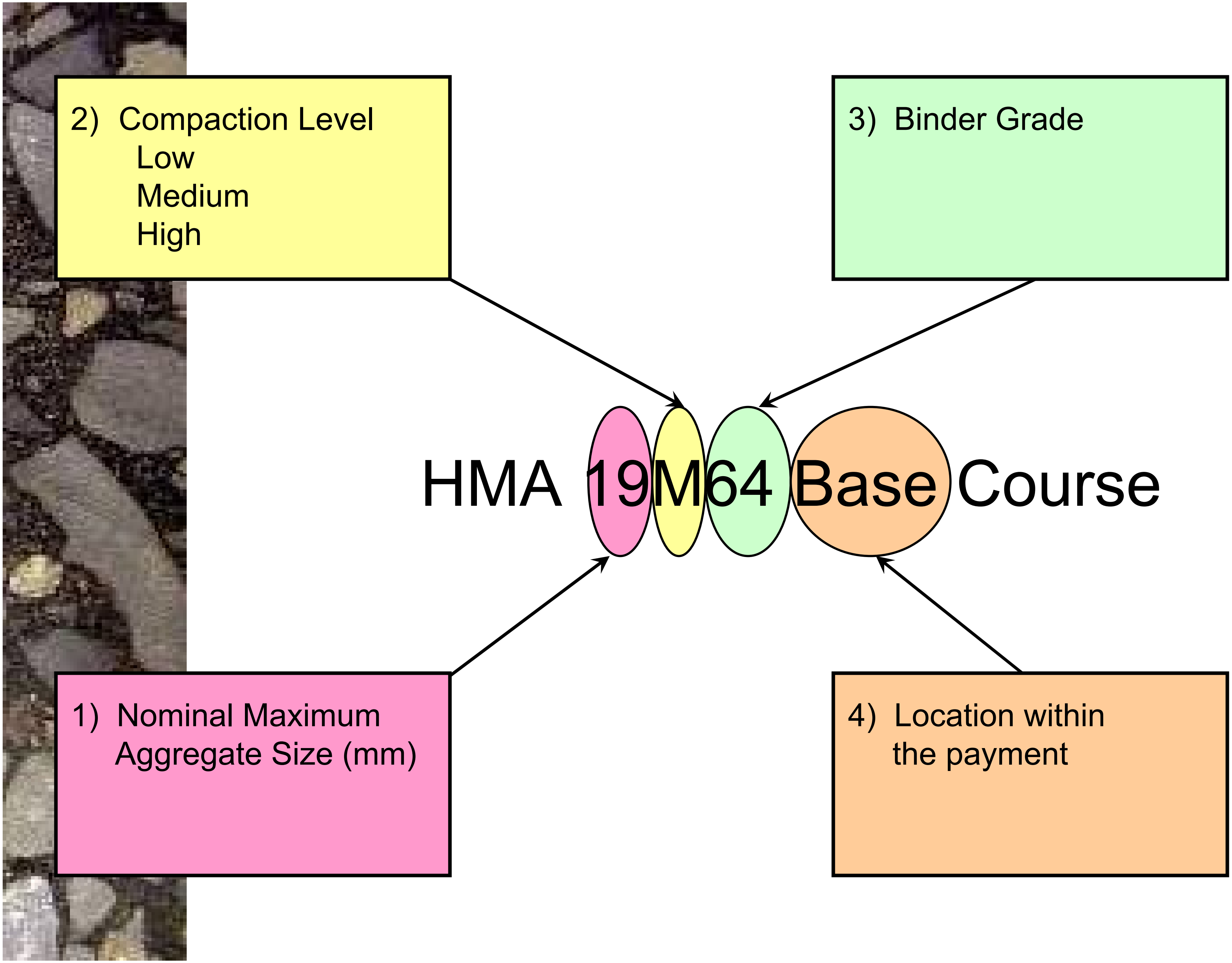


Mix size is determined by thickness of layer

(≥ 4 times Designation Name)




HMA 12.5 H 64 Surface Course
1) Nominal Maximum Aggregate Size (mm)
2) Compaction Level
Low
Medium
High
3) Binder Grade
4) Location within the payment


HMA 19M64 Base Course
2) Compaction Level
Low
Medium
High
3) Binder Grade
1) Nominal Maximum Aggregate Size (mm)
4) Location within the payment

Superpave Mix Selection

4.75

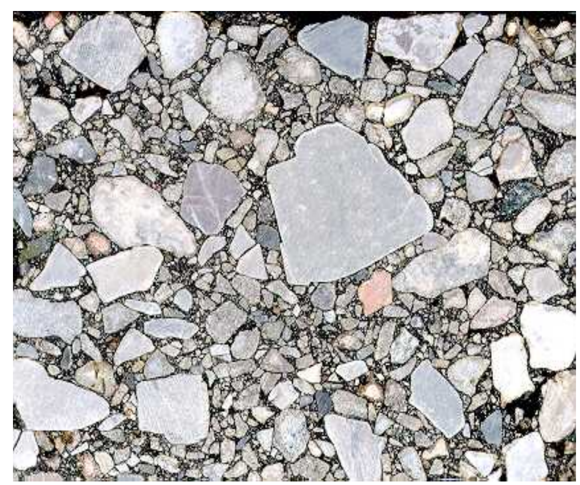
9.5

12.5

19.0

25.0

37.5

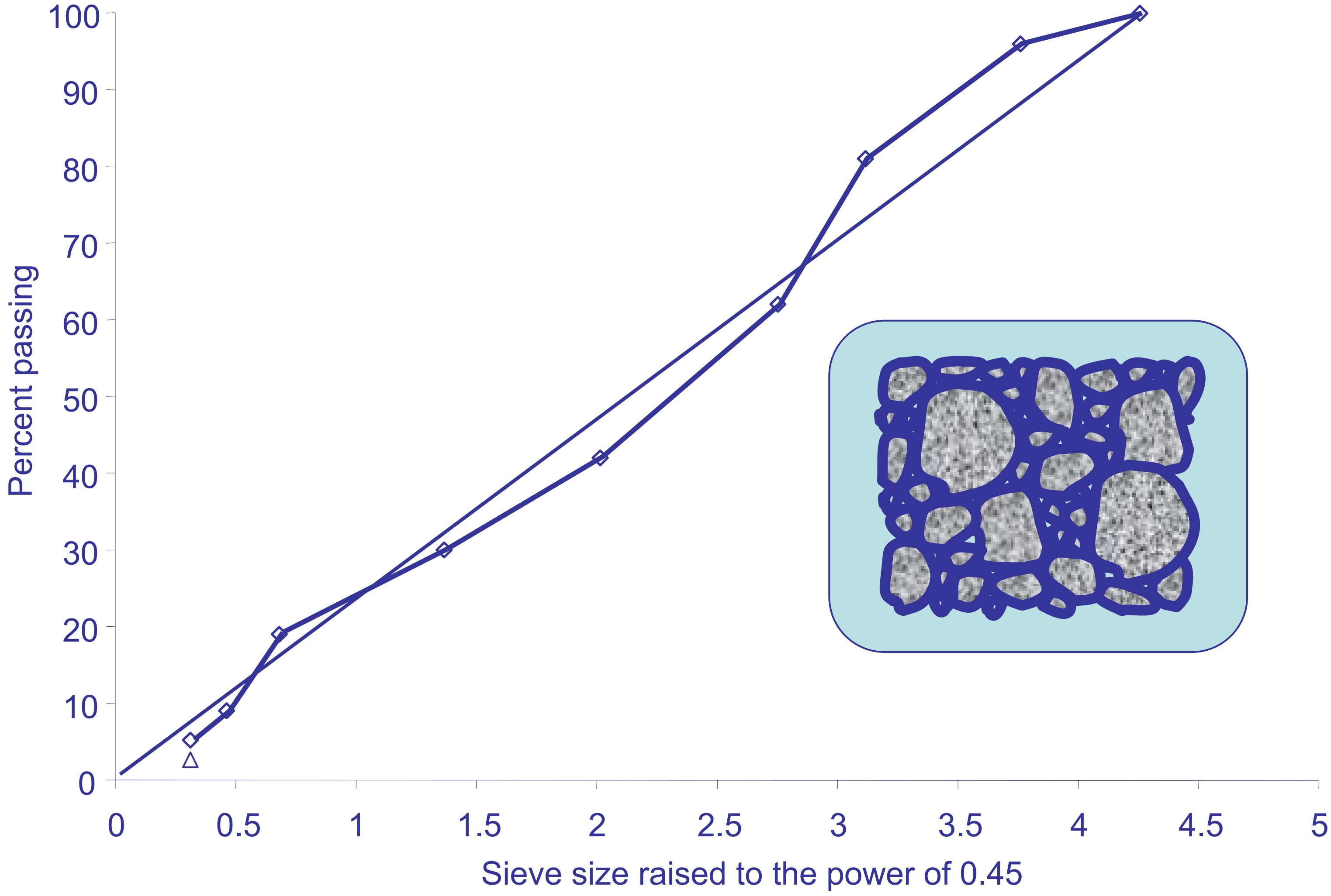


Dense Graded Mixes

“Ideal” HMA Mixture

- Resistant to permanent deformation
- Resistant to fatigue cracking
- “Impermeable”
- Workable
- Flexible
- Good surface texture

Dense-Graded Mixtures



Dense-Graded Mixtures

- Design procedure follows AASHTO R35
- Used extensively in the U.S.
- Binder content: typically 4.5 to 6%
- Field compacted air void content: typically 6 to 8%

Dense-Graded Mixtures: Advantages

- Good interlock of aggregate particles if compacted well
- Relatively low permeability if compacted well
- Strength and stiffness derived from binder and aggregate structure
- In NJ, generally a “stiff” mix
- Cheaper than other asphalt mixture types
  - Less asphalt binder, RAP

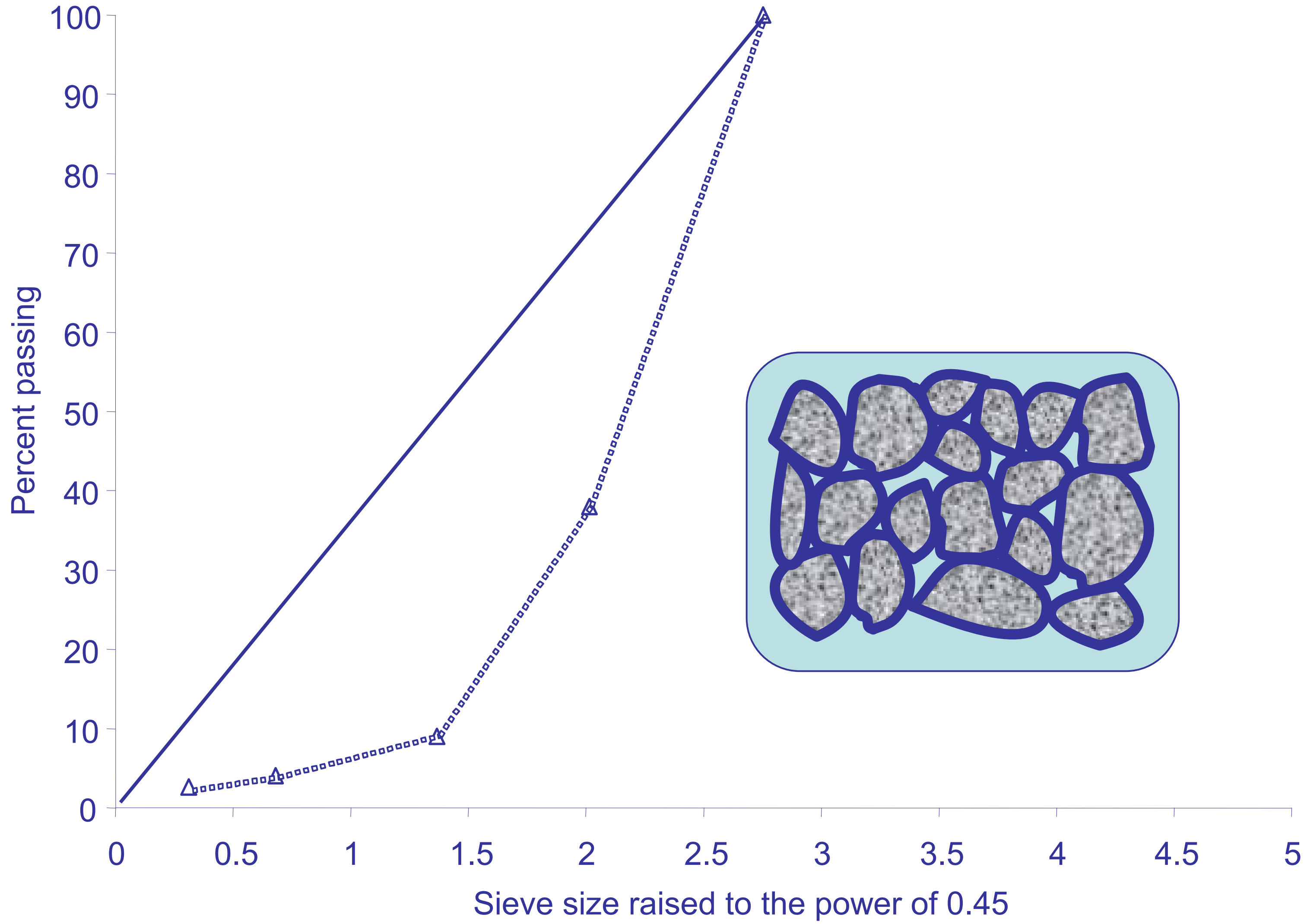
Dense-Graded Mixtures: Disadvantages

- Selection of optimum binder content:
  - Need enough binder for good durability and cracking resistance… BUT
  - Not too much binder for good permanent deformation resistance
  - Optimum asphalt binder content generally results in relatively thin binder film thickness
- Air void content and permeability are not optimum for moisture damage resistance
  - Design for 4% AV, generally placed between 6 to 8%

Open Graded Friction Course

OGFC

Open-Graded Mixtures



Open-Graded Mixtures: Advantages

- High permeability
- High asphalt binder contents resulting in thick binder films
- Lower noise generated by tires as compared with dense-graded mixtures
- Porous nature allows for surface water to drain off surface
  - Reduces splash and spray
- Best applied in areas of faster, continuous traffic with minimal sharp turns

Open-Graded Mixtures: Disadvantages

- Aggregate interlock is shape dependent (generally poor)
- Lower strength and stiffness
- Higher costs associated with polymer-modified binders, higher asphalt content and fibers
- Typically requires additional de-icing applications to maintain “ice free” in cold regions
- Recommended not to be used in areas of high, shear turning and slow moving traffic
  - High, shear turning may cause shoving-type failures
  - Slow moving traffic may clog porous structure

Wet Weather Accidents - TxDOT

	Before OGFC			After	
Year	**2001**	**2002**	**2003**	**2004**	**% Change**
Total # Accidents	**29**	**51**	**44**	**17**	**-58.9**
Dry Weather Accidents	**10**	**23**	**13**	**15**	**-2.2**
Wet Weather Accidents	**19**	**28**	**21**	**2**	**-91.2**
Fatalities	**0**	**1**	**5**	**0**	**-100**
Total Injuries	**25**	**16**	**21**	**0**	**-100**
Annual Rainfall (in)	**42.9**	**36.0**	**21.4**	**52.0**	**55.5**
Total Rain Days	**57**	**56**	**37**	**70**	**40.0**

Reduction in Splash and Spray

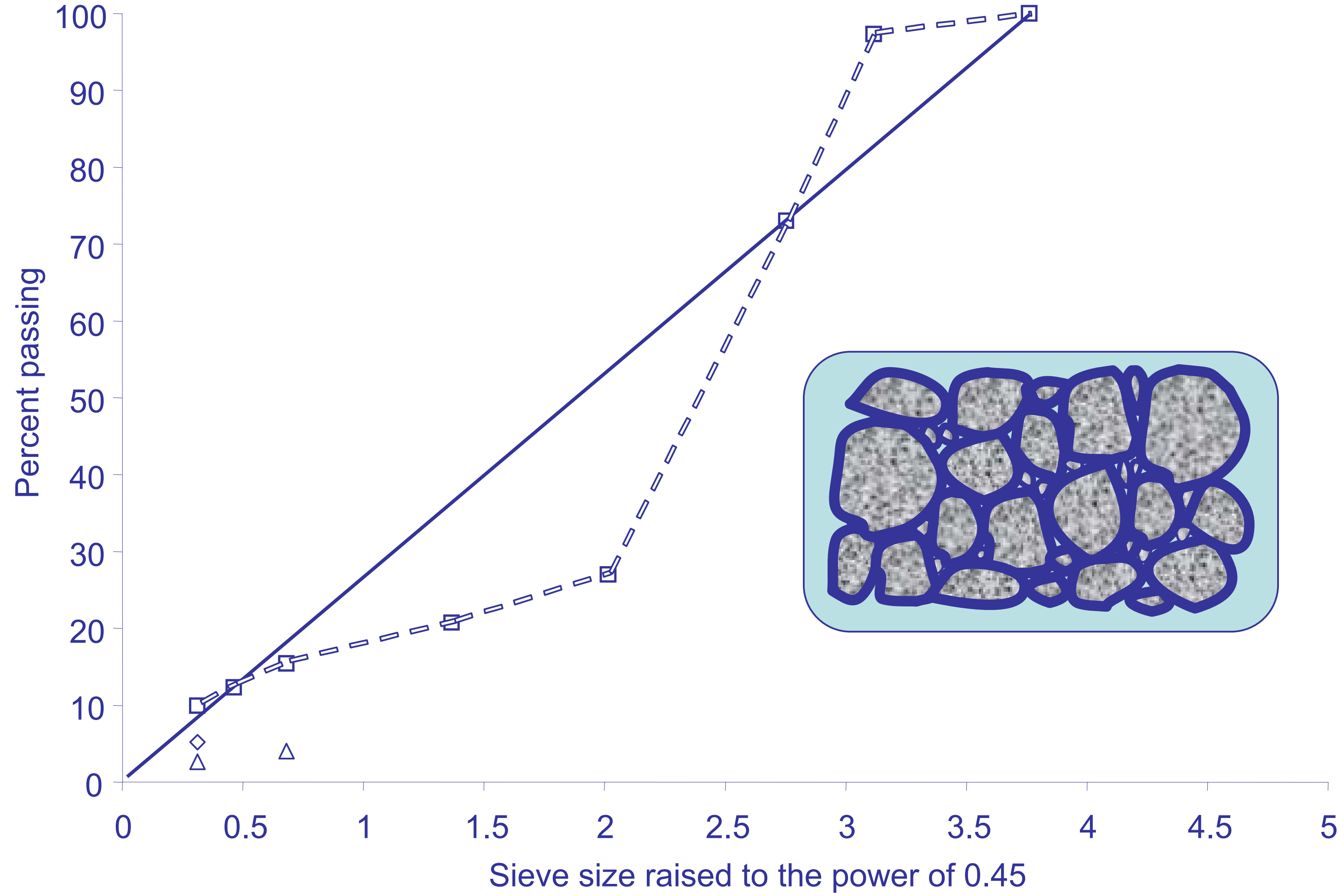
Reduced Pavement-Related Noise

Surface Type	dB(A)
OGFC	97.2
Novachip®	98.8
9.5 mm SMA	98.0
12.5 mm SMA	100.5
Micro-Surfacing	98.8
12.5 mm SP	97.8

Stone Matrix (Mastic) Asphalt

SMA

Stone Mastic (Matrix) Asphalt (SMA) or Gap-Graded Mixtures



SMA Mixtures

- Used as a wearing course (e.g., SMA)
- Mix design methods:
  - AASHTO R46-08, Designing Stone Matrix Asphalt (SMA)
  - Some states have variations of AASHTO R46
- Binder content: typically 5 to 7%
  - Polymer-modified binder and fibers used to minimize draindown
- Compacted air void content: typically 6 to 8%

SMA Materials

- Usually use locally available aggregates:
  - Cubical and tough
  - Modified (lime, antistrip liquids)
- Usually use locally available binders:
  - Modified

SMA Advantages

- Good aggregate interlock
- Low permeability
- Strength and stiffness derived from binder and aggregate structure
- Relatively high binder contents provide good durability
- Best used in areas of heavy traffic where rutting and fatigue cracking are concerns

SMA Disadvantages

- Asphalt suppliers not accustomed to producing – some "growing pains"
- Additional time and effort in material production
  – Aggregates!
- Typically use a modified binder (higher cost)
  – Costs typically prohibit use in "normal" traffic areas

Designing with Asphalt Rubber

Asphalt Rubber Applications

- Asphalt rubber is the process of adding recycled, crumb rubber to hot mix asphalt (called dry process) or the asphalt binder (called wet process) to modify the final mixture
- Difficult to use in dense-graded mixtures due to residual crumb rubber
- Best used in gap-graded type mixtures (SMA and OGFC)

Why Put Tire Rubber in Asphalt?

Tire rubber is an engineering tool to:

- Reduce cracking
- Naturally increase asphalt content and asphalt film thickness (providing an increase in durability)
- High asphalt binder viscosity prevents bleeding, flushing and drain-down
- Asphalt enhancement due to rubber increases both the high and low temperature performance
- Limited research has shown the addition of rubber also reduces pavement-related noise

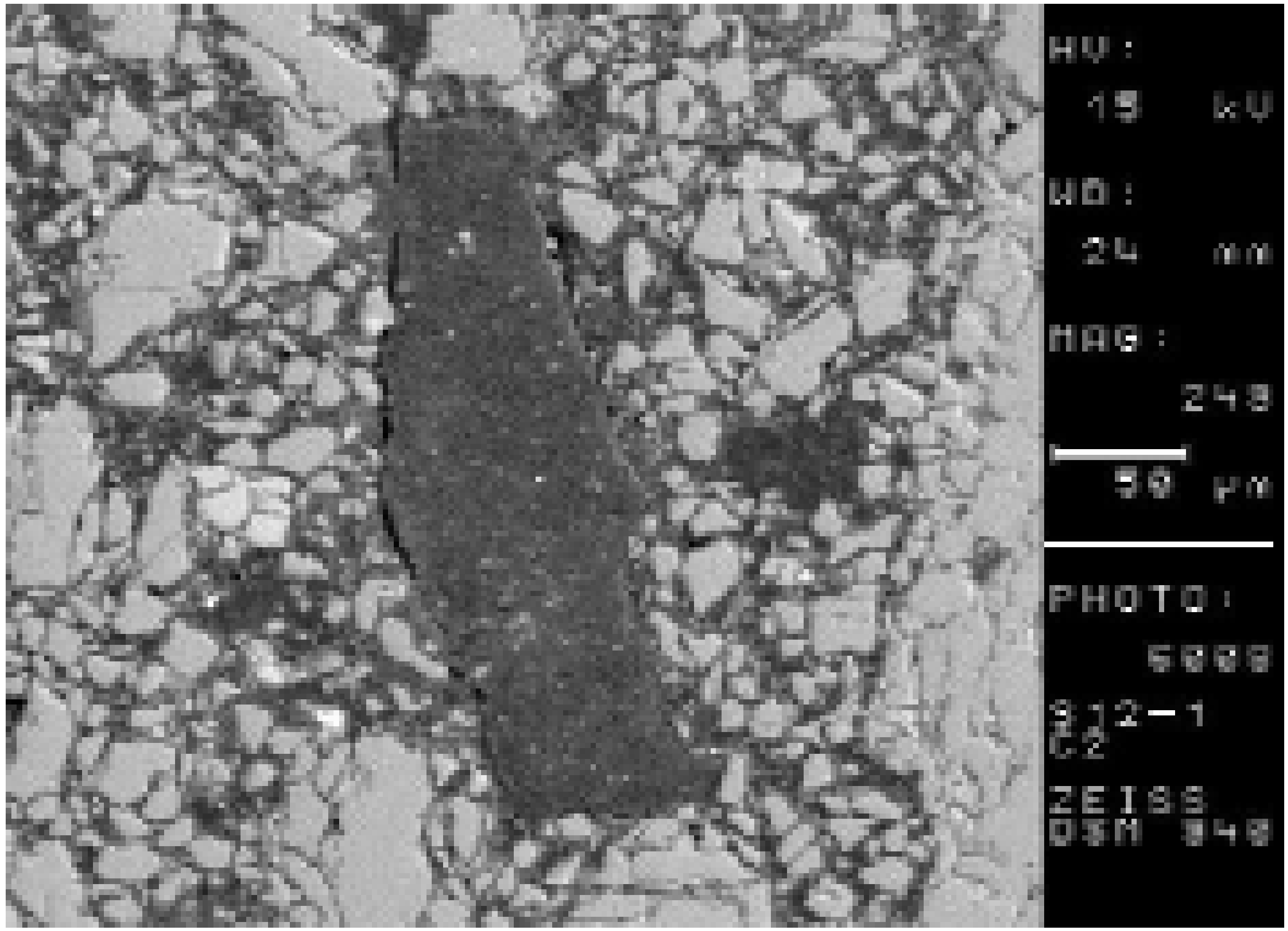
AR-OGFC Uses Approximately 1000 Tires Per Lane-Mile

What Defines Asphalt Rubber?

ASTM D6114

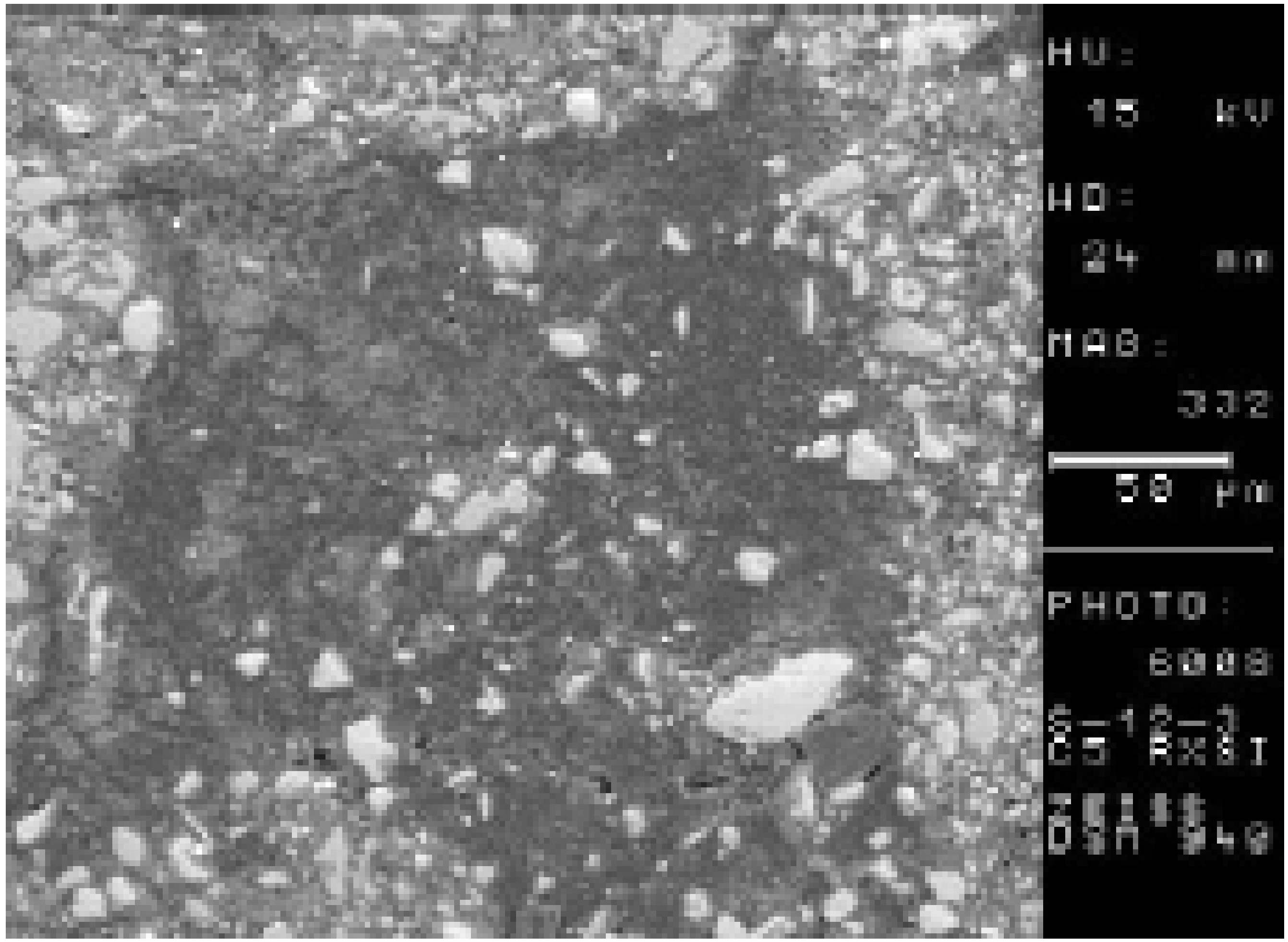
- Asphalt rubber is a blend of asphalt cement, reclaimed tire rubber and certain additives, in which the rubber component is at least 15% by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles

Swelling of Crumb Rubber



Electron-microscope: Immediately after mixing (dry process)

Swelling of Crumb Rubber (cont.)



Electron-microscope: 2 hours after mixing (dry process)

Asphalt Rubber

Methods of adding rubber to asphalt

- Wet Process – rubber is added to the liquid asphalt binder before being mixed at the hot mix asphalt plant (i.e., rubber is wet before mixing)
- Dry Process – rubber is added at the same time the asphalt and aggregate are mixed (i.e., rubber is dry before mixing)

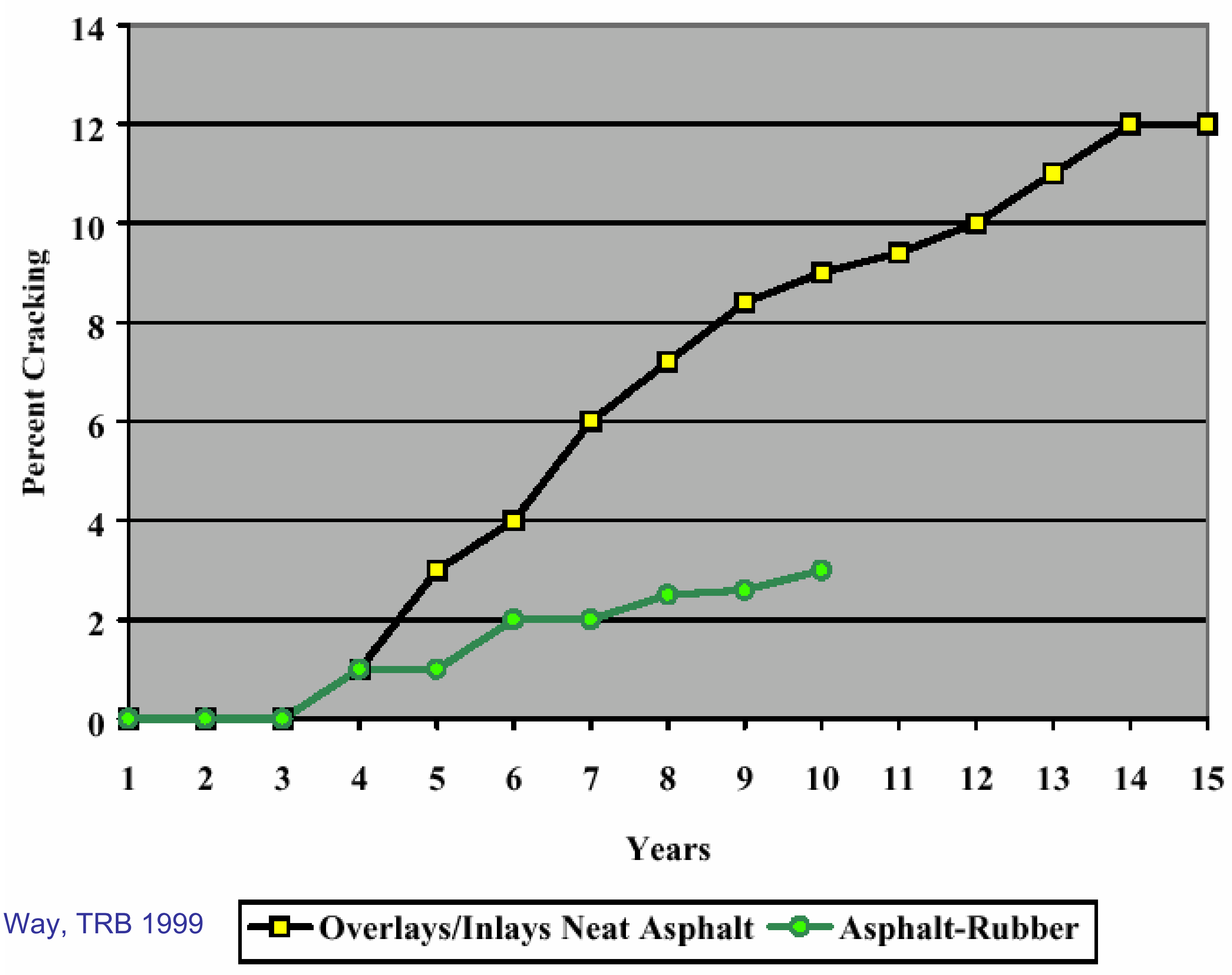
Designing with Asphalt Rubber

- If wet process, previous SMA and OGFC design procedures can be used
  - Some state agencies utilize the “Arizona” method
- Only exception is evaluating compatibility and modification of crumb rubber with proposed base asphalt binder

Asphalt Rubber Binder

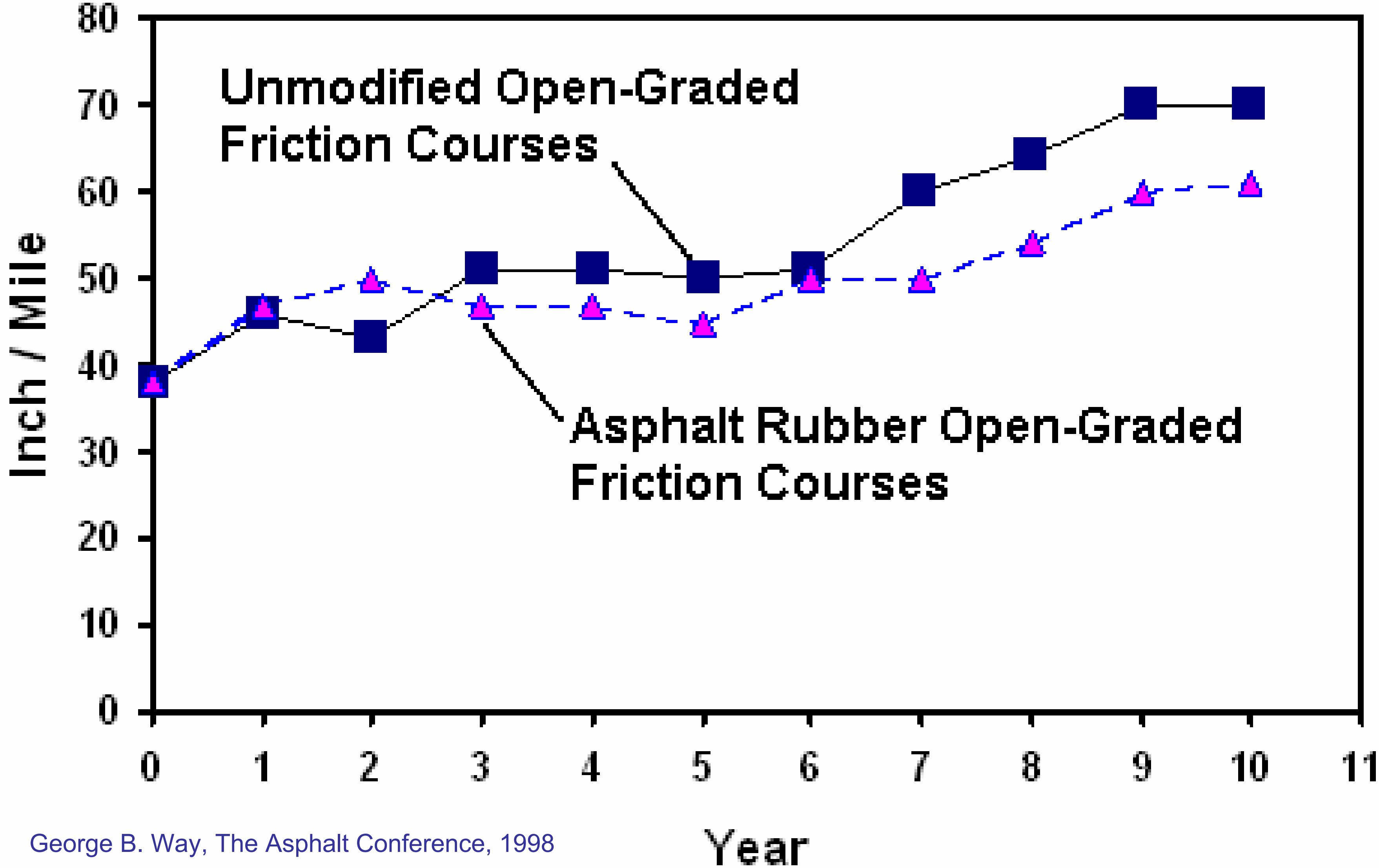
- Brookfield viscosity
- Resilience (ASTM D5329)
- Softening point
- Penetration
- Ductility

Fatigue Cracking Resistance of Asphalt Rubber Mixtures vs. Conventional Mixtures



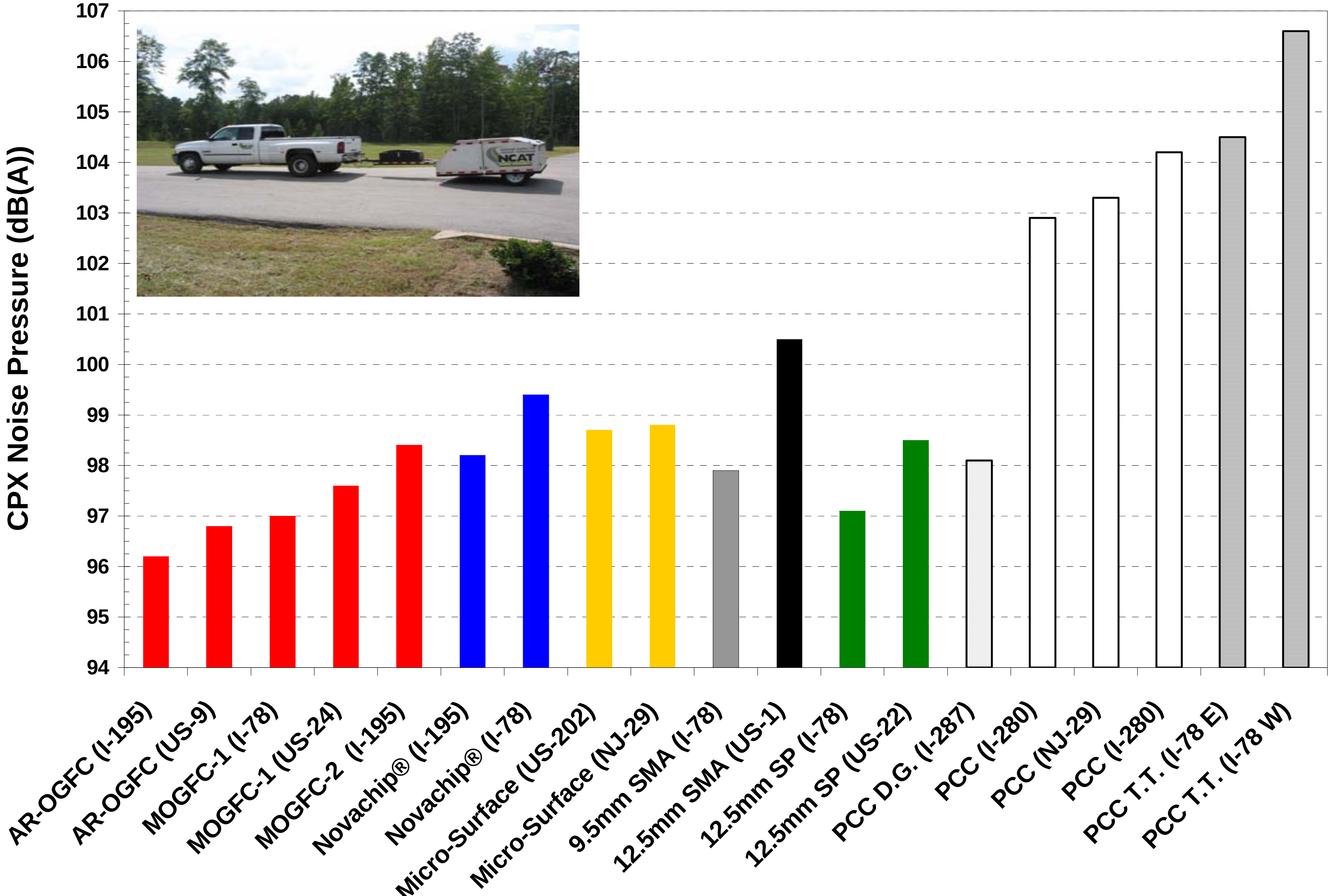
George B. Way, TRB 1999

AR-OGFC vs. Unmodified OGFC



George B. Way, The Asphalt Conference, 1998

Tire/Pavement Noise Results



(Bennert et al., 2005)