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Hot Mix Asphalt Materials
and
Mix Design for Airfield Pavements

By V. Aurilio

Asphalt Institute

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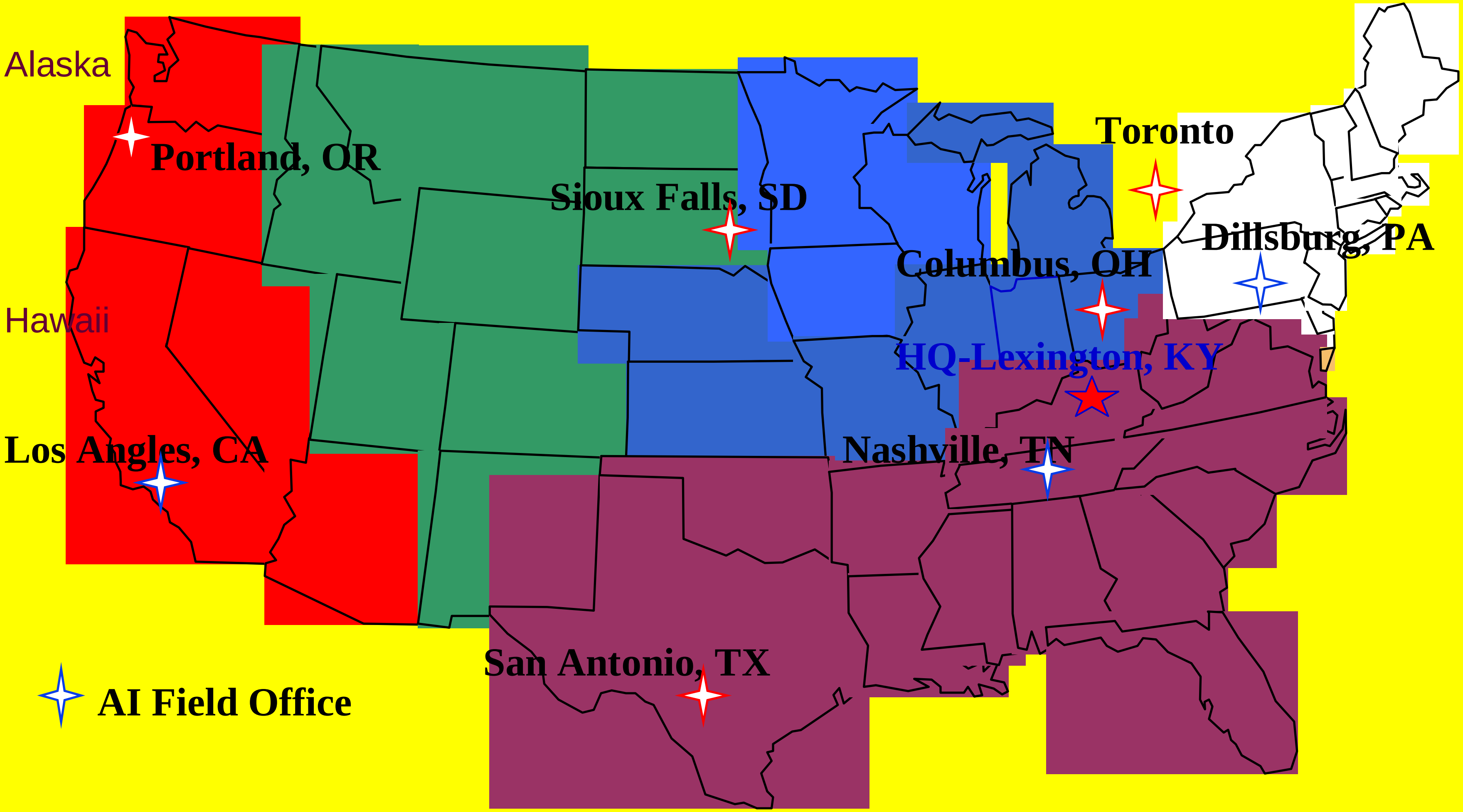
US-based **association** of international asphalt **producers, manufacturers**, and **affiliated** businesses.

AI’s Mission

- Is To Promote Asphalt:
  - Usage
  - Benefits
  - Quality performance
- Emphasizing
  - Education,
  - Research,
  - Engineering,
  - Technical Development
  - Resolution Of Issues

Asphalt Institute Field Engineer Offices



AI Background

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- Formed back in 1919. Now in its 86th year
  - 102 different ways to specify liquid asphalt
  - 9 penetration grades
- Today
  - Has about 90 member companies.
  - That produce 95% of the asphalt in the US.

ASPHALT INSTITUTE MEMBER COMPANIES

ASPHALT INSTITUTE AFFILIATE MEMBERS

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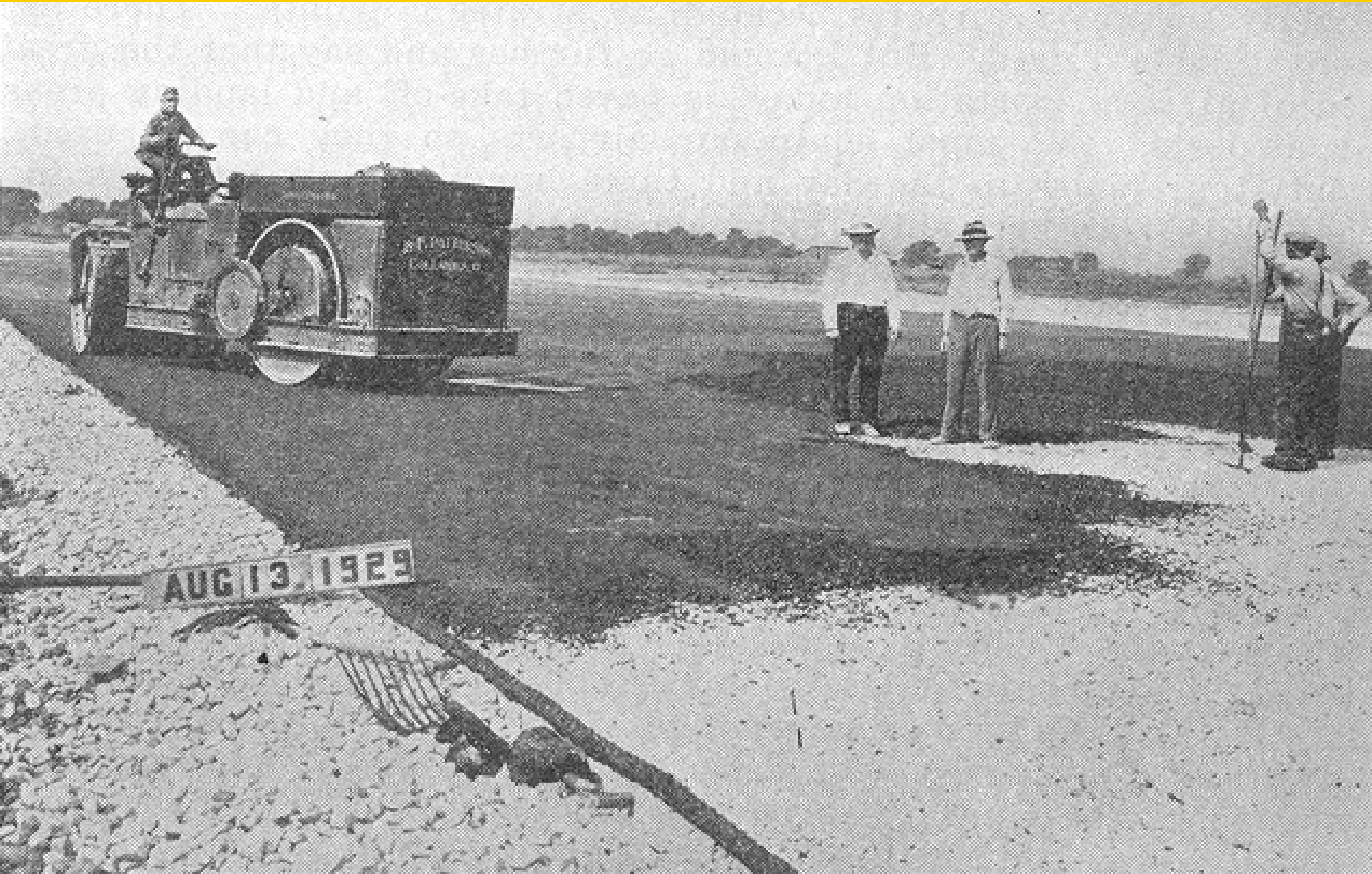
Airfields and Asphalt



Airfields and Asphalt

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Washington National Airport, Built in 1939

- AI worked closely with USACOE
- More than 1 Million SYs HMA

Airfields and Asphalt

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PERPETUAL PAVEMENT AWARD

- **Recognizes in-service long-life asphalt pavements with no structural problems.**
- **Minimum Requirements**
  - **Age: at least 35 years**
  - **Avg. resurfacing interval > 12 yrs**
  - **No structural failures**
  - **Minimal maintenance through life**
  - **If highway, length > 5 miles**
- **Award Considerations**
  - **Resurfacing/ maintenance/ traffic history**

Baltimore Washington International Runways 15/33 and 10/28

- Constructed in 1948
- 317,000 annual operations in 2000
- Overlaid in'64, '73, and '87
    - All overlays: less than 4 inches
    - Average resurfacing interval: 14 years
- No structural failure throughout life
- Perpetual Pavement Award Winner for 2002

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Airfields and Asphalt

- Eareckson A.S. Runway: West tip of Aleutian Islands
- Precip: 250 days/yr. Supports Heavy Traffic (350K lbs)

- Photo during last overlay (2”), 1976. Same surface today.
- No major maintenance or repairs since.
- First project to use COE’s *Pay for Performance* spec.

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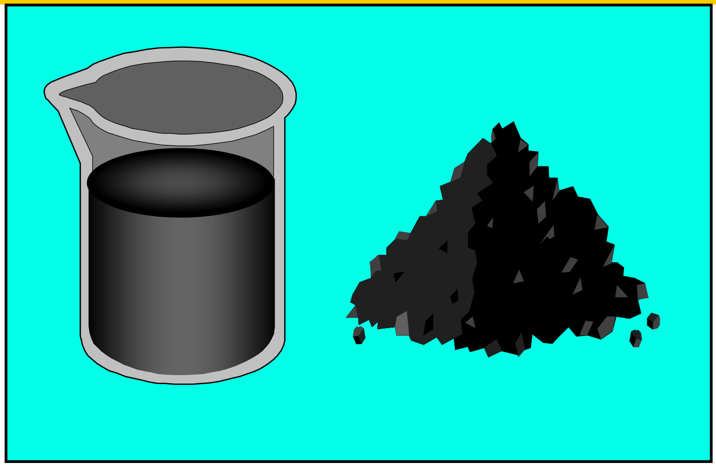
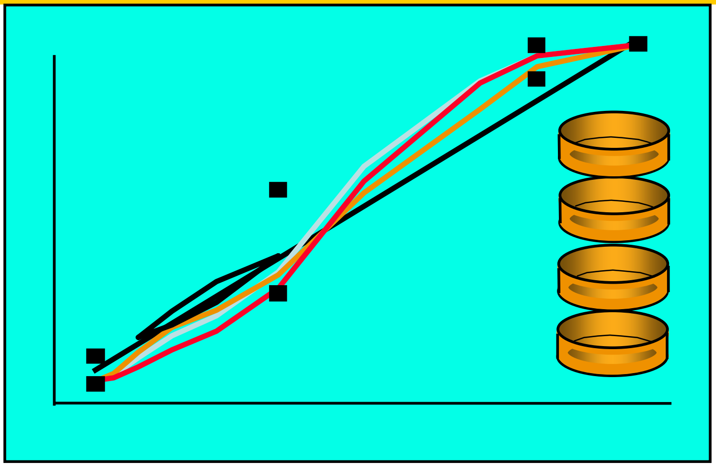
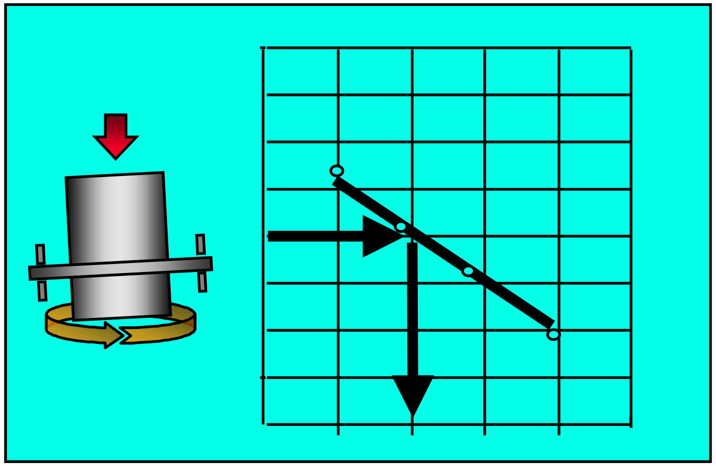
Mix Design Process



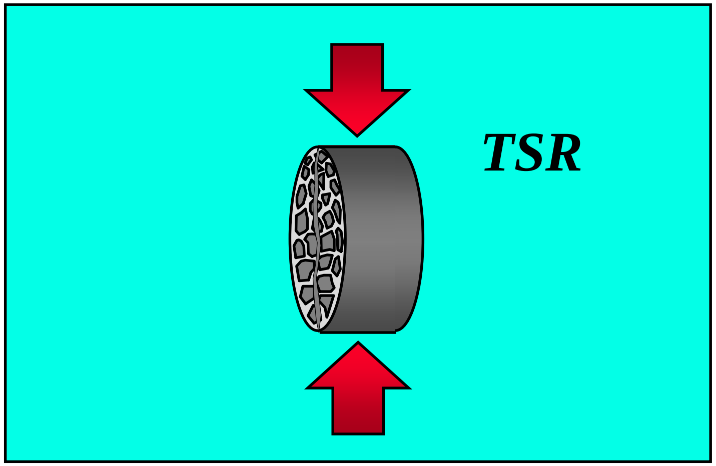
1. Materials Selection



2. Design Aggregate Structure



3. Design Binder Content



4. Moisture Sensitivity

Asphalt Binders: Specifications and Selection

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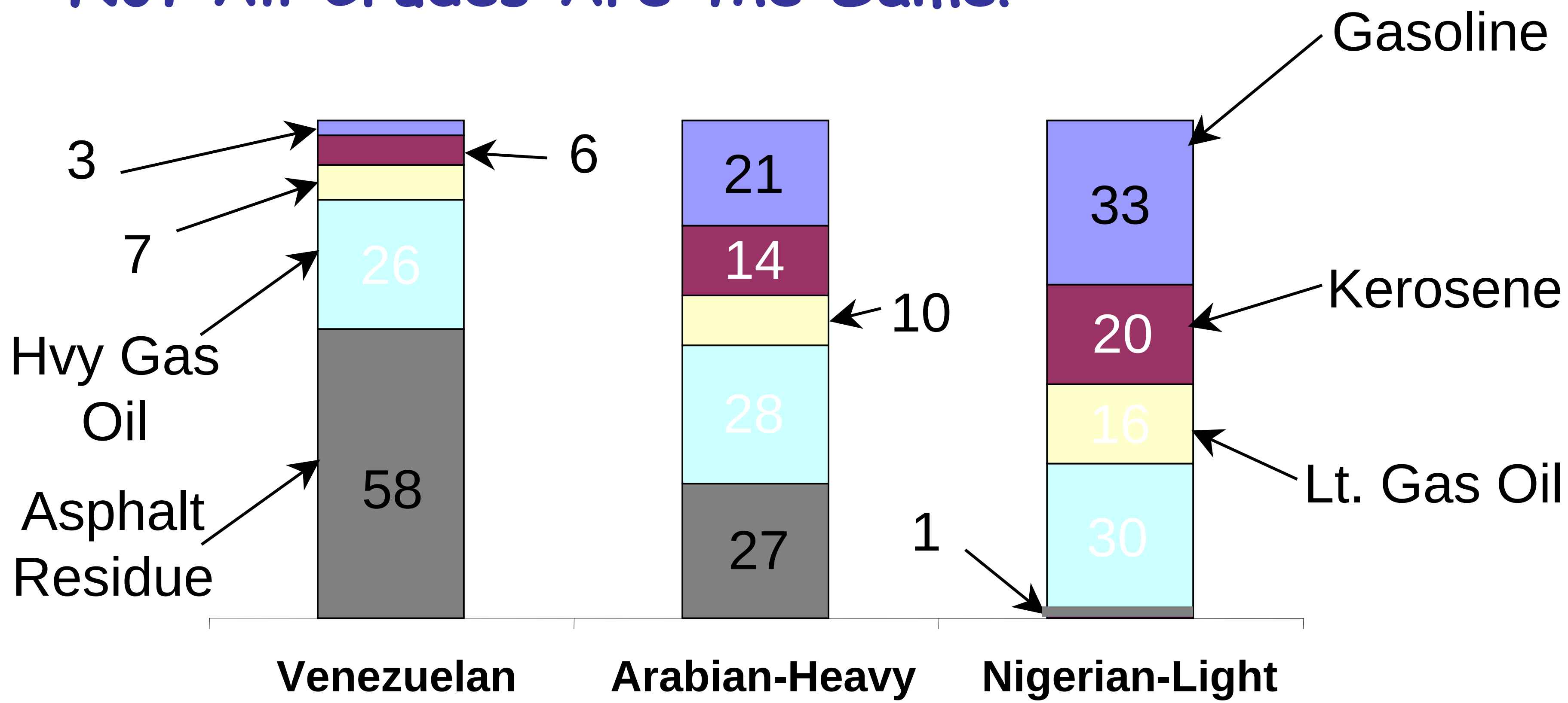
Not All Crudes Are the Same!



Some Typical Crude Make Ups

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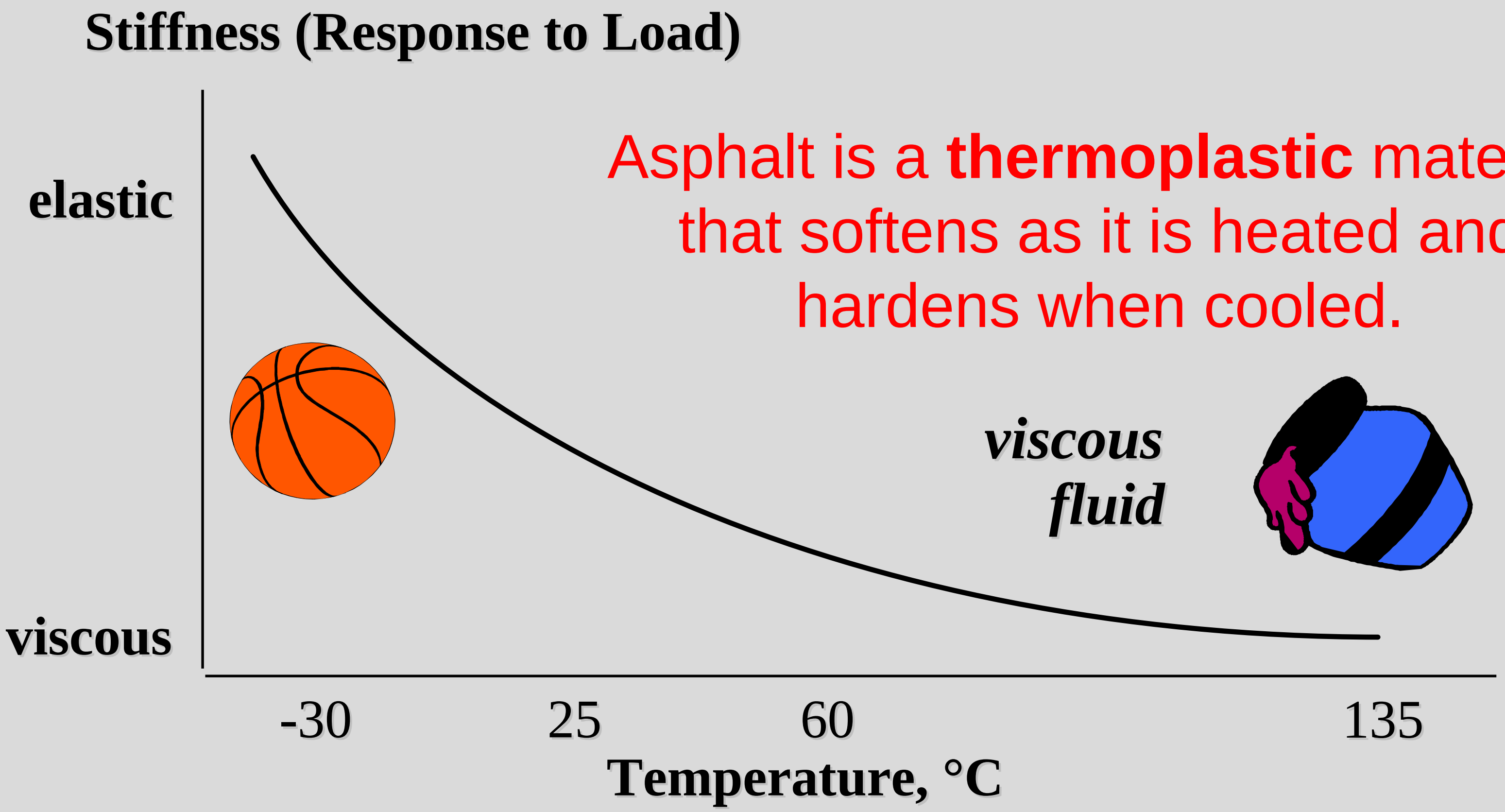
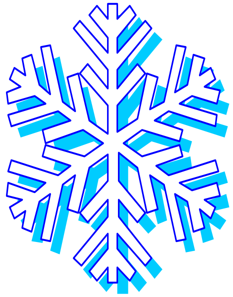
Asphalt Binder Selection

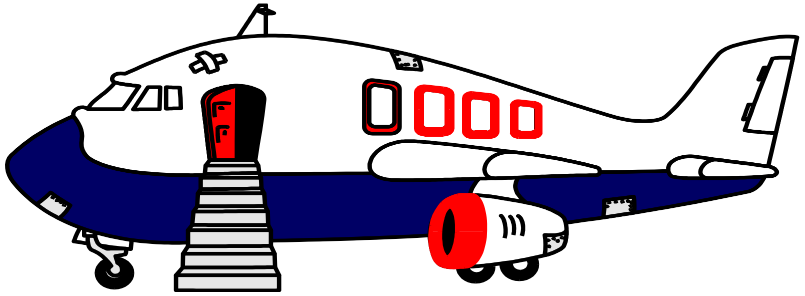


Stiffness vs. Temperature

Asphalt Binder Selection

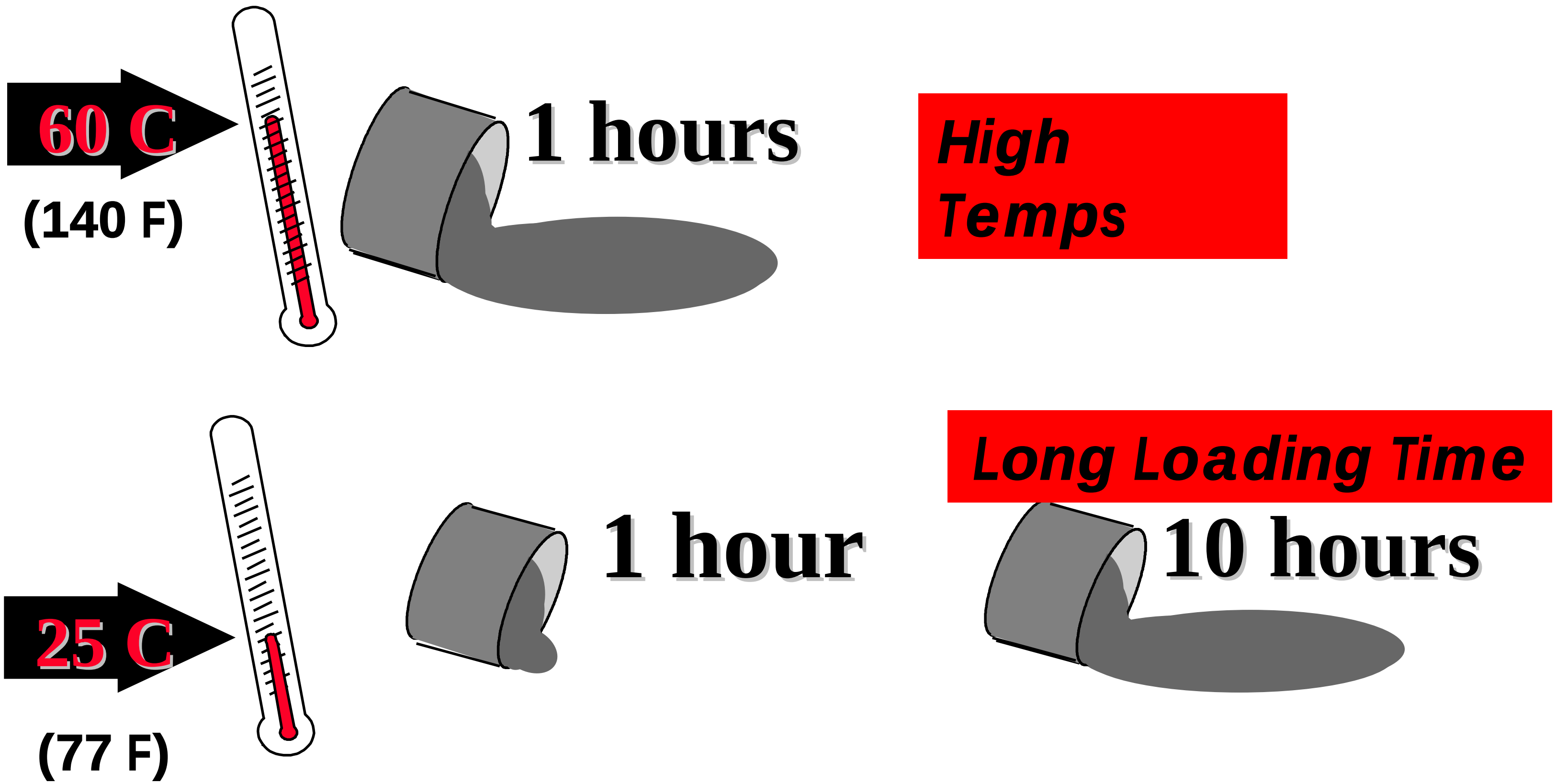
- **Temperature**
- **Magnitude of Load**
- **Time of Loading**
- **Aging**





Asphalt Binder Selection

Loading Time vs. Temperature



Asphalt Binder Selection

High Temperature Behavior

- **Summer Climates**
- **High Tire Pressures**
- **Long Loading Times**
  - **slow or standing aircraft**
  - **aprons**

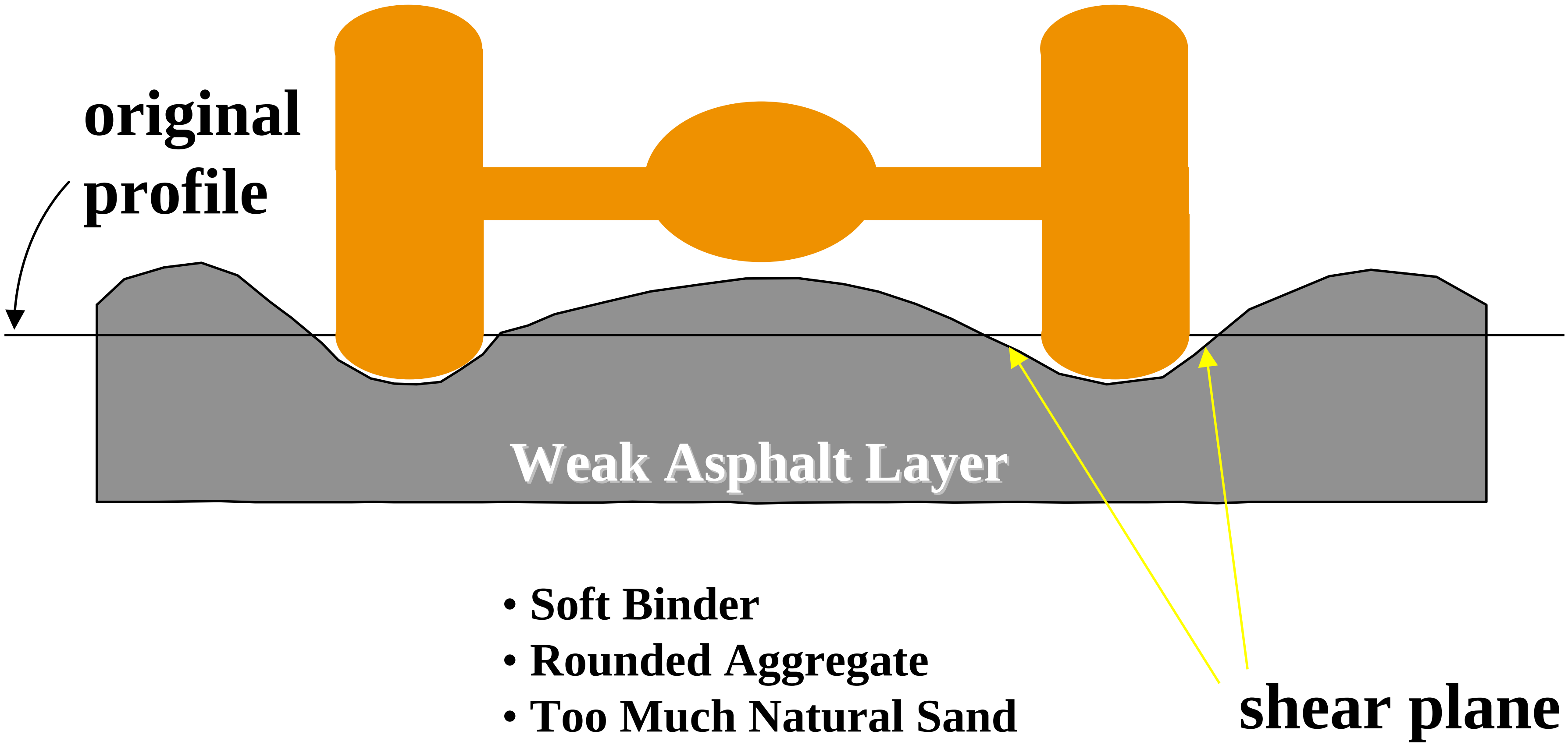
Binder acts like a viscous liquid

•Insufficient mix stability

•Pavement deformation

Asphalt Binder Selection

Plastic Flow



- Soft Binder
- Rounded Aggregate
- Too Much Natural Sand
- Excessive Binder (Low Air Voids)

Heavy Loads
Payload up to: 150 metric tons

Antonov An 124

The Problem?

Looking south on Taxi A at AD

Performance?

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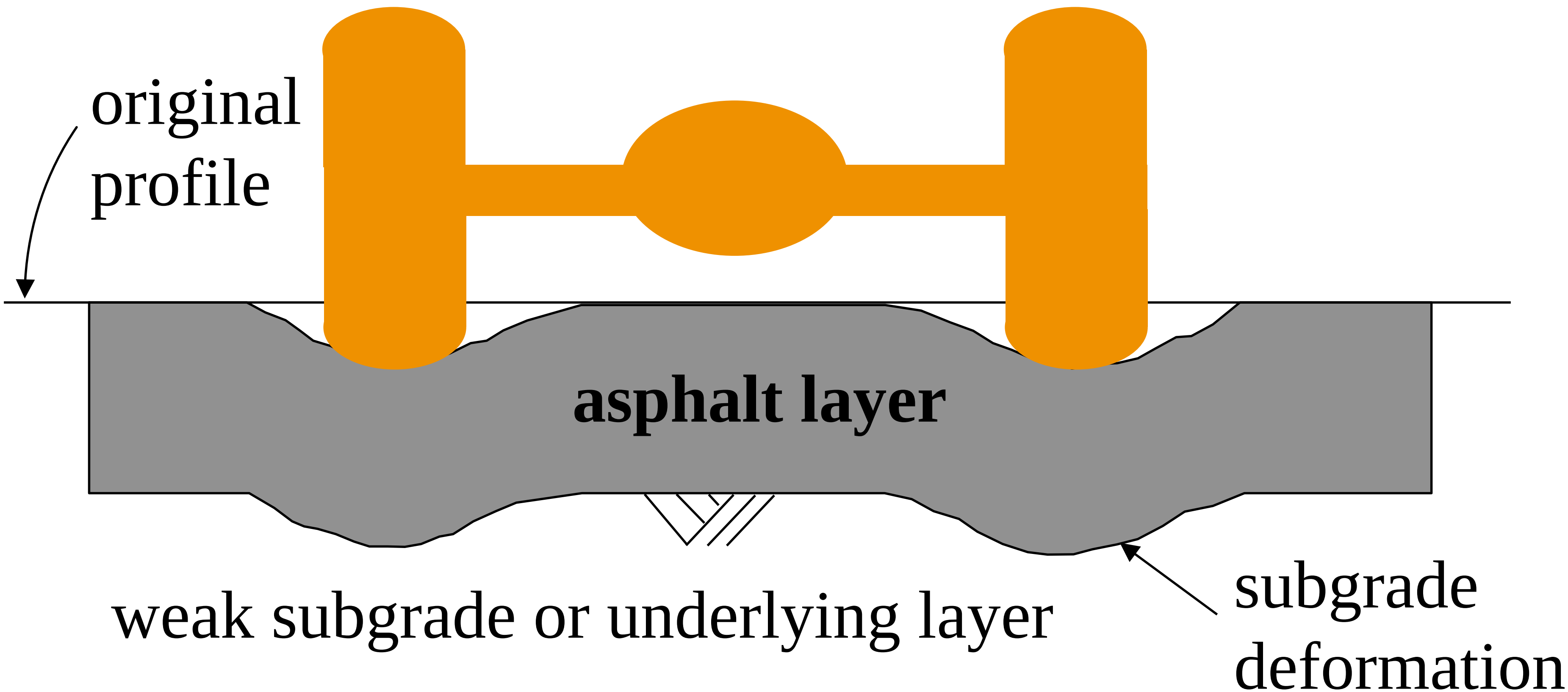
Rutting in Subgrade or Base



Asphalt Binder Selection

To Prevent Rutting

- Asphalt Binder
  - Adequate stiffness
    - high temperatures
    - tire pressures
    - loading conditions
- Aggregate
- Mix Design
- Compaction
- Structure

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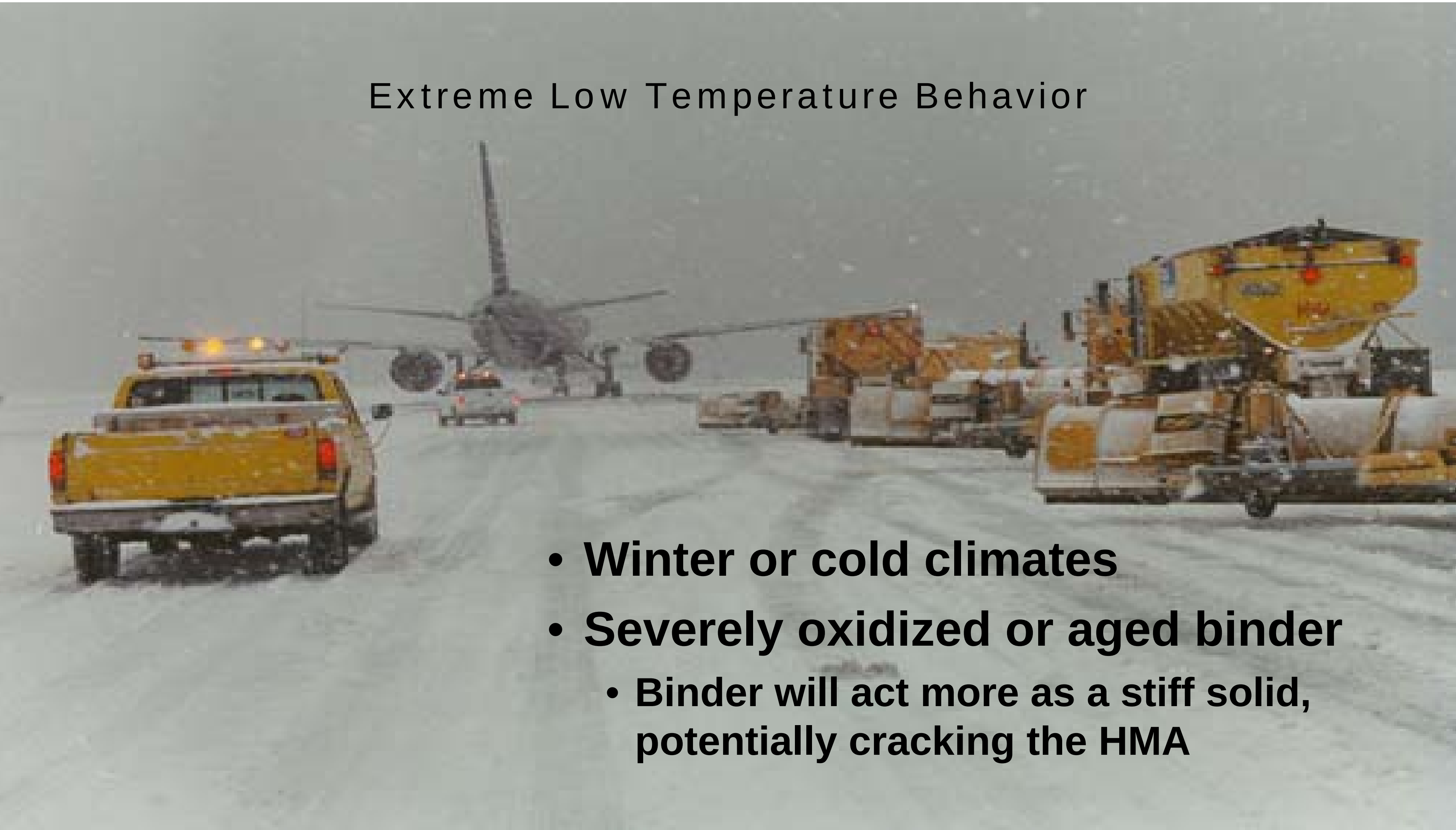
Asphalt Binder Selection

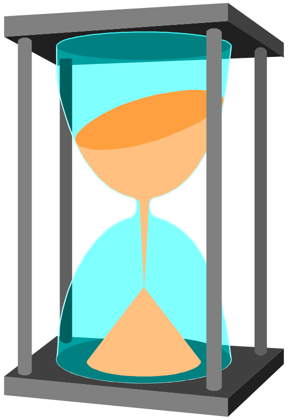


Extreme Low Temperature Behavior

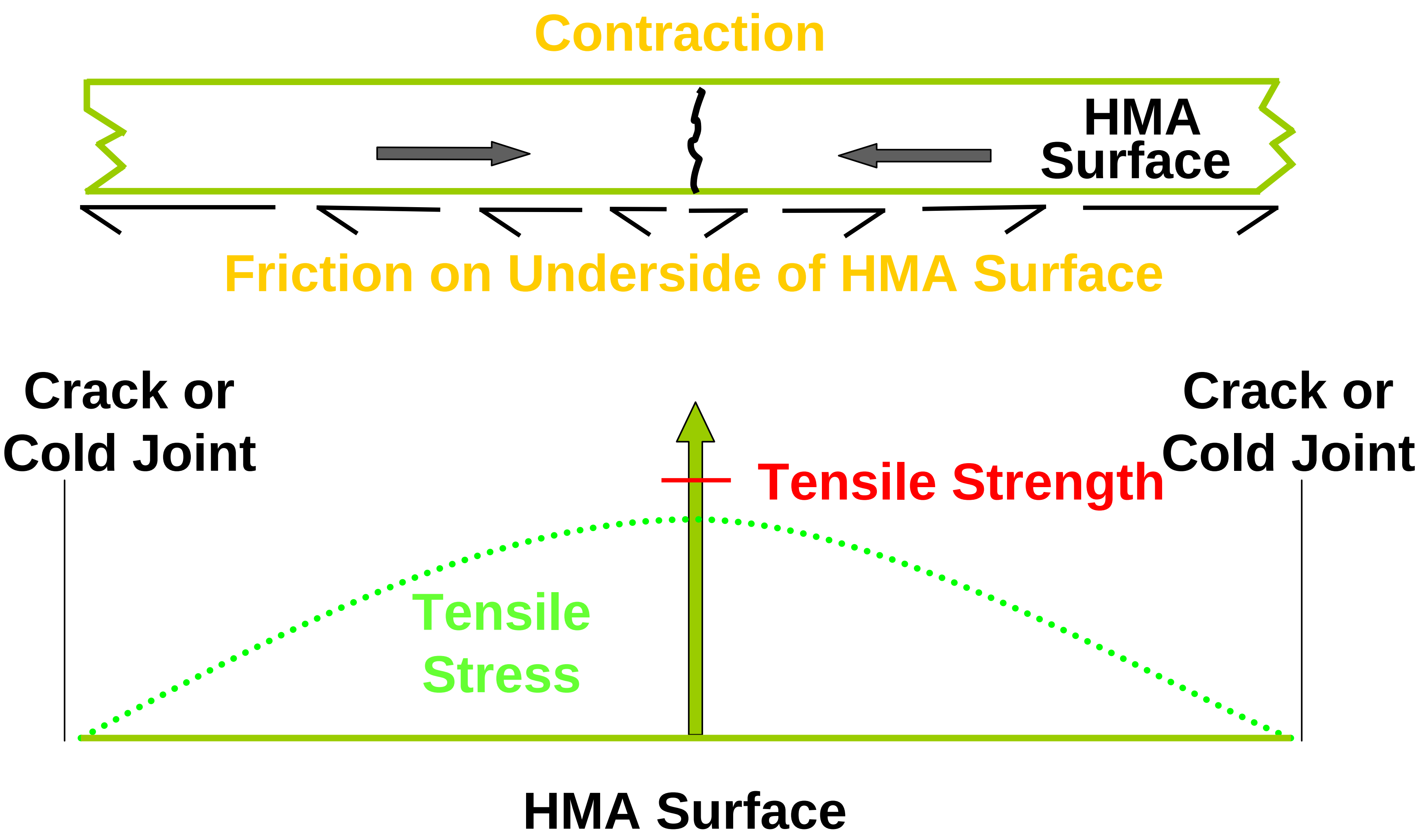
- **Winter or cold climates**
- **Severely oxidized or aged binder**
  - **Binder will act more as a stiff solid, potentially cracking the HMA**

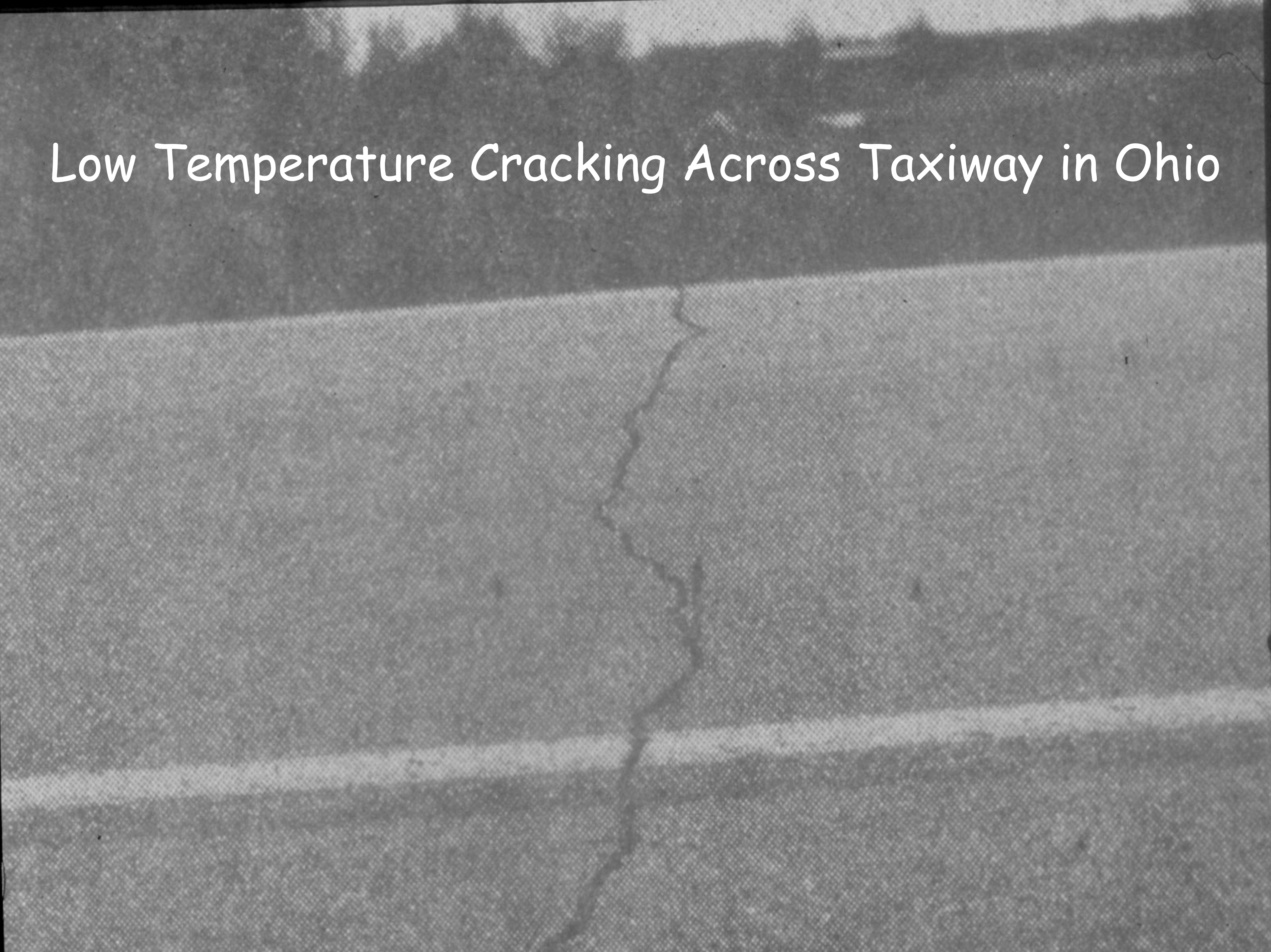
Asphalt Binder Selection

- **Asphalt Reacts with Oxygen**
  - **“oxidize” or “age-hardening”**
- **During Construction - Short Term**
  - **volatiles evaporate**
  - **hot mixing, placing, and compaction**
- **In Service - Long Term**
  - **hot climate worse than cool climate**
  - **summer worse than winter**



Thermal Cracking Mechanism




Low Temperature Cracking Across Taxiway in Ohio

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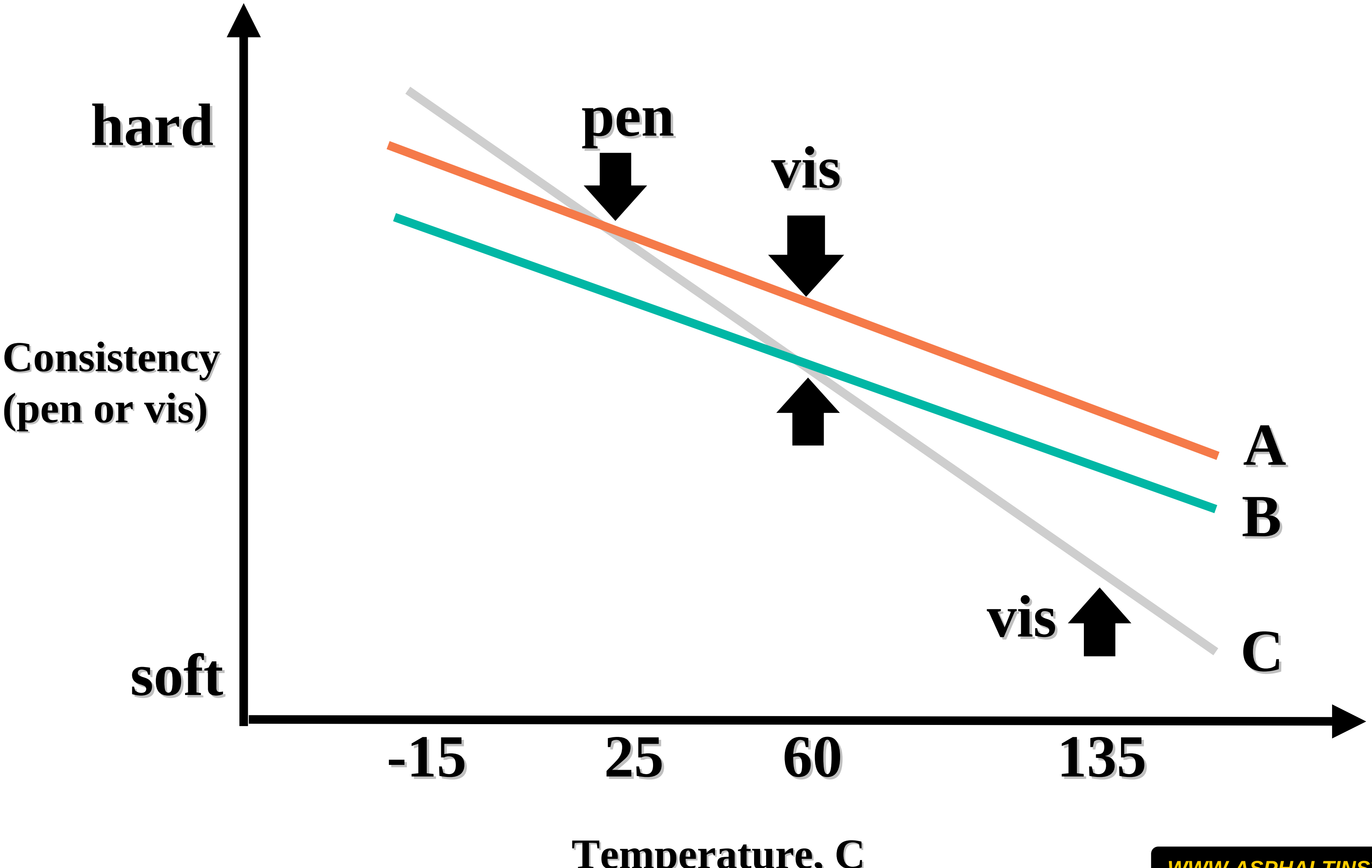
Block Cracking

Cracking on Airfield Pavement Surfaces Leads to Foreign Object Debris (FOD)

To Prevent Cracking

- **Asphalt Binder**
  - **Adequate low-temperature properties**
    - **Soft and elastic at low temps.**
    - **Relaxation of stresses**
    - **Less prone to aging**
- **Mix Design**
- **Compaction - Good Construction Practices**
- **Pavement Structure**

Three Asphalts with Same Viscosity Grade



Pre-Superpave Shortcomings

- **Penetration**
  - **empirical measure of hardness only at one temp.**
- **Viscosity**
  - **viscous effects only**
- **No Low Temperature Properties Measured**
- **Problems with Modified Asphalt Characterization**
- **Specification Proliferation**
- **Long Term Aging not Considered**

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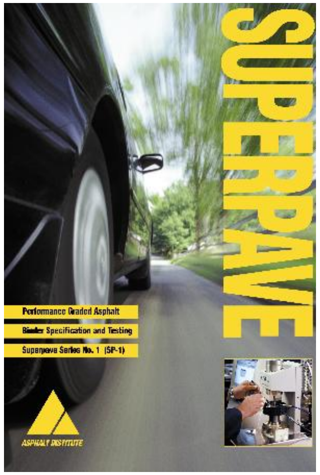
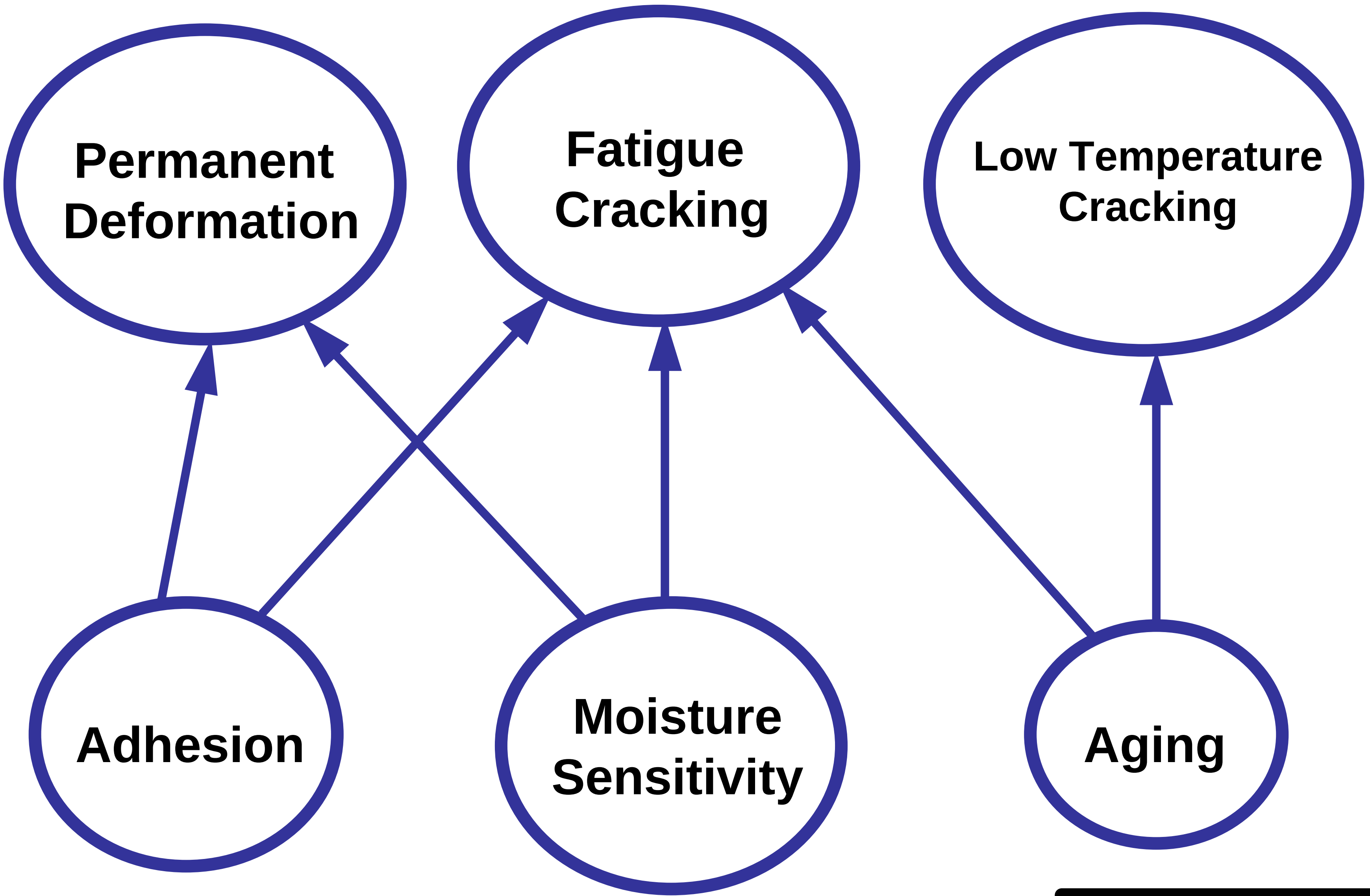
What is SUPERPAVE?

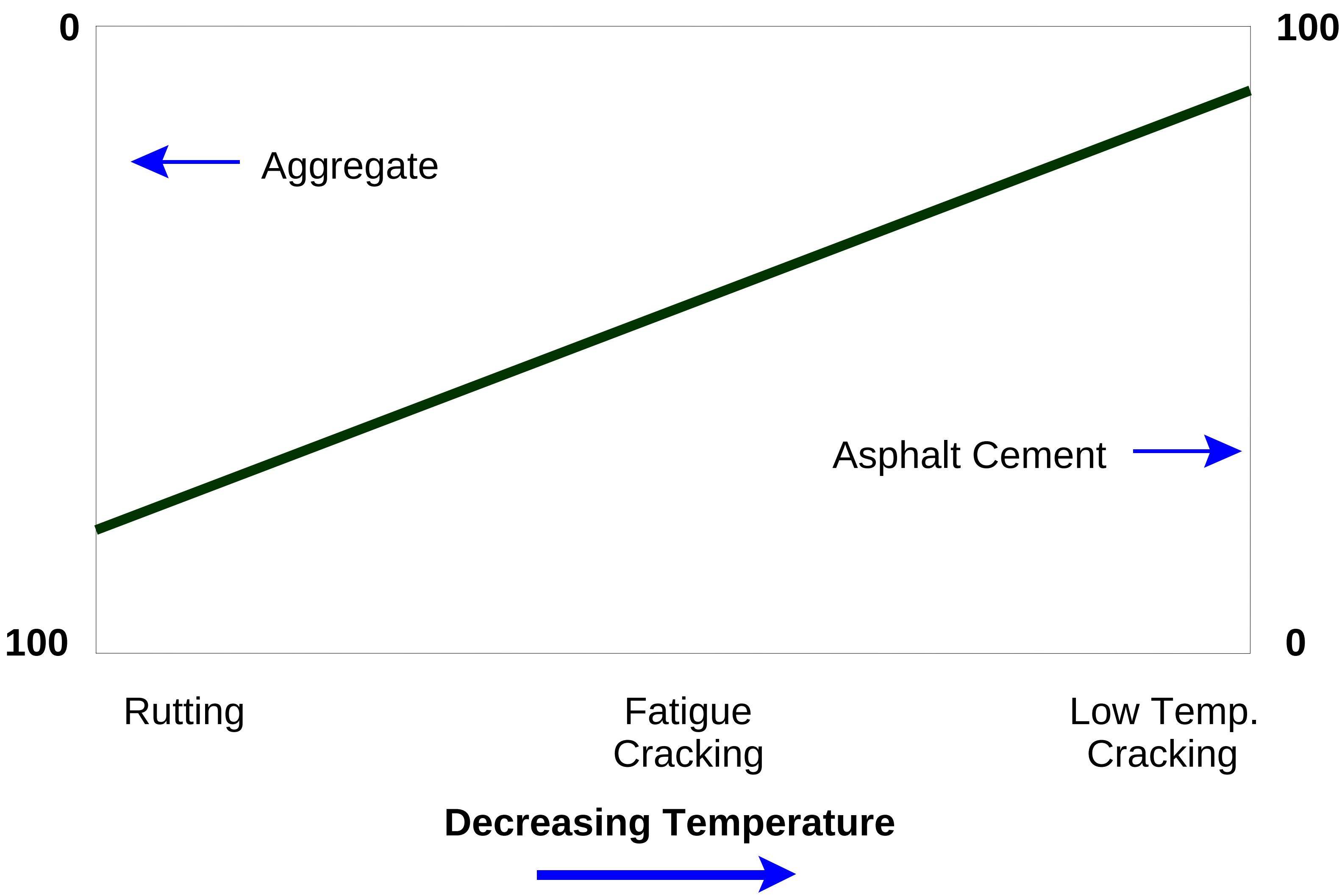


- New Asphalt Binder grading system and specification
- New Mix Design procedure using a new laboratory compaction device

Performance Relationships



Asphalt Cement and Aggregate Contribution to Pavement Performance



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Superpave Asphalt Binder Spec

Grading System Based on Climate

PG 64-22

Performance Grade → PG

Average 7-day max pavement design temp → 64

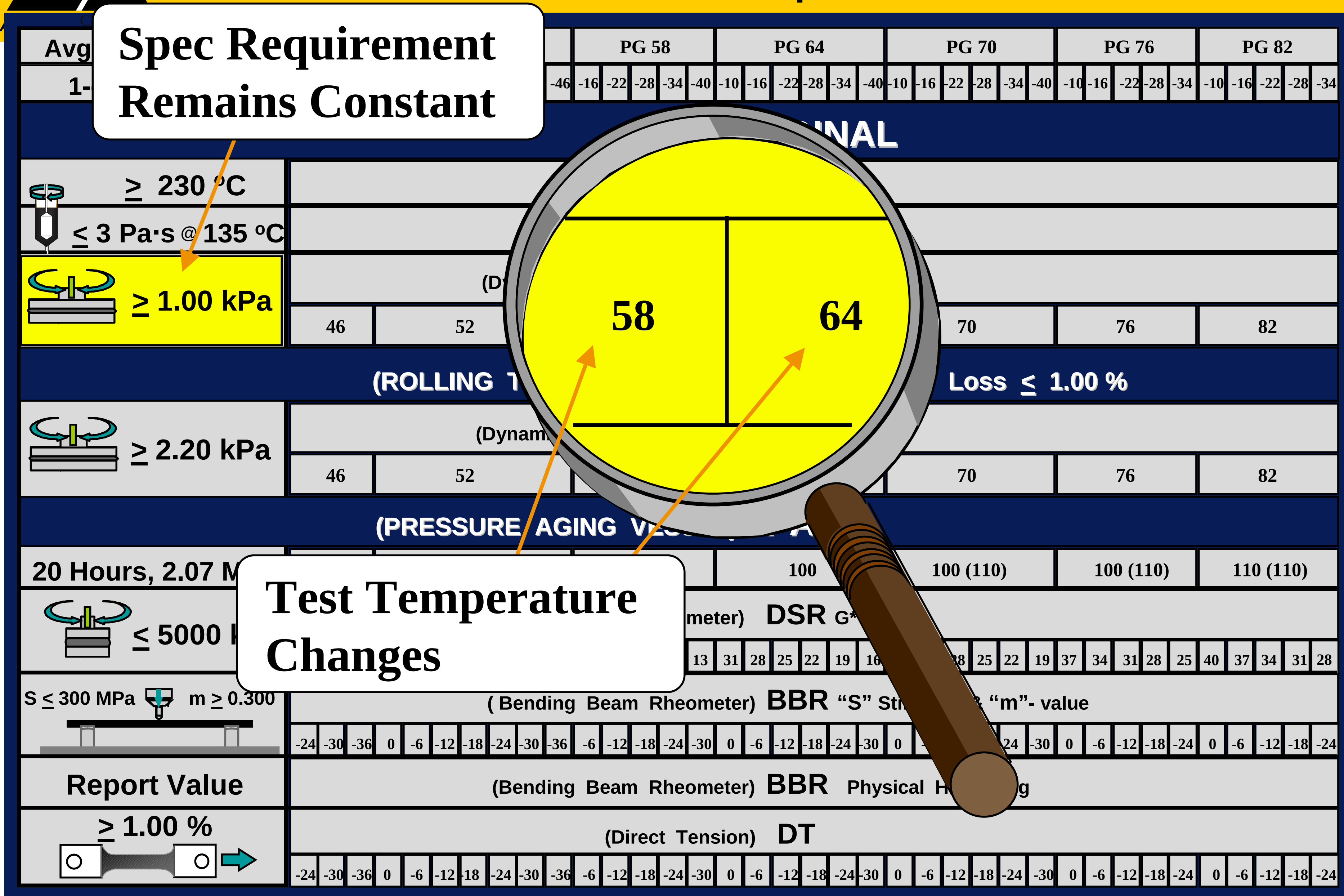
Min pavement design temp → 22

Performance Grades

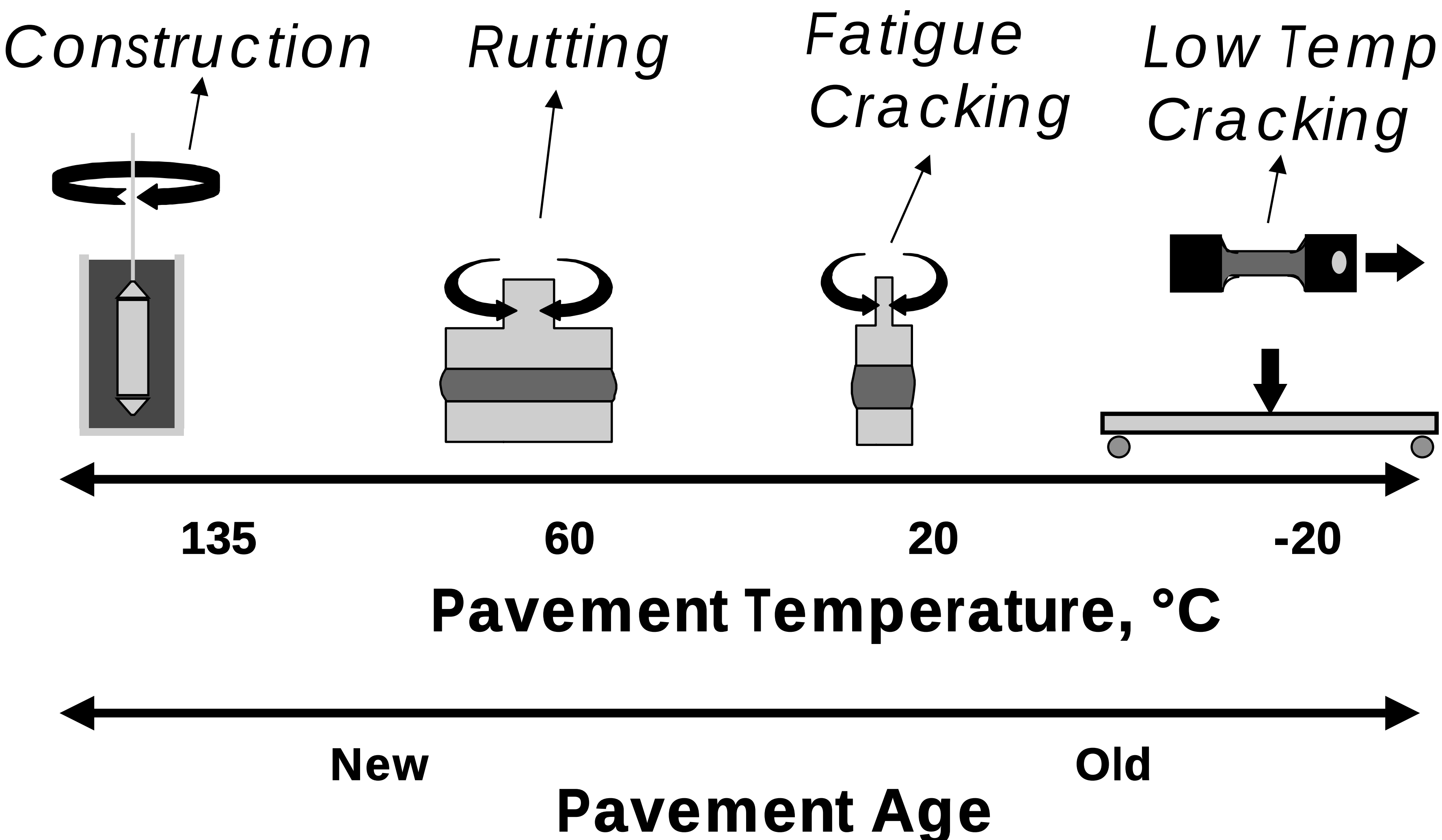
CEC

Avg 7-day Max, °C	PG 46	PG 52	PG 58	PG 64	PG 70	PG 76	PG 82
1-day Min, °C	-34 -40 -46	-10 -16 -22 -28 -34 -40 -46	-16 -22 -28 -34 -40	-10 -16 -22 -28 -34 -40	-10 -16 -22 -28 -34 -40	-10 -16 -22 -28 -34	-10 -16 -22 -28 -34
ORIGINAL							
≥ 230 °C — (Flash Point) FP							
≤ 3 Pa·s @ 135 °C — (Rotational Viscosity) RV							
≥ 1.00 kPa — (Dynamic Shear Rheometer) DSR G*/sin	46	52	58	64	70	76	82
(ROLLING THIN FILM OVEN) RTFO Mass Loss ≤ 1.00 %							
≥ 2.20 kPa — (Dynamic Shear Rheometer) DSR G*/sin	46	52	58	64	70	76	82
(PRESSURE AGING VESSEL) PAV							
20 Hours, 2.07 MPa	90	90	100	100	100 (110)	100 (110)	110 (110)
≤ 5000 kPa — (Dynamic Shear Rheometer) DSR G* sin	10 7 4	25 22 19 16 13 10 7	25 22 19 16 13	31 28 25 22 19 16	34 31 28 25 22 19	37 34 31 28 25	40 37 34 31 28
S ≤ 300 MPa, m ≥ 0.300 — (Bending Beam Rheometer) BBR "S" Stiffness & "m"- value	-24 -30 -36	0 -6 -12 -18 -24 -30 -36	-6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24	0 -6 -12 -18 -24
Report Value — (Bending Beam Rheometer) BBR Physical Hardening							
≥ 1.00 % — (Direct Tension) DT	-24 -30 -36	0 -6 -12 -18 -24 -30 -36	-6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24 -30	0 -6 -12 -18 -24	0 -6 -12 -18 -24

How the PG Spec Works

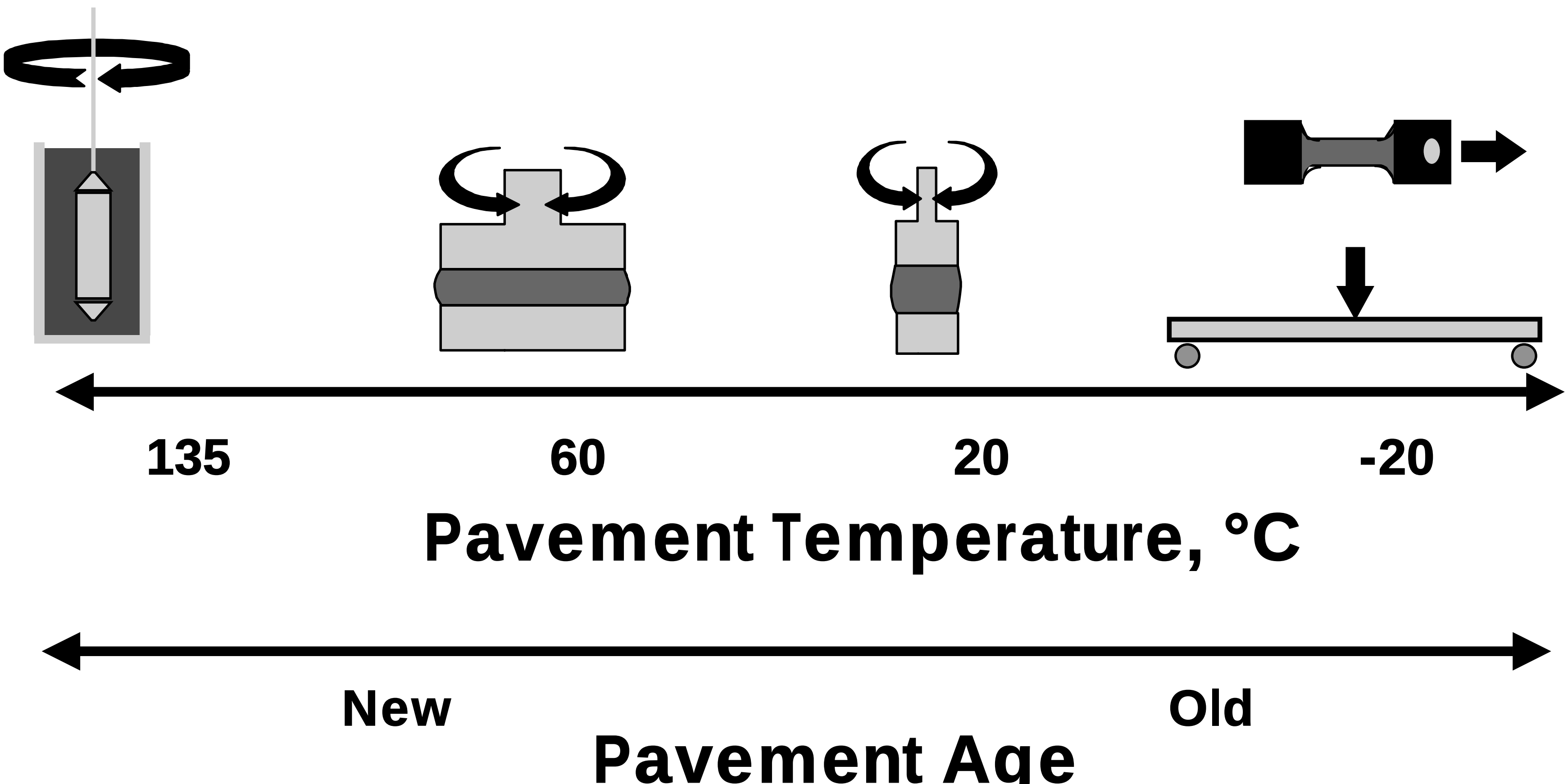


Superpave Performance Tests



Superpave Performance Tests

Determine Extreme Test Temperatures Under Which Criteria Are Met



Superpave Binder Equipment

Which PG should be used???

- Many factor to consider
  - Suggested grades from Superpave Weather Database
  - Amount and type of traffic loadings
  - Desired reliability
  - Reclaimed Asphalt Pavement (RAP) usage
  - Current available grades
  - Capabilities of binder suppliers
  - Typical types of distress in pavements
  - Binder costs

"Rule of 90"

PG 70 - 28 = 70 - - 28 = 98

Binder will be modified !!

PG 58 - 28 = 58 - - 28 = 86

Straight run or neat asphalt

(Depends on Asphalt Source!)

FAA and DoD General Guidelines for Binder Selection on Airfields

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➢ Consult with local agency specs

- **Determine grades that are typically being used and are available for the particular area**
- **Determine the "Standard Grade"**
  - **Typically used for highways with less than 10 million ESALs**
  - **Sufficient on most GA airports**
- **Consider 'Bumping' for top 4 inches <u>if</u> concerned:**
  - **High Temps or Rutting**
  - **Past performance?**
  - **High tire pressures?**
  - **Standing or slow traffic (stacking on TWs)?**
  - **Channelized traffic (alleyways)?**


Typical GA Aircraft
Raytheon King Air 200
Gross Take-off Weight 12,500 pounds

Grade Bumping Criteria - Airfields

Criteria used by DoD in UFGS 02749 --------------- Aircraft Tire Pressure (psi)	High Temperature Grade Bumps from "Standard Grade" for all Airfield Pavement Types (Runways, Taxiways, Aprons)	Criteria used by FAA in P401 (SP) ----------------- Aircraft Gross Weight (lbs)
< 100	0	< 12.5
100 – 200	0 - 1	12.5 – 100K
> 200	1 - 2	> 100,000

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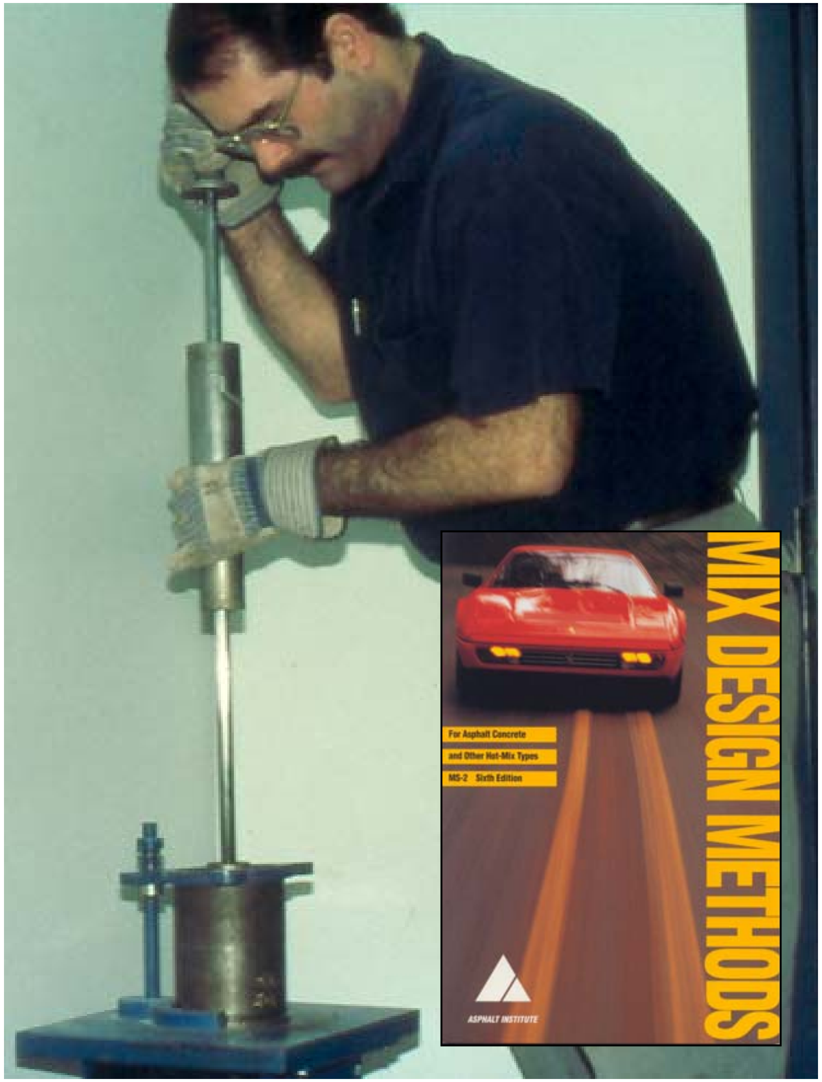
Grade Bumping Criteria - Airfields

- For Aircraft < 12,500 lbs PG 58-28
- For Aircraft < 100,000 lbs PG 64-28
- For Aircraft > 100,000 lbs PG 70-28
- Need to Consider Traffic Flow

Mix Design Objective

"…to determine the combination of asphalt cement and aggregate that will give long lasting performance…"



Asphalt Institute MS-2, *Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types*

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HOT MIX ASPHALT

- **Comprised of two ingredients:**
  - **Asphalt Cement ~ 5-6 % by mass**
  - **Aggregate ~ 94- 95% by mass**

Desirable Properties of HMA

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"The final goal of mix design is to select a unique asphalt content that will achieve a balance among all the desired properties." (MS-22)

Seven Desirable Properties of HMA	
• Stability	• Flexibility
• Durability	• Fatigue Resistance
• Impermeability	• Skid Resistance
• Workability	

Stability

1

To Satisfy the Demands of Traffic w/o Distortion or Displacement

Stability

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- Ability to resist permanent deformation due to traffic loading
  - rutting
  - shoving
- Stability depends on
  - internal friction
  - particle interlock
  - cohesion due to bonding by asphalt
  - asphalt content

} aggregate texture, shape, & gradation

Durability

2

Ability to Resist Aging, Disintegration, and Stripping

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Durability

- Ability to resist
  - asphalt oxidation
  - aggregate disintegration
  - stripping
- High film thickness enhances durability
  - reduced oxidation
  - seals voids
- Dense aggregate gradation

Impermeability

Prevents the Passage of Air and Water into or through the Mix

Impermeability

- Resistance to water infiltration
  - Air voids > 8 % are likely interconnected
  - This high permeability can lead to accelerated oxidation due to contact with air and water
- Virtually all pavements are permeable to some degree

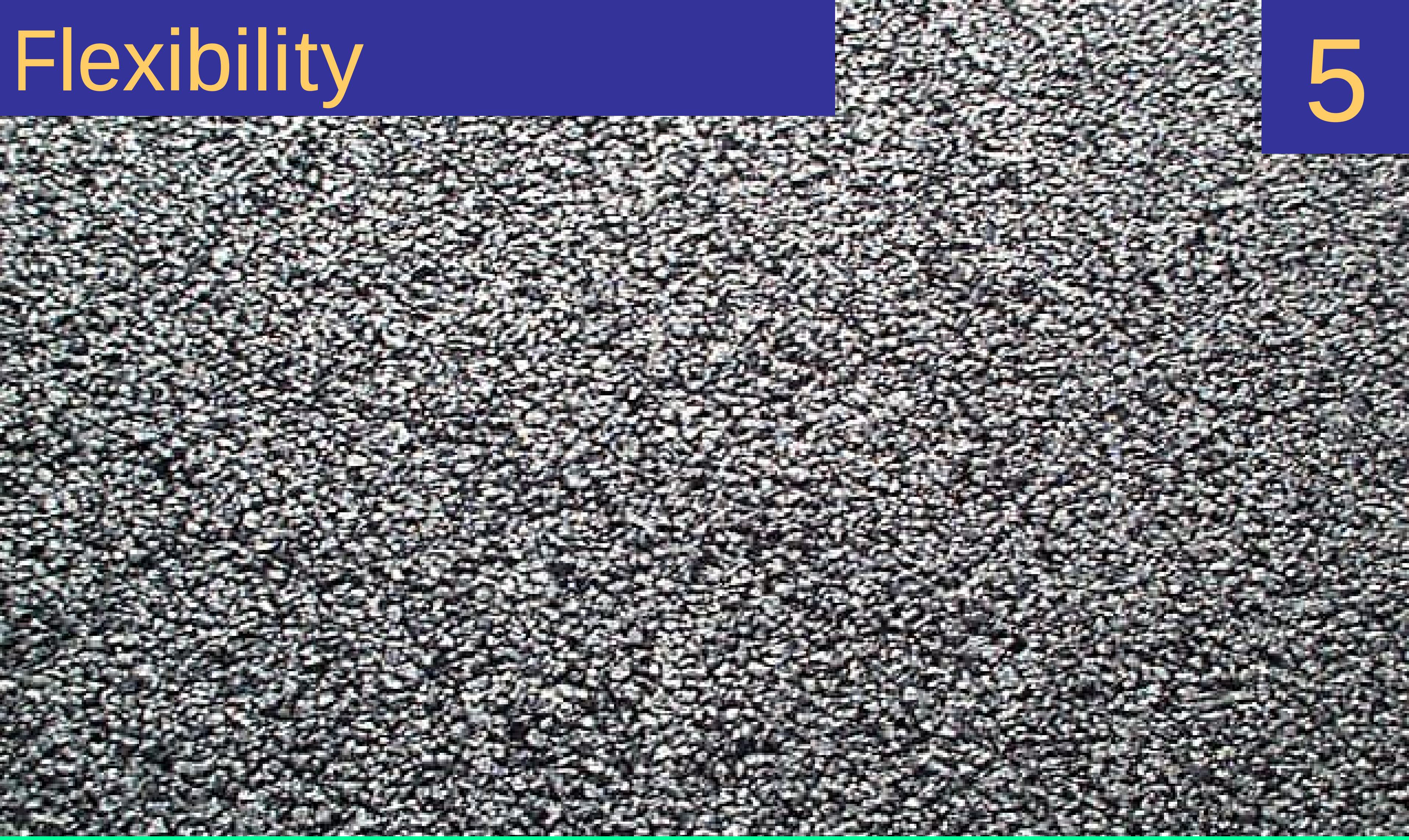
Workability

Without Segregation and without Sacrificing Stability or Performance

Workability

- Harsh mixes ***tend to segregate***
  - high amount of coarse aggregates
  - aggregates with high texture
- Tender mixes ***are difficult to compact***
  - shortage of mineral filler
  - excessive medium size sands (No. 30 Sieve)
  - smooth, rounded aggregate particles
  - high moisture content
  - asphalt binder stiffness/grade

Flexibility



So an HMA pavement can adjust to gradual settlements in subgrade

Fatigue Resistance

Resistance to Repeated Bending under wheel loads (traffic)

Fatigue Resistance

- Ability to carry repeated wheel loads
- Requires adequate pavement structure
- Causes of Inadequate Fatigue Resistance
  - Low Asphalt Content
  - High design air voids
  - Lack of Compaction
  - Inadequate Pavement Thickness

Skid Resistance

Minimize Skidding or Slipping of Vehicles in Wet Weather Conditions

Skid Resistance

- Texture of the pavement surface
  - Aggregate Texture
    - ability to resist polishing
  - Aggregate Gradation
    - Open Graded vs. Dense Graded Mixes
- Excessive asphalt and inadequate voids lead to bleeding or flushing

Desired Aggregate Properties

Toughness

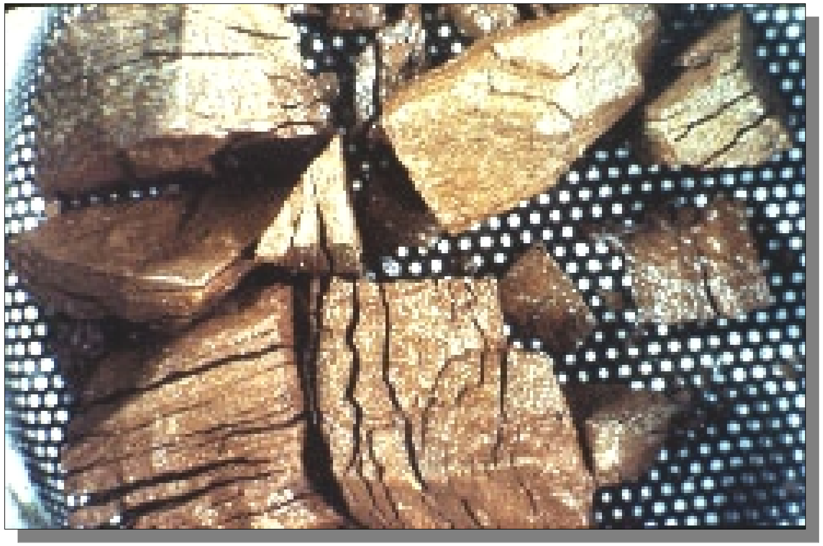
Soundness

Deleterious Materials

Gradation

Soundness

Before



After

Percent Crushed

0% Crushed

100% with 2 or More Crushed Faces

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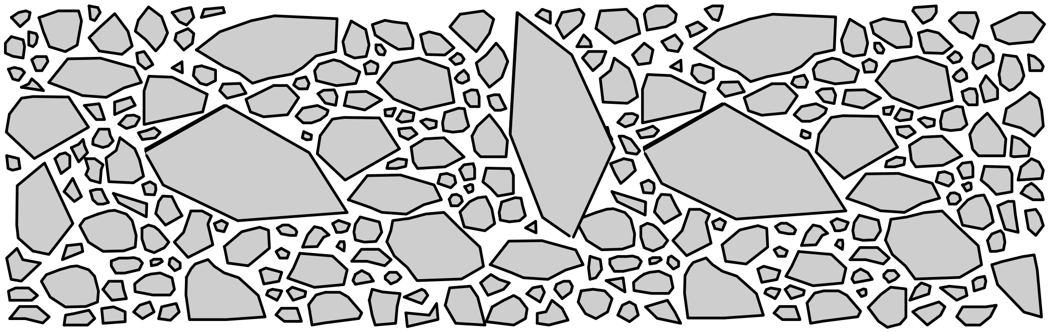
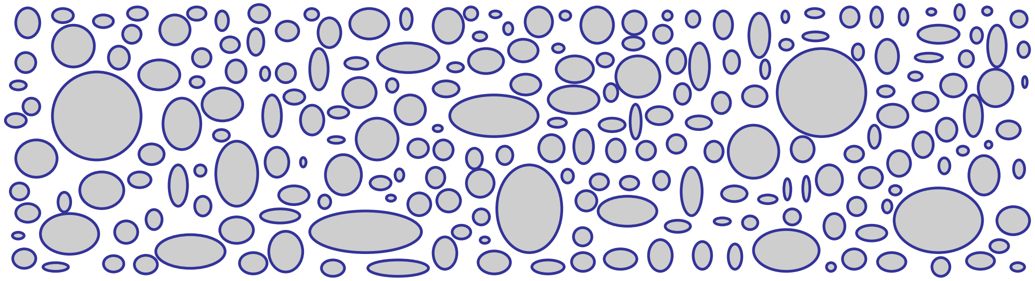
Contrasting Stone Skeletons



Angular Particles

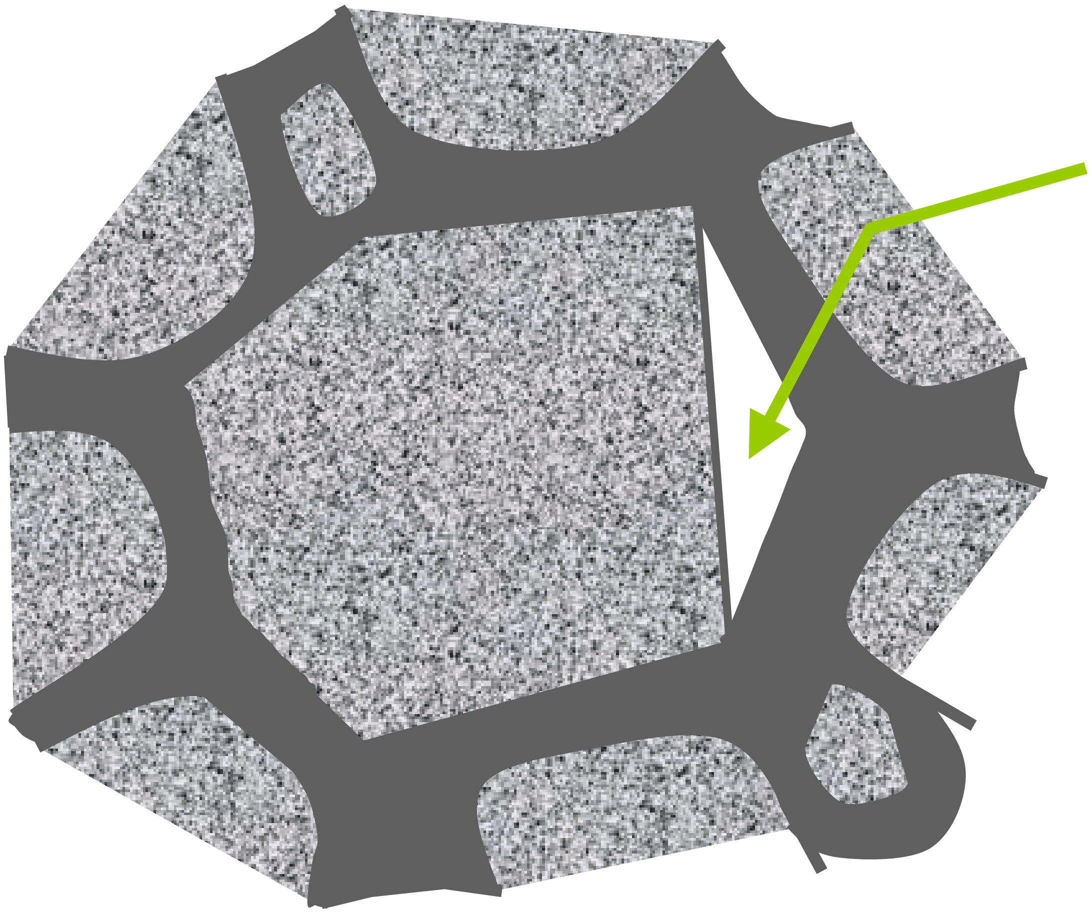


Rounded Particles

Cubical

Flat

Stripping Mechanism



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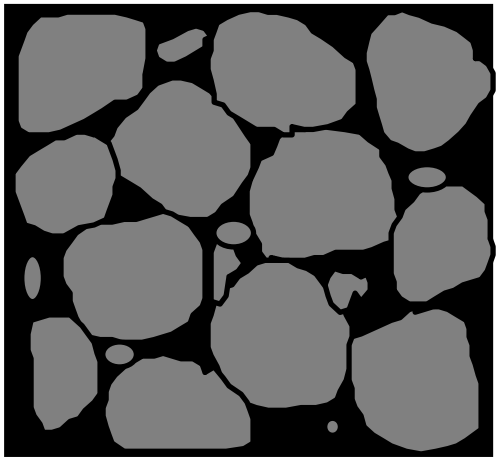
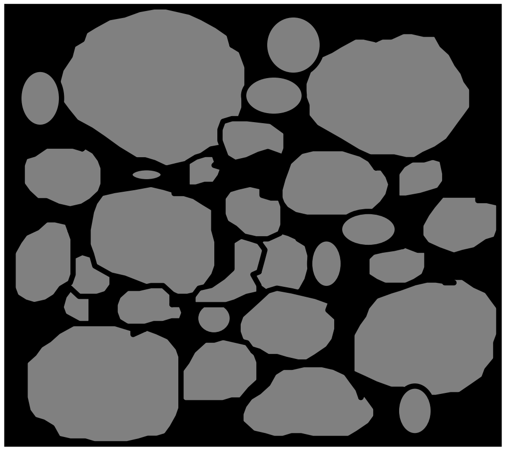
Effects of Aggregate Properties on Mixtures

Property	Effects on Mixture
Mineral type	Resistance to polishing, affinity to asphalt
Particle size	Asphalt content, lift thickness
Particle shape	Resistance to deformation, volumetric properties
Cleanliness	Adhesion between asphalt and aggregates, mixture volumetric properties
Toughness	Resistance to degradation, weathering

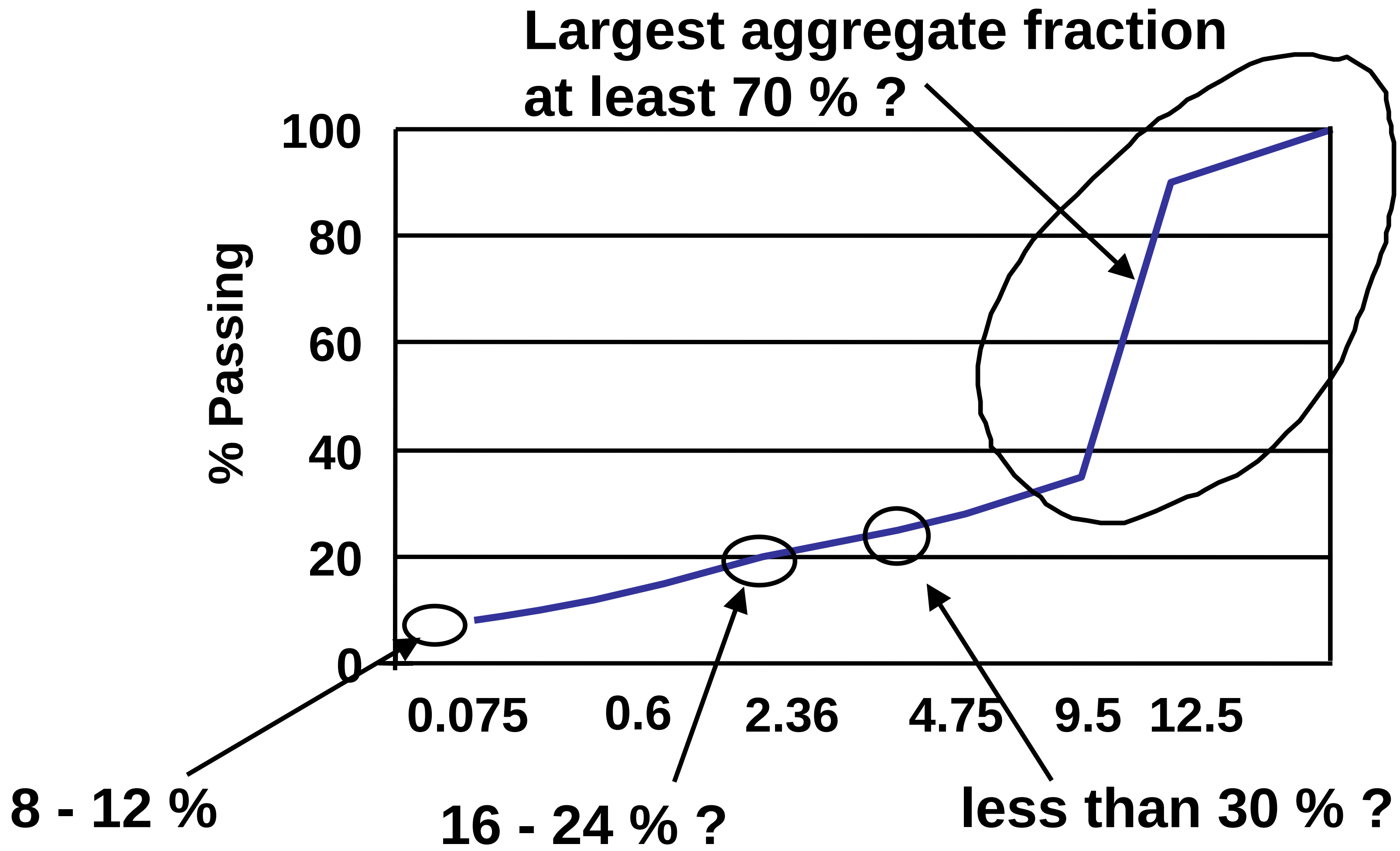
SMA Structure

- ✓ Binder rich (higher AC)
- ✓ Self-supporting stone to stone skeleton
- ✓ Mortar consisting of mineral filler forming a voidless and semi-fluid mastic
- ✓ Enhanced asphalt + additives (fibers) to reduce draindown tendency





SMA Gradation



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Superpave Gyratory Compactor

Specimens compacted 100 gyrations

SMA Surface Texture

Many Elements affect Volumetric Properties

Binder Quantity

Binder Properties

- Stiffness
- Modification
- Temperature

Aggregate characteristics

- Gradation
- Particle shape
- Surface texture
- Hardness
- Absorption

When Selecting Mixtures

- Consider lift thickness, construction constraints when selecting mixture classification
- Lift thickness should be at least 2-3 times the maximum size or 3 times the nominal maximum size
- This has become particularly more important for the coarser mixtures

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Objective of Mix Design

"The overall objective for the design of asphalt paving mixes is to determine a cost-effective blend and gradation of aggregates and asphalt..." (MS-2)

- Sufficient Asphalt
- Sufficient Stability
- Sufficient Voids
- Sufficient Workability

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Asphalt Binders for Airfields

Questions?

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