INTRODUCTION TO ASPHALT MATERIALS FOR MANAGERS AND OWNERS

ASPHALT PAVEMENT ASSOCIATION OF OREGON

John Hickey P.E., Esq.

BACKGROUND

- **Flexible Pavements**
- **Part of a Layered/Composite System**
- **Elastic Behavior**

BACKGROUND

- National Effort to Improve Asphalt Pavements
- Strategic Highway Research Program (SHRP)
- SuperPave™ Mix Design System
- Rely on good Mix Design Practices and Field Management

WHAT MAKES GOOD MIX?

- **Mixes with the best performance have *by volume*:**
  - **96% Aggregate and Oil**
  - **4% Air Voids**

WHAT MAKES GOOD MIX?

- Rollers usually get pavement to about 8% air voids, 92% aggregate and oil.

WHAT MAKES GOOD MIX?

Goal: design an asphalt mix that will stabilize at 4% air voids after one to three years of secondary compaction.

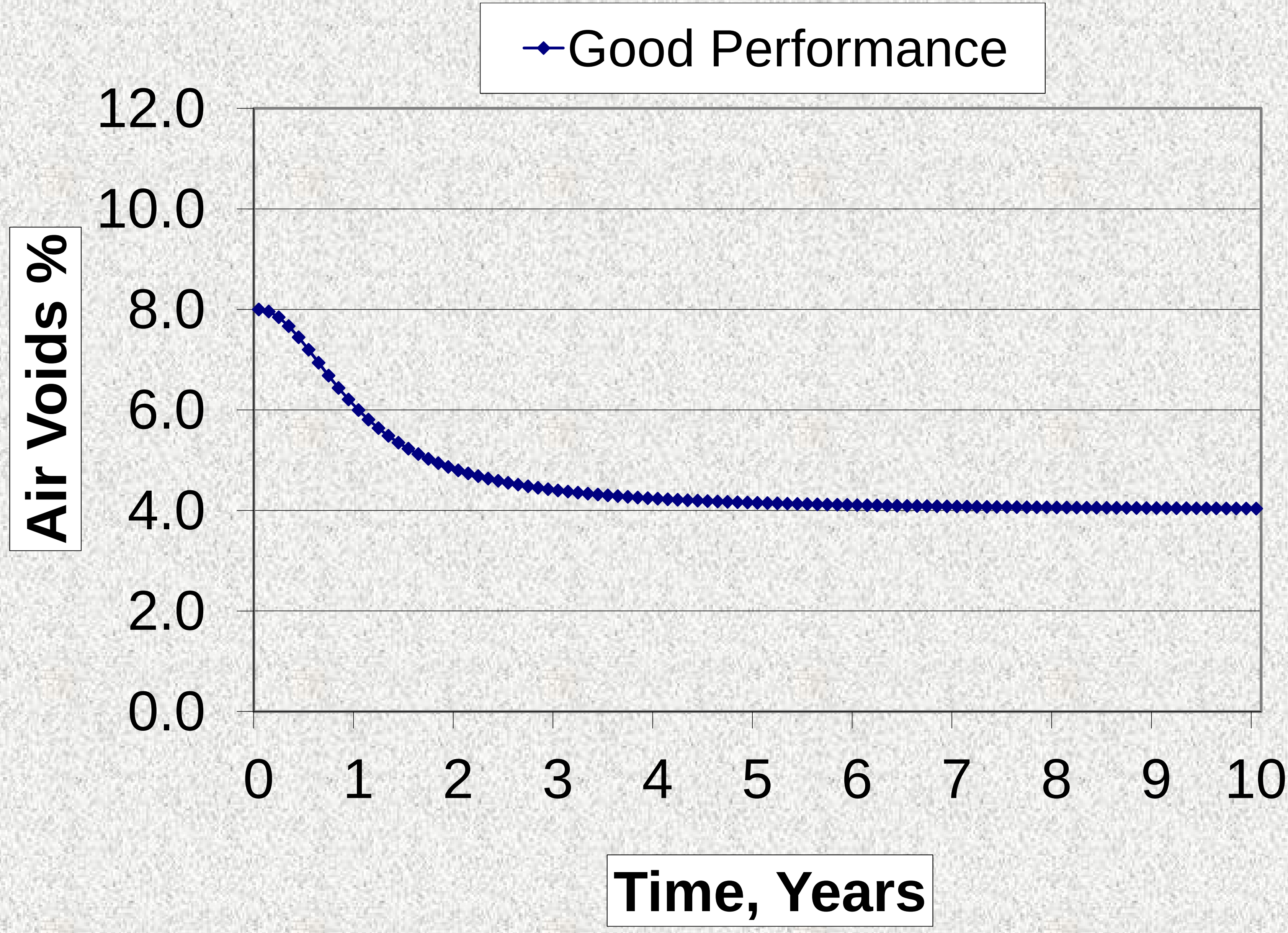
Secondary Compaction: 4% more compaction

MIXTURE TYPE SELECTION

Level	Traffic Type	20 Yr EALs
1	Low traffic, few or no trucks, 1 / day	0 - 30,000
2	Moderate truck traffic, < 140 /day	30,000 - 1 million
3	Heavy truck traffic	1 - 10 million
4	Very heavy truck traffic	> 10 million

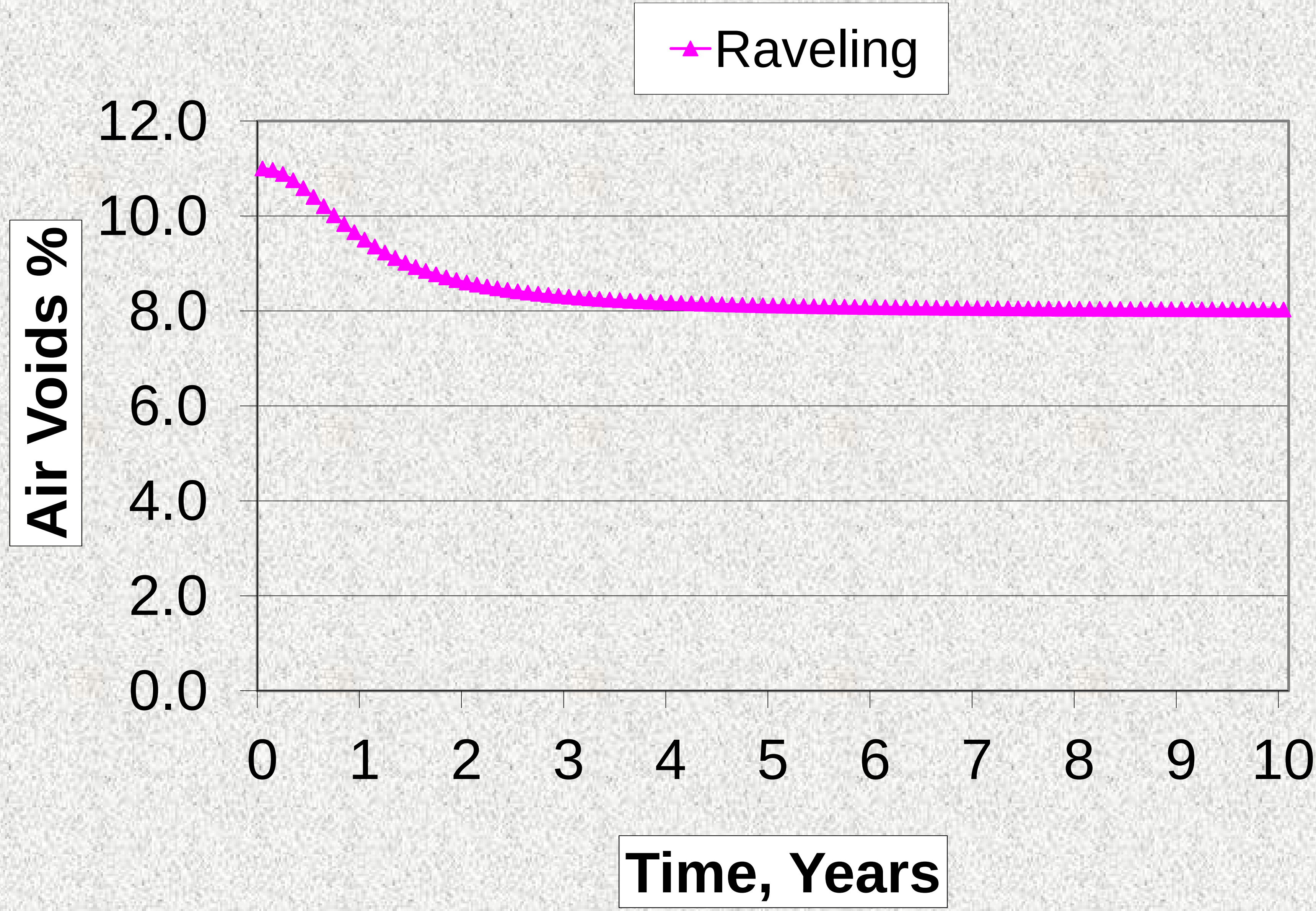
WHAT MAKES GOOD MIX?

If the pavement receives significantly more or significantly less secondary compaction than the design amount, then performance of the pavement will be negatively impacted.


Good Performance
Air Voids %
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
1
2
3
4
5
6
7
8
9
10
Time, Years

WHAT MAKES GOOD MIX?

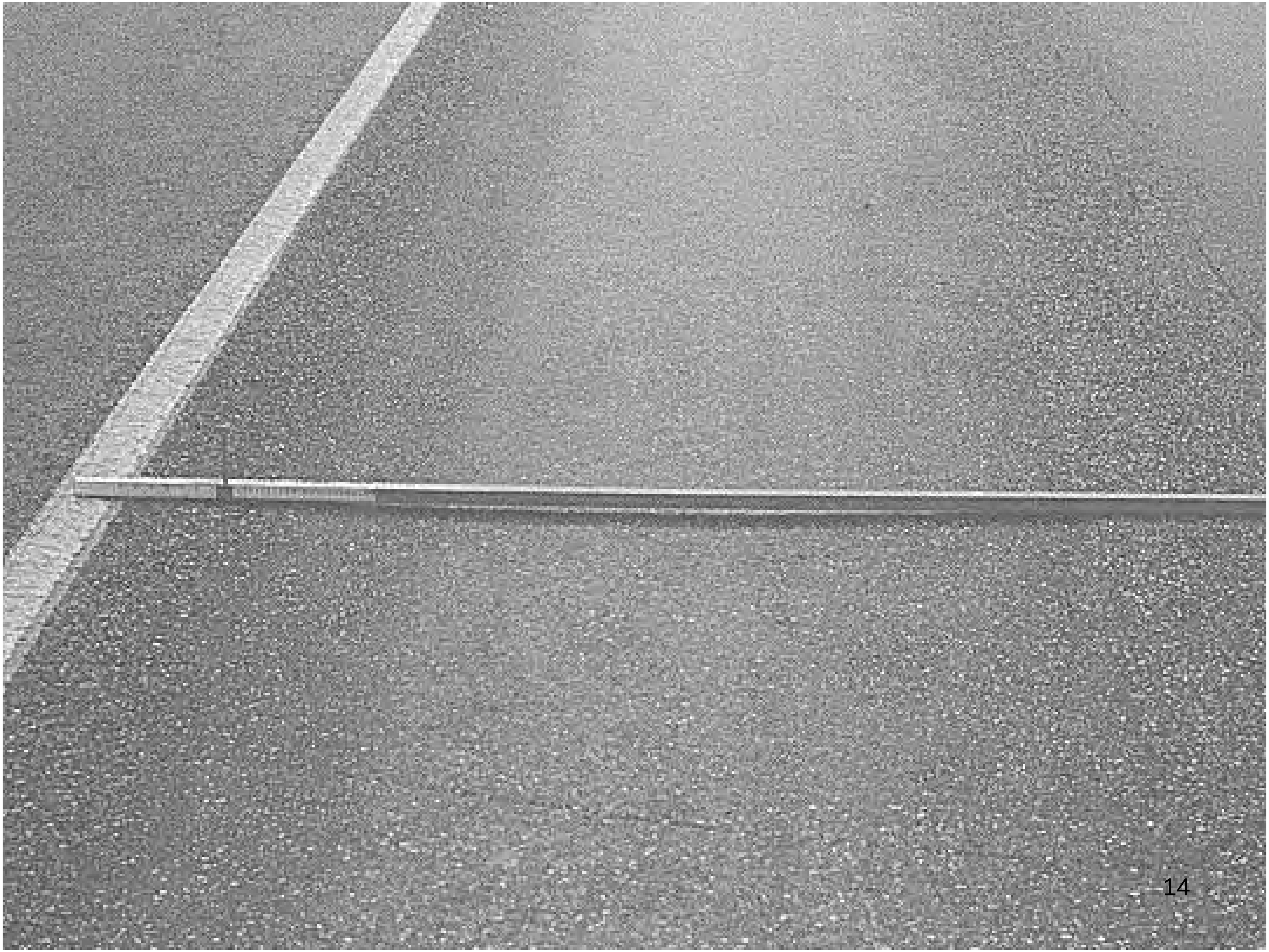
Pavements that don't properly densify after construction are much more prone to "*raveling*" (loss of fine surface matrix).

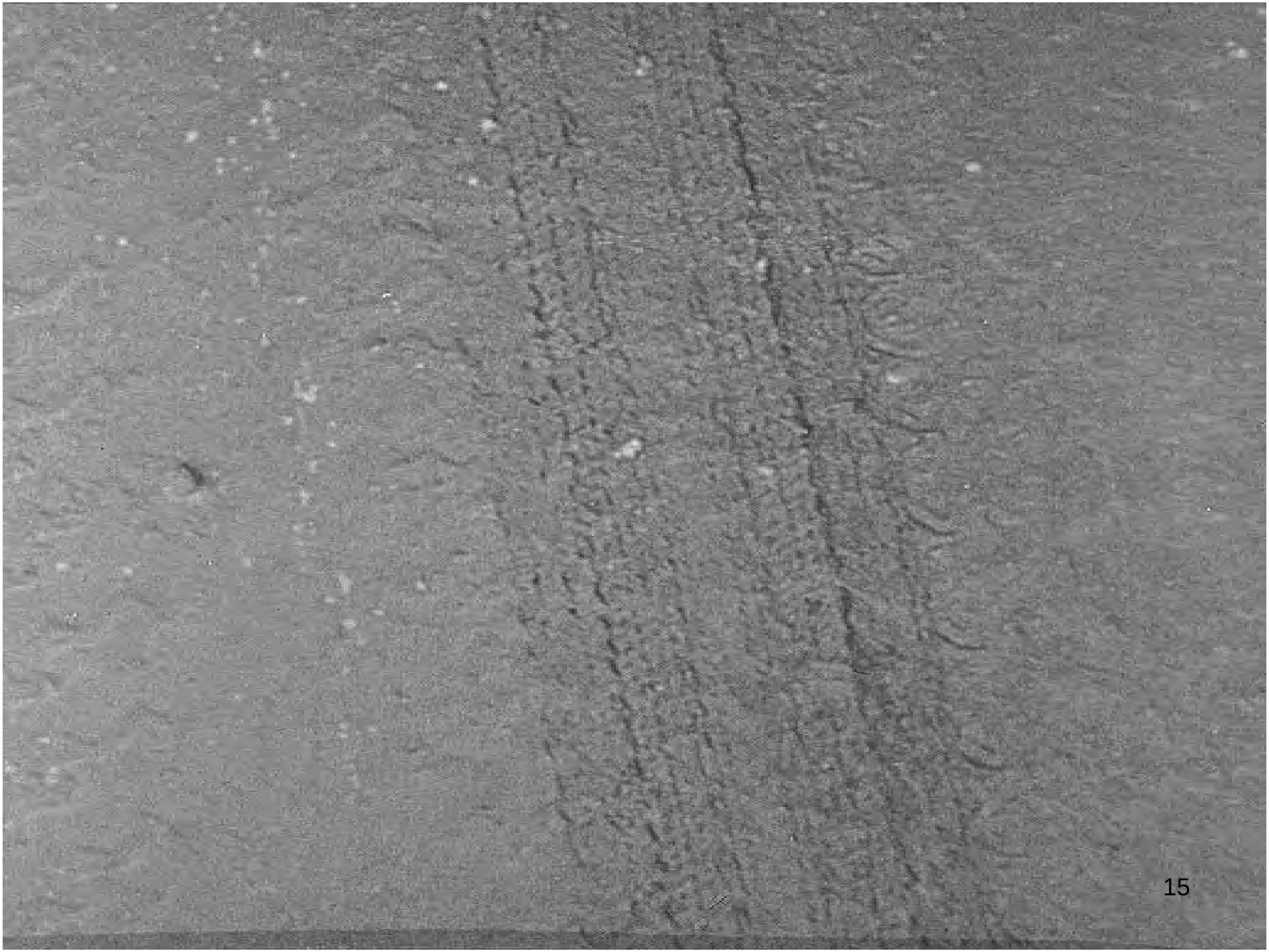

Raveling
Air Voids %
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
1
2
3
4
5
6
7
8
9
10
Time, Years

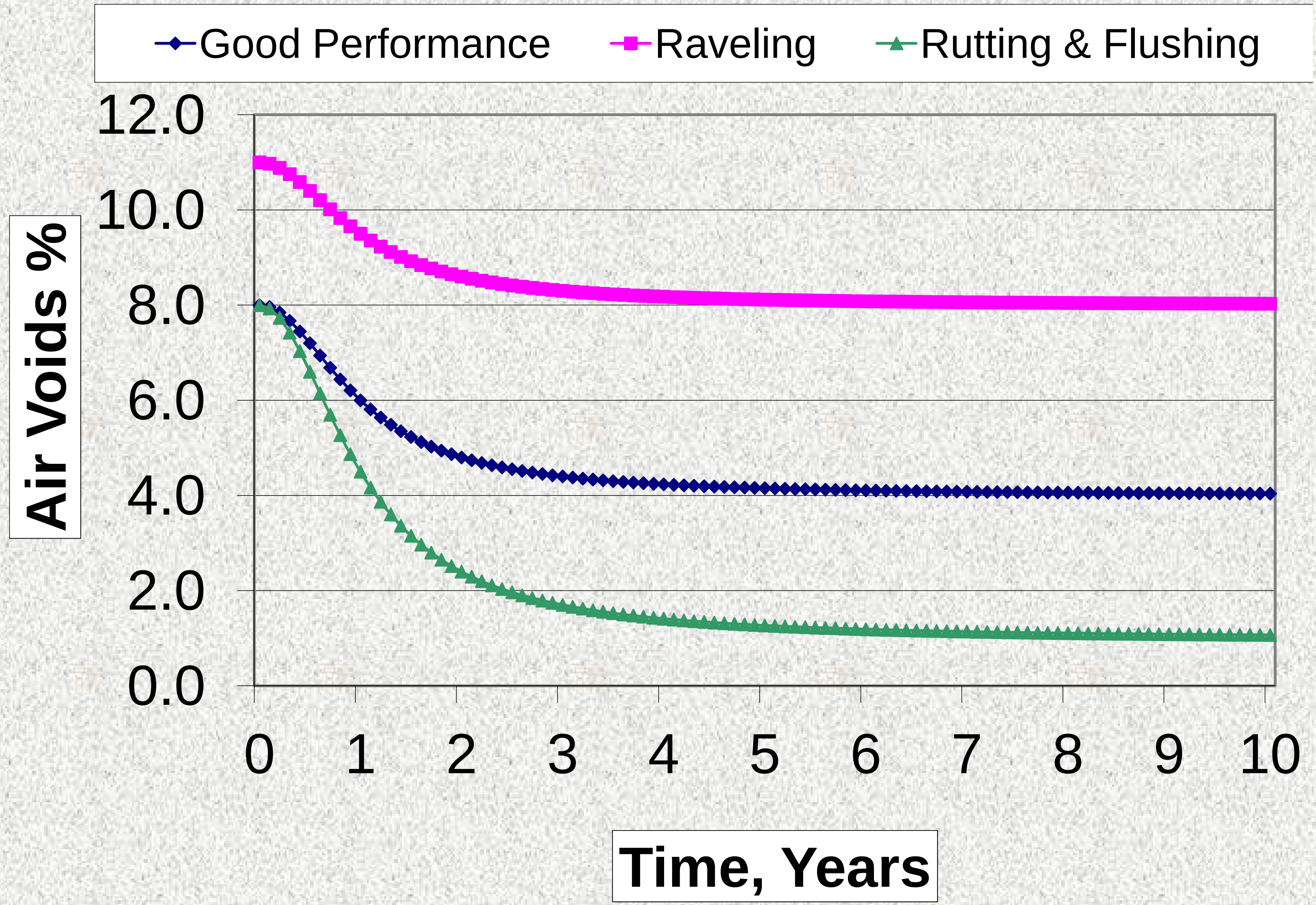
The Reverse Problem – Too Much Secondary Compaction

A classic case for creating a pavement that ruts or flushes is to use a mixture designed for a low traffic application such as a parking lot mix and putting it on a high volume roadway such as an “arterial” or “truck route.”


Rutting & Flushing
Air Voids %
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
1
2
3
4
5
6
7
8
9
10
Time, Years






Good Performance
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10
Time, Years

Modeling Secondary Compaction

- **Correctly quantifying energy to model secondary compaction is *not easy***
- **Each “Mix Design” is tailored to level of anticipated traffic**

SUPERPAVE™ GYRATORY – ATM

- **Level establishes the amount of energy imparted to lab specimens in mix design process.**
- **Energy comes from the gyrations used in the gyratory compactor.**

SUPERPAVE™ GYRATORY - ATM

- Use same mixing and placement temps as construction
- Cure for two hours at elevated temperature to allow absorption to occur.

INTRODUCTION TO MIX DESIGN

4 Step Process

- Material Selection
- Select Aggregate Blend (Stage 1)
  - Three different gradations
- Select Asphalt Binder Content (Stage 2)
  - Four different asphalt contents
- Performance Testing (Stage 3)
  - Two performance tests

MATERIAL SELECTION

- Aggregate
- Recycled Asphalt Materials (Optional)
  - RAP (Asphalt Pavement)
  - RAS (Asphalt Shingles)
- Asphalt Cement (binder)
- Additives (lime, anti-strip, etc.)

AGGREGATE MATERIALS

- Skeleton (94 to 95% of mix)
  - Withstand loads
  - Resist damage from traffic and environment
- Source Dependent Properties

AGGREGATE MATERIALS

Source Review Testing

- **In Oregon, Aggregate Quality Testing is done prior to Developing a Source**

AGGREGATE MATERIALS

Product Compliance Testing

- **After Aggregate Production begins**
- **Required for each Stockpile**
- **Required prior to JMF Approval**

AGGREGATE MATERIALS

Separated Sizes (Aggregate Stockpiles)

Coarse Stockpiles: + No. 4 sieve

Fine Stockpiles: - No. 4 sieve

Particle Shape

- Fractured Particles
- Flat and Elongated
- Blend Sand

Passing No. 200 Material

- No. 200 refers to 200 openings per lineal inch of screen
- “Dust” has large impact on mix properties
- Mitigating stockpiles with excessive dust:
  - Blend with cleaner piles
  - Wash
- Waste Baghouse Dust

Quality Level Analysis

- **Statistical Summary referred to as Quality Levels (QL)**
- **Designers use QL’s to determine JMF target blend**

RECYCLED ASPHALT MATERIALS

RAP

- Asphalt Content
- Gradation
- Based on testing by Ignition Method

RECYCLED ASPHALT MATERIALS

- **Amount of RAP Allowed:**
  - 30% for dense-graded
  - 20% for Level 4 dense-graded Wearing Courses
- **Practical Limits:**
  - RAP Availability
  - Plant Capacity/EPA Emissions Requirements
- **Benefits:**
  - Improves rut and stripping resistance
  - Sustainable practice
  - Reduced cost

RECYCLED ASPHALT MATERIALS

RAS

- Two Categories:
  - Manufacturing Waste (MW)
  - Tear Offs (TO)
- Both Categories require shredding
- TO-RAS may require additional steps to remove fasteners and debris
- Special Considerations
  - Stiffer aged asphalts
  - High Passing No. 200 (dust)
  - ~ 5% RAS allowed

SELECTION OF ASPHALT BINDER

- **PG Grading system (PG 64 – 22)**

SELECTING THE BINDER GRADE

- Climate – High and Low Pavement Temp
- Volume of traffic
- Speed of traffic
- RAP content

SPECIFIC GRAVITY AND VOLUMETRICS

INTRODUCTION TO SPECIFIC GRAVITY

- **Density Compared to H_2O**

$$Density = \frac{Mass}{Volume}$$

INTRO TO SPECIFIC GRAVITY

- **Volumes of even sided Geometric Objects are easy to Measure**
- **Volumes of Irregular Objects (HMAC mix) are not so easy to Measure**
- **Specific Gravity is an easy means to measure the Volume of Irregular Objects**

MEASURING SPECIFIC GRAVITY

Definition:

Specific Gravity **– the ratio of the weight in air of a unit volume of a material at a stated temperature to the weight of an equal volume of gas-free distilled water at a stated temperature.**

FIVE FUNDAMENTAL GRAVITIES

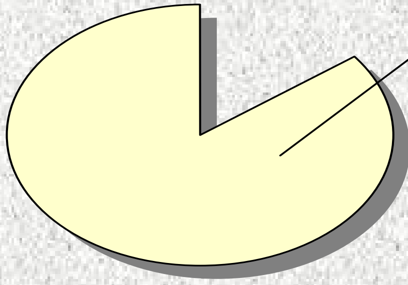
- Liquid Asphalt Sp. Gr., G_b
- Bulk Sp. Gr. of Aggregate, G_{sb}
- Effective Sp. Gr. of Aggregate, G_{se}
- Maximum Sp. Gr. of Mixture, G_{mm}
- Bulk Sp. Gr. of Compacted Mix, G_{mb}

BULK SP. GR. OF AGGREGATE

$$G_{sb} = \frac{P_1 + P_2 + \ldots + P_n}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \ldots + \frac{P_n}{G_n}}$$

- **Includes pore space in the aggregates**
- **AASHTO T 85 for Coarse Aggregate**
- **AASHTO T 84 for Fine Aggregate (weakest link)**
- **Typical values: 2.400 to 2.800**

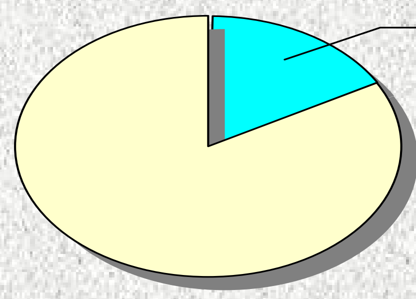
COMPARISON OF AGGREGATE GRAVITIES



Volume of Dry Aggregate

(Smallest Volume)

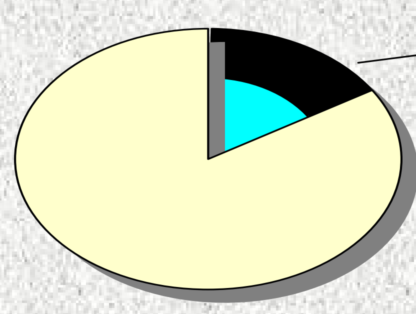
Used to Determine Apparent Specific Gravity, Gsa



Volume of Water Permeable Voids
plus
Volume of Dry Aggregate

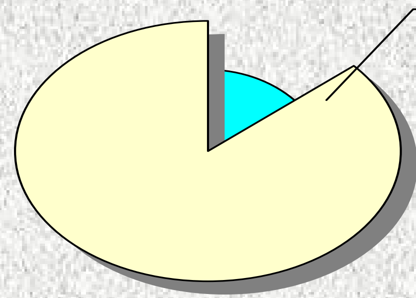
(Largest Volume)

Used to Determine Bulk Specific Gravity, Gsb



Volume of Asphalt Permeable Voids

(Note: Is less than the Volume of Water Permeable Voids)



Volume of Water Permeable Voids less
Volume of Asphalt Permeable Voids plus
Volume of Dry Aggregate

(Intermediate Volume)

Used to Determine the Effective Specific Gravity, Gse

MAX SPECIFIC GRAVITY OF MIXTURE

- "Rice" Test
- Performed on loose mix
  - Tends to trap air bubbles
  - Vacuum

BULK SPECIFIC GRAVITY OF COMPACTED MIXTURE

- Lab gyratory sample
- Mix with air voids
- Weight in water method

INTRO TO VOLUMETRICS

- Volume occupied by each constituent:
  - Aggregate
  - Asphalt Cement
  - Air Voids
- Based on specific gravities and masses

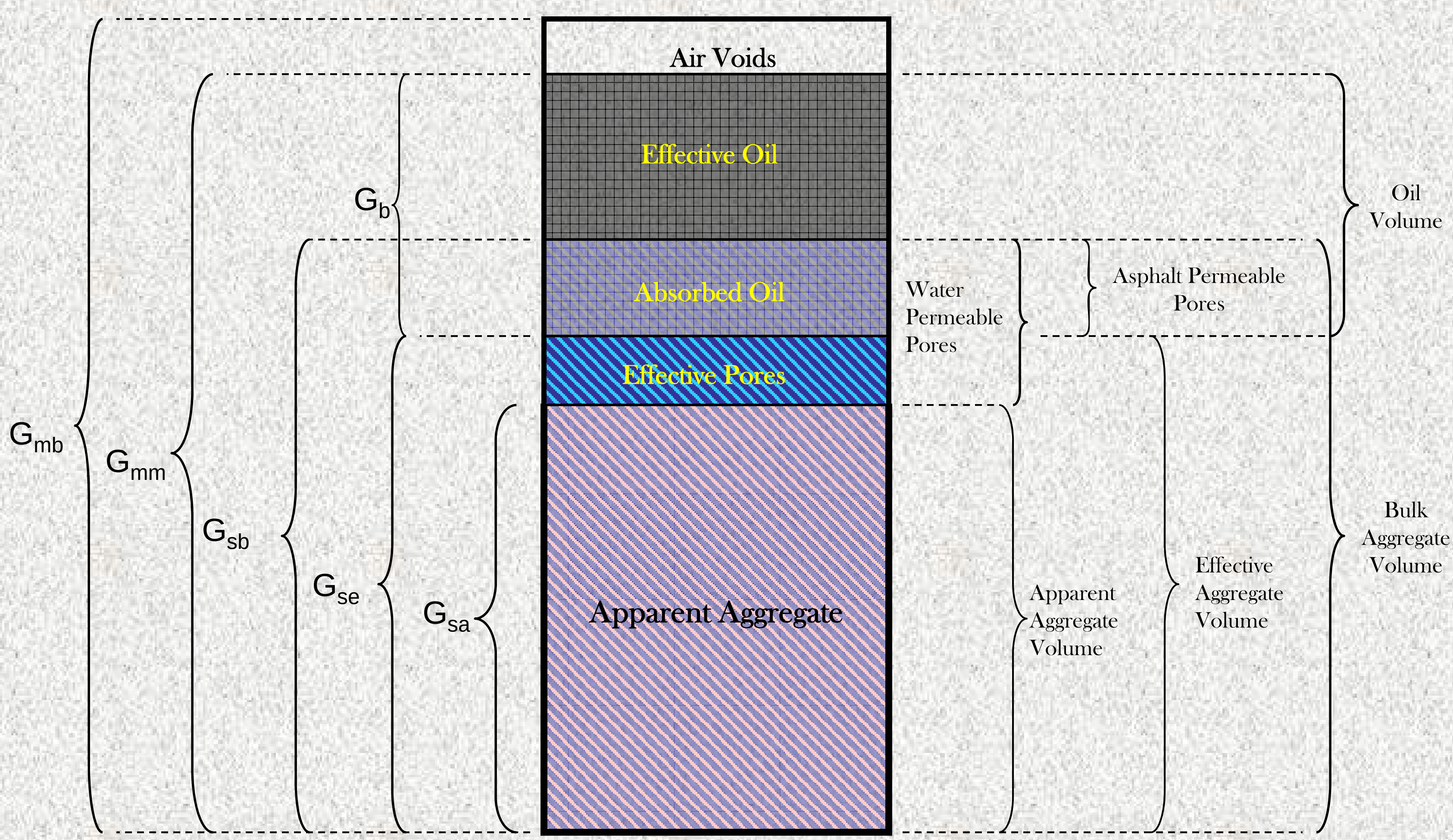
Percent by Volume

V_a = Air Voids

VMA = Voids in Mineral Aggregate

VFA = Voids Filled with Asphalt

HMAC Constituent Diagram



Definitions:

Voids in Mineral Aggregate, VMA: volume of void space between the aggregate particles of a compacted paving mixture that includes air voids and effective asphalt content.

Expressed as a percent of the total volume of the sample.

Fundamental Relationship:

$$VMA = V_a + V_{be}$$

- **Typical values:** 13.0 to 17.0%

SUMMARY OF VOLUMETRICS

- **Specific Gravity is used to measure the density of irregular shaped objects**
- **Volumetrics for Mix Design and QC come from specific gravities**
- **Monitor and manage the five specific gravities**

DENSE-GRADED MIX DESIGNS

Stage 1: Selection and testing of three trial aggregate blends

Stage 2: Selection and testing of the JMF blend with four asphalt contents

Stage 3: Selection and testing of the JMF blend and asphalt content for rut susceptibility and moisture sensitivity (stripping)

STAGE 1: AGGREGATE GRADATION

- CMDT seeks a blend which meets the design criteria
- Gradation Controls:
  - VMA
  - P200 to Effective Ratio
- Historically used a single “best guess” blend
- SuperPave™ requires three blends

IDEAL GRADATION TARGETS

- **The ideal targets for various mix types have been around for many years**

- **The street term for ideal targets is “Golden Gradations”**

SELECTION OF TRIAL GRADATIONS

- **Review Historical Data:**
  - **Product Compliance Data**
  - **Existing Mix Designs**

- **Look for:**
  - **VMA problems**
  - **P200 problems**
  - **Stripping problems**
  - **Absorption problems**
  - **Compaction problems**

Material Information

- **For each stockpile:**
  - **Quality Level Analysis (QL)**
    - **Are stockpiles crushed or are we guessing?**
    - **How much aggregate is crushed?**
  - **Product Compliance**
  - **Specific Gravities:**
    - G_{sa}
    - G_{sb}
  - **Same for RAP, lime, and other additives**

BATCHING AGGREGATE SAMPLES

- Model the HMAC Plant
- Dry materials

SELECTING TRIAL ASPHALT CONTENT

- Designer's best judgment

STAGE 1 RESULTS

- **Chances are we didn't hit 4.0% air voids with our WAG on asphalt content.**
- **"Normalize" the results to predict the volumetrics at 4.0% air voids**
  - **Math process (paper exercise)**
  - **Compare the three different blends**
- **Compare the three normalized results against the specification requirements**
- **Select *one* gradation for further testing**

STAGE 1: MIX ADJUSTMENTS

Adjusting VMA

- Requires a change in gradation
- Change particle shape
- Blend Sand
- Adjust P200 (dust)

STAGE 1: MIX ADJUSTMENTS

Adjusting Dust-to-Effective

- **Waste Dust (P200)**
- **Blend Change**

STAGE 1:

The final product of Stage 1 is a single proposed aggregate blend that will be further evaluated in Stages 2 & 3.

STAGE 2: DESIGN ASPHALT CONTENT

- **Test selected blend with different asphalt contents**
- **Select the asphalt content that gives the desired air voids (normally 4.0%)**
- **Minimum of 4 asphalt contents**

EXAMPLE: P_b = 5.0%, 5.5%, 6.0%, and 6.5%

CONDITIONING OF SAMPLES

- Two hours at the compaction temperature
- Per AASHTO R 30

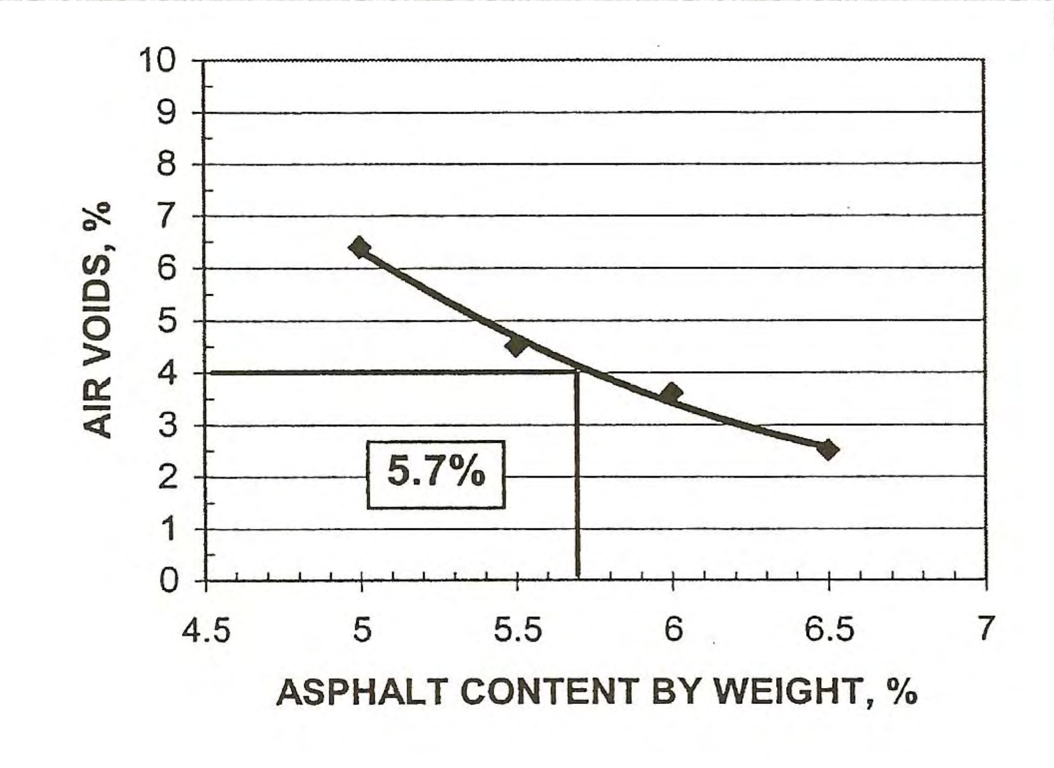
COMPACTION OF SAMPLES

DESIGN ASPHALT CONTENT

- Compute the volumetric properties for all four asphalt contents
- Data is graphed versus asphalt content:
  - Air Voids
  - VMA
  - VFA
  - Dust-to-Effective Asphalt Content

DESIGN ASPHALT CONTENT

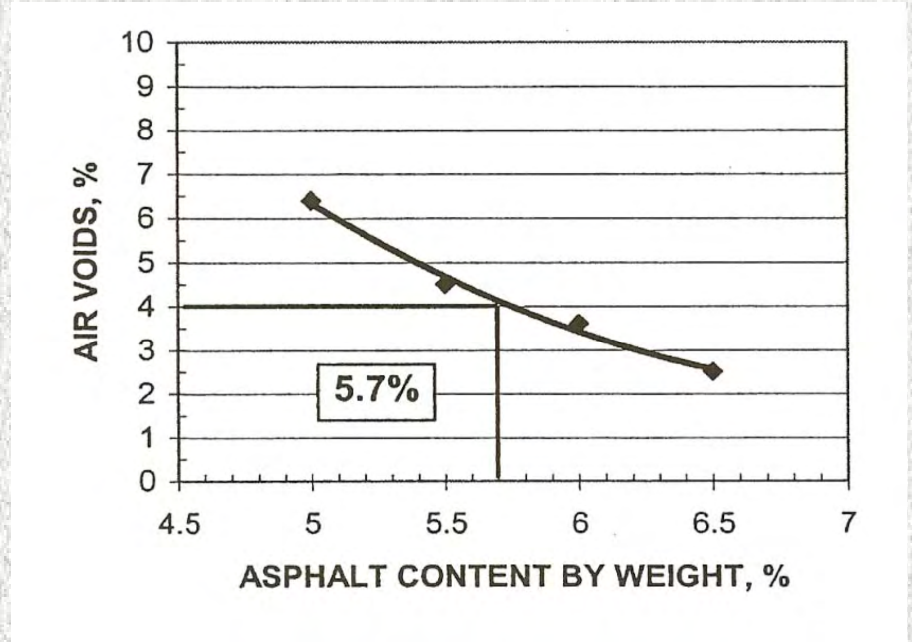
If the graphs look reasonable, then the design asphalt content is selected as the oil content that provides the target air voids (usually 4.0%) after compaction in gyratory compactor



ASSESSING STAGE 2 DATA

Air Voids vs. Asphalt Cement:

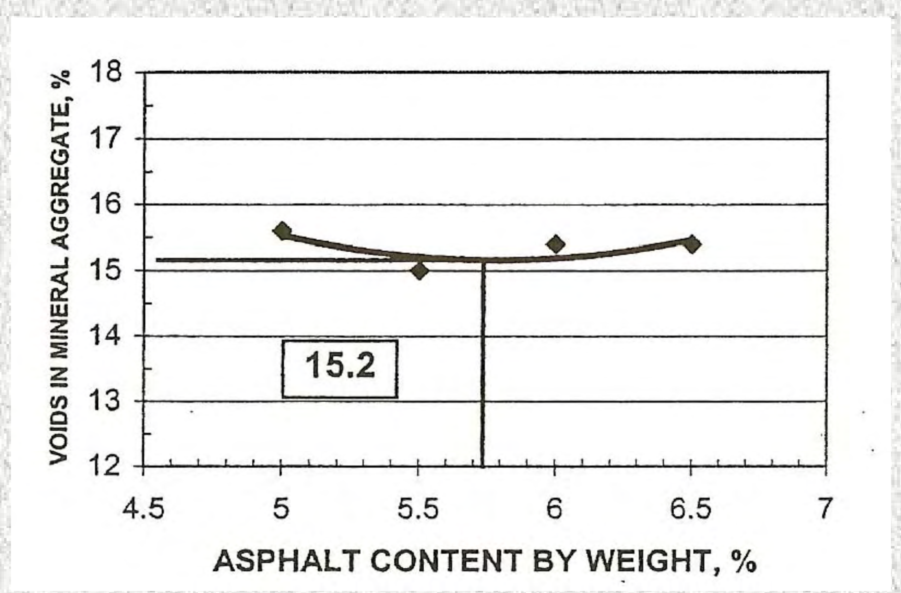
- **Smooth curve w/o dips or bumps**
- **Should match Stage 1**



ASSESSING STAGE 2 DATA

VMA vs. Asphalt Content:

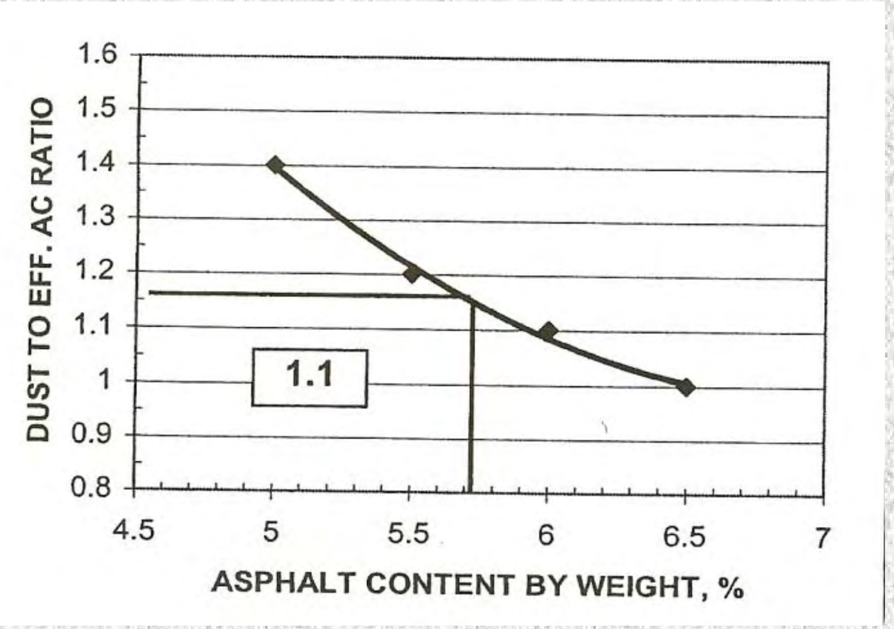
- Within 1.0 to 1.5% of each other
- Should be a shallow concave curve
- Design near the bottom or on "dry" side



ASSESSING STAGE 2 DATA

Dust-to-Effective Ratio vs. Asphalt Content:

- **Smooth**
- **Only thing changing between points is P_{be}**
- **P_{be} should go up in 0.5% increments**



WHAT MAKES A GOOD DESIGN?

- **Smooth volumetric plots**
- **Stage 1 and Stage 2 match**
- **Design P_b is on the "dry" side of the VMA curve**
- **Design VMA is 0.5 to 1.0% above the minimum**
- **Design Pbe/P200 is approximately 1.2**
- **Design TSR above 80**

The final product of Stage 2 is the design asphalt content.

STAGE 3: PERFORMANCE TESTING

- **AASHTO T 283 – Moisture Damage Testing (TSR)**
- **AASHTO T 340 – Rut Susceptibility Testing**
- **Time consuming and expensive**

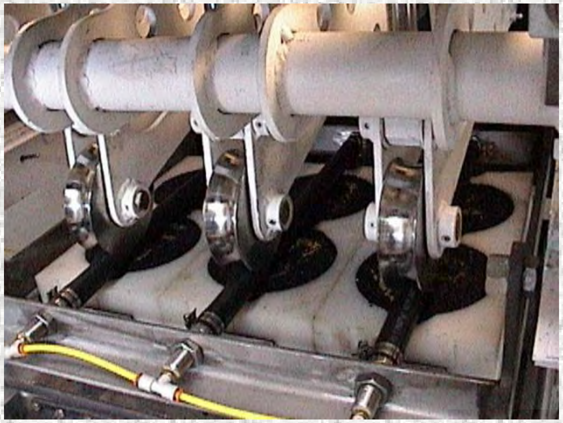
Rut Susceptibility Testing

Impacted by aggregate properties:

- Particle Shape
- Voids in Mineral Aggregate

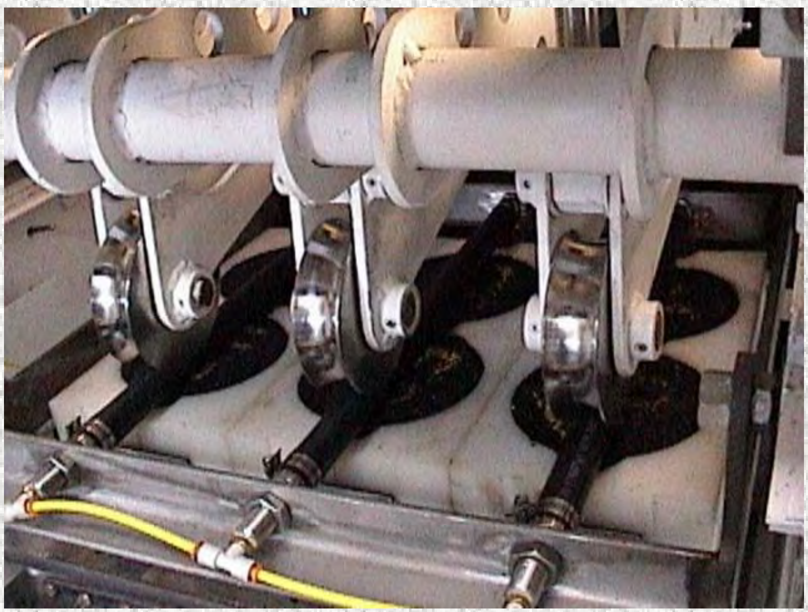
Tested at 64° C:

- 8000 cycles
- 100 psi hose
- 100 lb wheel load



STAGE 3: PERFORMANCE TESTING

Rut Susceptibility Testing:



Mitigating Rut Problems:

- Add RAP
- Increase crushed faces
- Eliminate flat and elongated particles
- Stiffer grade of asphalt cement

Moisture Damage Testing

Tensile Strength Test (TSR)

- "Stripping Test"
- Stripping occurs in the presence of water and heavy loads
- Mitigated with "anti-strip" or lime

STAGE 3: PERFORMANCE TESTING

Moisture Damage Testing (TSR):

- **Fabricate 6 gyratory specimens**
- **Divide in to two subsets: (3 wet and 3 dry)**
- **Saturate and "torture" the 3 wet specimens in a 140° F hot water bath for 24 hours**
- **Measure tensile strength of all 6 specimens**
- **Calculate the ratio of the wet tensile strengths to the dry tensile strengths**

STAGE 3: PERFORMANCE TESTING

Mitigating a TSR (Stripping) Problem:

- **Add a liquid anti-strip to the oil (0.25% increments)**
- **Try other brands of oil**
- **Treat the aggregates:**
  - **Lime**
  - **Latex**
- **Contact the Engineer**

SUMMARY

- **Materials selection followed by 3 stage mix design process**
- **Stage 1: Identifies optimal blend of aggregates**
- **Stage 2: Identifies optimal asphalt content**
- **Stage 3: Checks for stripping and rut susceptibility**

SUMMARY

Understanding the basics is an important step in being able to recognize a good JMF