XVI CONGRESO ARGENTINO DE VIALIDAD Y TRÁNSITO
7ma EXPOVIAL ARGENTINA

22 al 26 de OCTUBRE 2012

COMPLEJO FERIAL CÓRDOBA - CIUDAD DE CÓRDOBA . ARGENTINA

North American Approach to Asphalt Mix Design and Production

- Gerald Huber
  Heritage Research Group

IX CONGRESO INTERNACIONAL ITS
XXXVII REUNIÓN DEL ASFALTO
SEMINARIO INTERNACIONAL DE PAVIMENTOS DE HORMIGÓN

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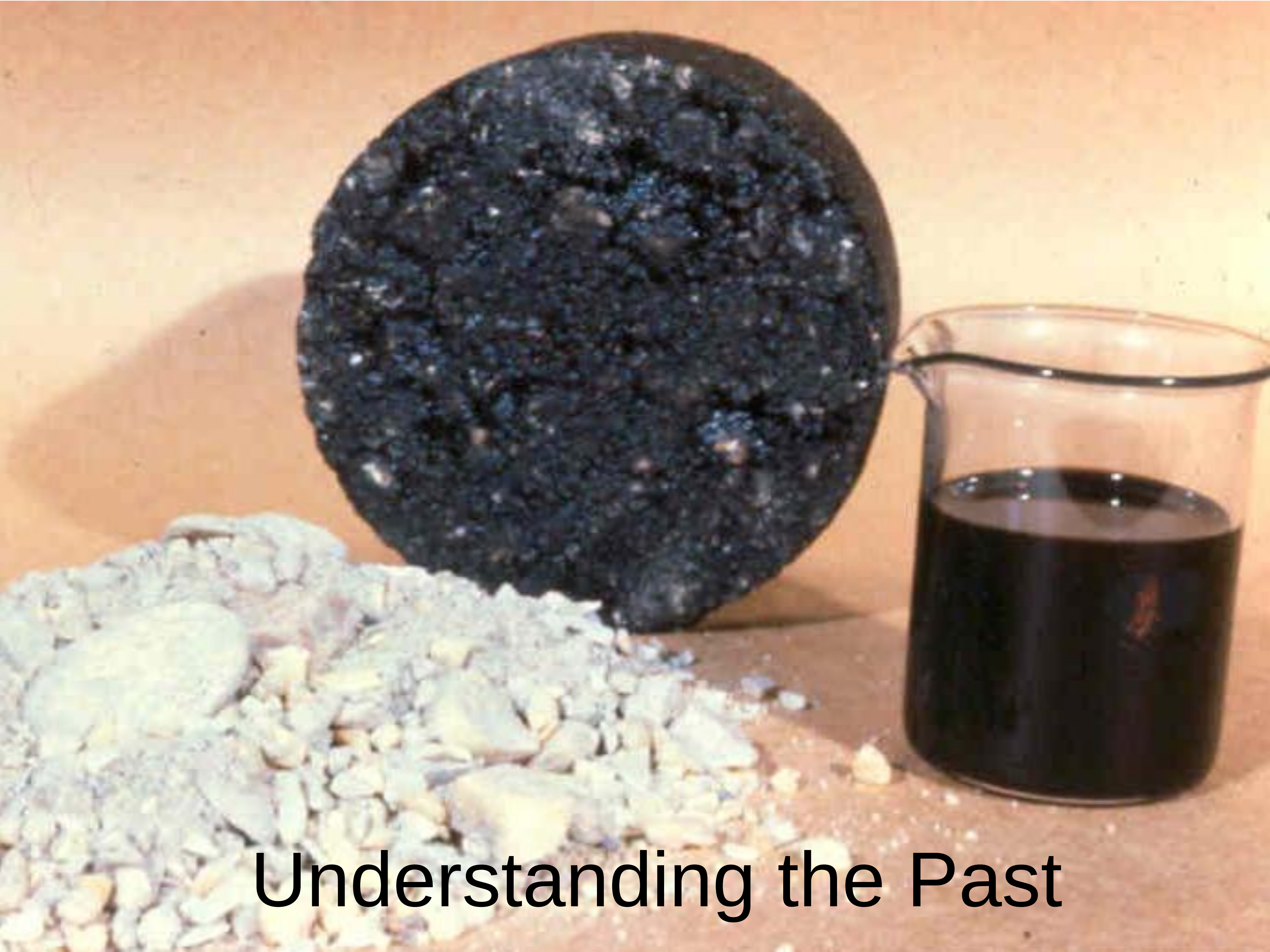

Understanding the Past

1890 E.G. Love

- Engineering and Building Record
- Articles on paving streets
  – Brick
  – Cobblestones
  – Wood pavers
  – Concrete
  – Asphalt

Philadelphia 1911

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Lake Trinidad Asphalt (Barber Co.)

- First HMA (1870's)
  - Pennsylvania Ave.
- Naturally occurring from lake in Trinidad

Barber Asphalt Paving Company

- Recipe Design
  - 70 to 83% sand
  - 5 to 15% lime
- Sand heated to 150ºC
  - Lime added cold
    - Amount adjusted visually
  - Asphalt added

Barber Design

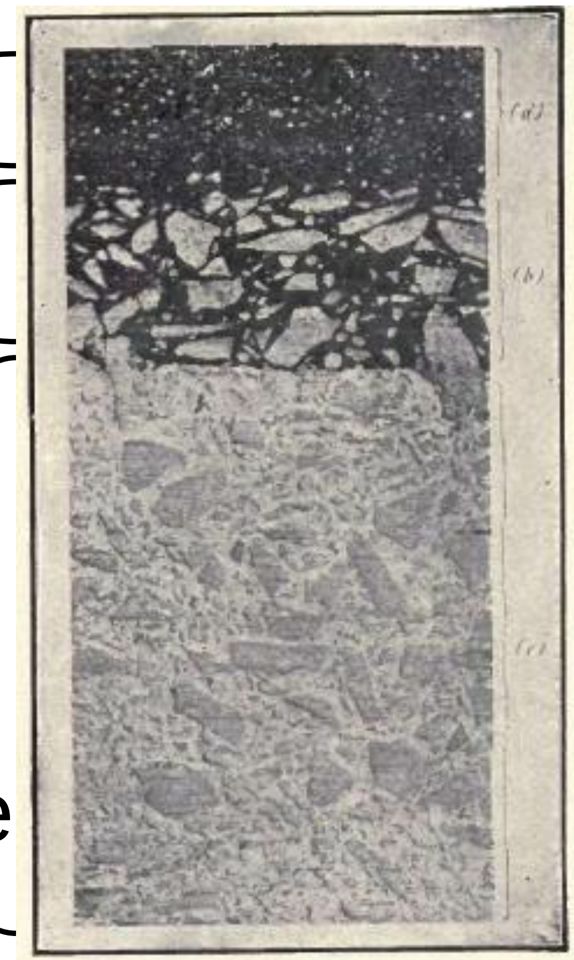
- Cushion Coat (Top Lift)
  - 14 to 19% Asphalt
- Surface Coat
  - 12 to 15% Asphalt
- Macadam

Clifford Richardson (1905)

- New York Testing Company
- Published book
  - “The Modern Asphalt Pavement”
- Pavements built in 1890s and 1900s

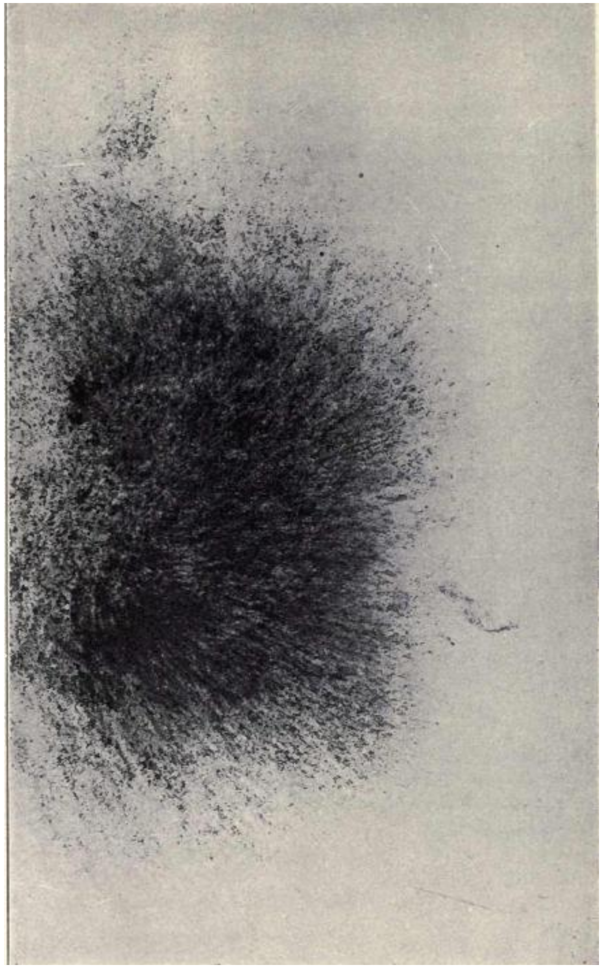
Typical 1900s Pavement

- Surfacing Mix
- Asphalt Concrete
- Hydraulic Cement Stabilized Aggregate



Surface Recipe Design

- Components (typical)
  - 78% sand
  - 12% lime
  - 10% asphalt
- Sand heated to 300ºF
  - Asphalt added
  - Lime added cold
    - Amount adjusted visually
- Paper Pat Test
  - Brown paper
  - Mixture dumped on to paper



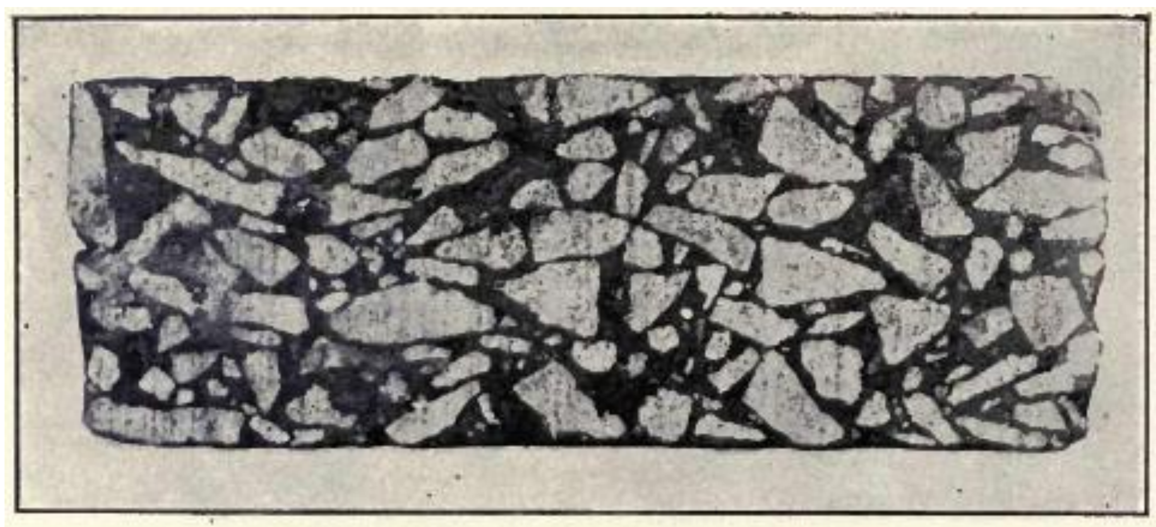
Good Performing Surface Mix

- Asphalt Content 11%
- Gradation
  - #10 100
  - #40 87%
  - #80 49%
  - #200 15%
- Air Voids approx 0%
  - No weathering
  - No cracking
  - No disintegration

Toronto 1890s

Asphalt Concrete as Surface Mix

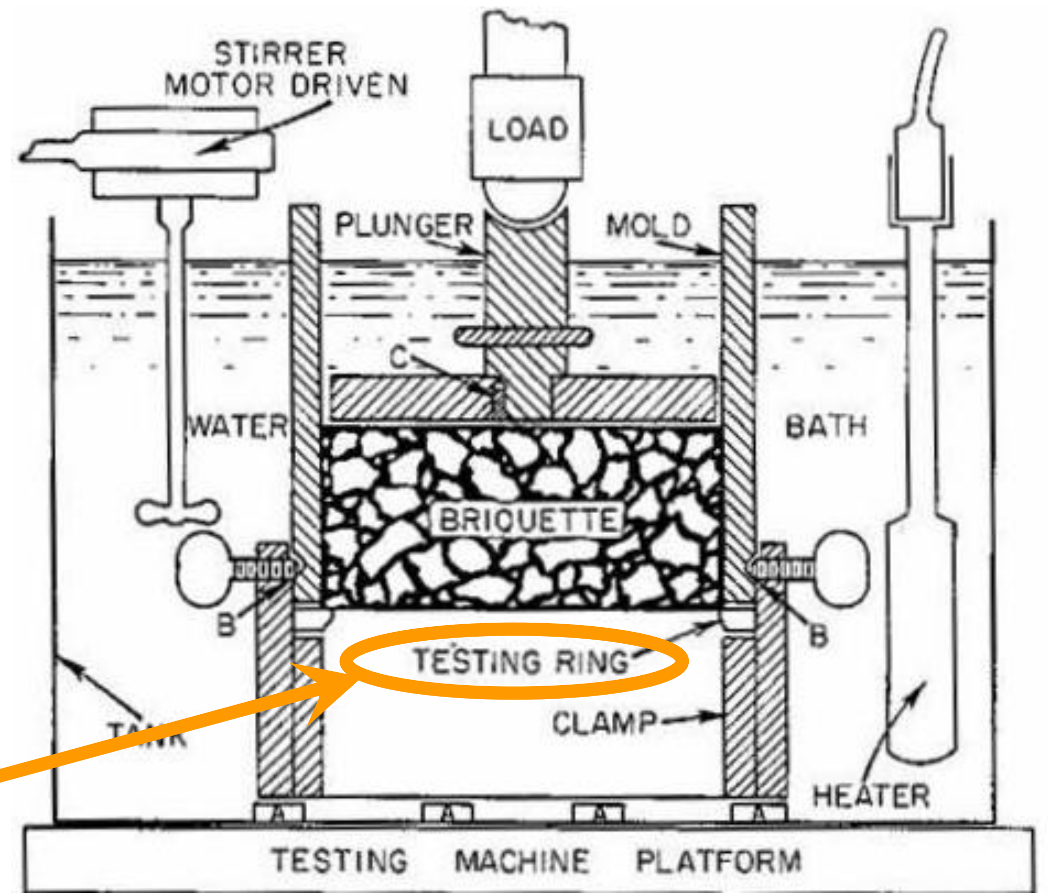
- Developed by Barber Company
  - 1902 Project
  - Asphalt 7.4%
  - VMA 16.4%



Hubbard Field Mix Design (1920s)

- Compact Mixture with rammer

- Specifications
  - Air voids
  - Voids in compacted aggregate
  - Hubbard Field Stability



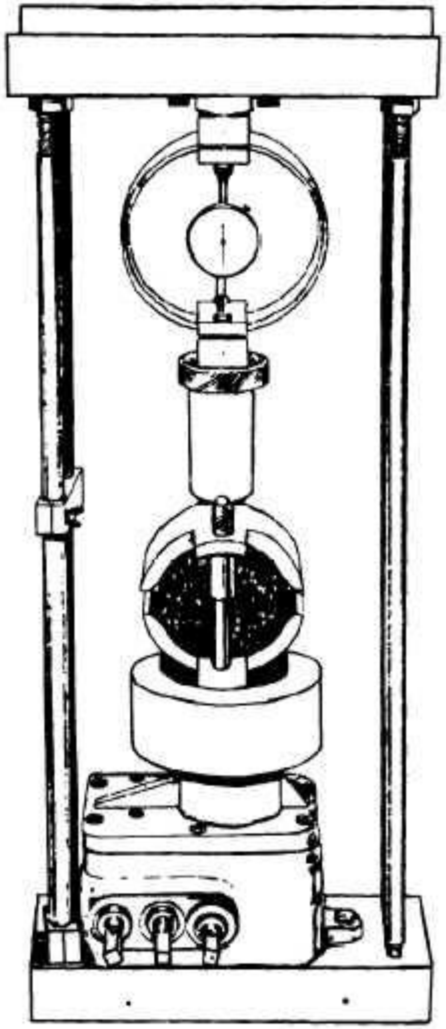
Marshall Method of Mix Design (1930s)

- Developed by Bruce Marshall of Mississippi Department of Highways
- In 1943 Marshall joined Corps of Engineers
- Adopted by Corps
  - World War II
- Post WWII method was applied to highways

Marshall Mix

- Used drop hammer instead of hand rammer
- Air voids calculated
- Stability test
  - Geometry different than Hubbard Field
- No VMA
- No absorption

Added in 1960s



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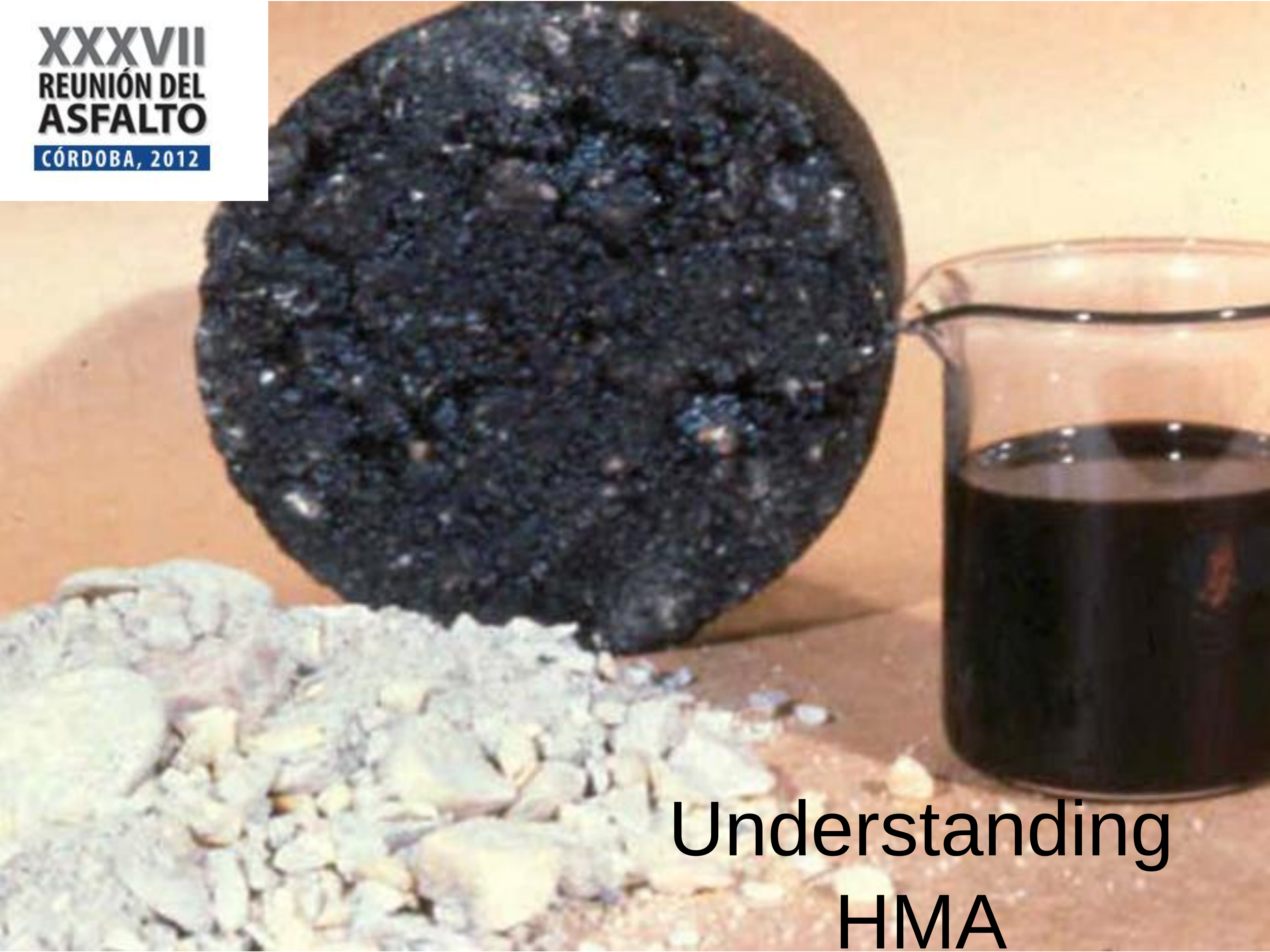
Strategic Highway Research Program (1990s)

shrp

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

Result of SHRP Research

- Performance Based Asphalt Binder Spec ✔
- Performance Based Asphalt Mixture Spec ✘ ✔
- Performance Based Mix Design System ✘



Understanding HMA

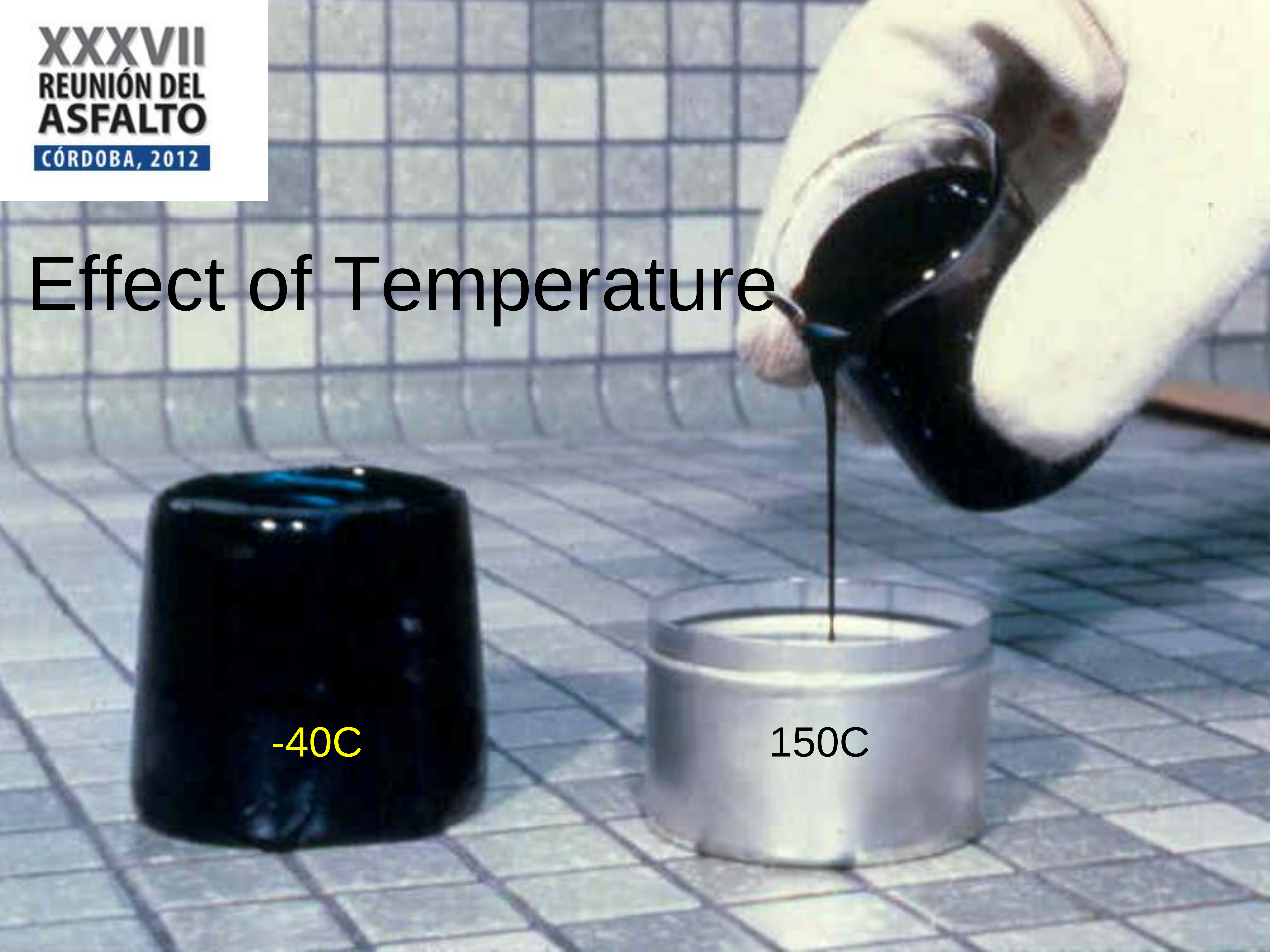
HOT MIX ASPHALT

- Hard elastic particles

- Visco-elastic, visco-plastic asphalt binder

- Effected by
  - Asphalt binder properties
  - Aggregate properties
  - Proportion of each

Effect of Temperature



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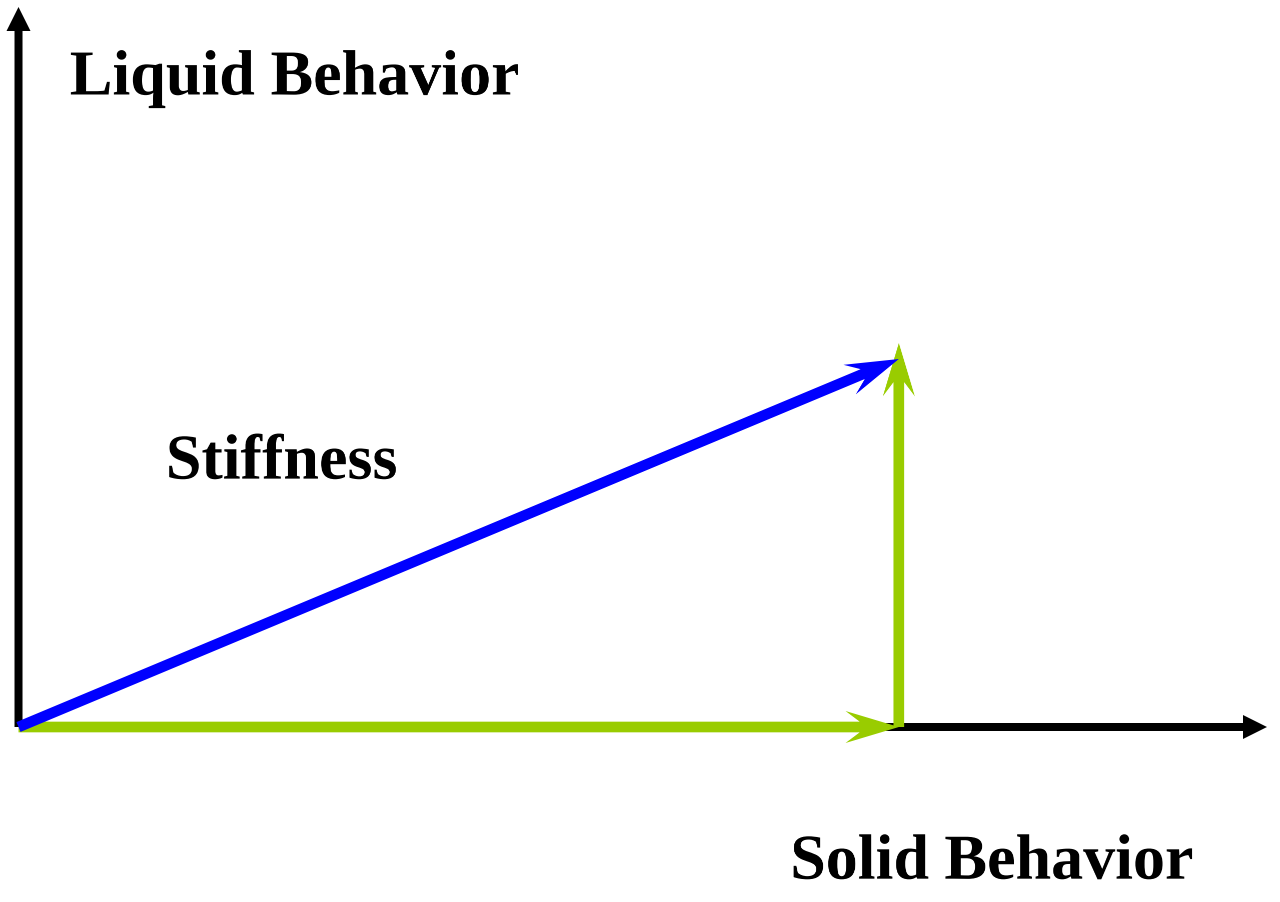
How hard is the water?

ASPHALT BINDER



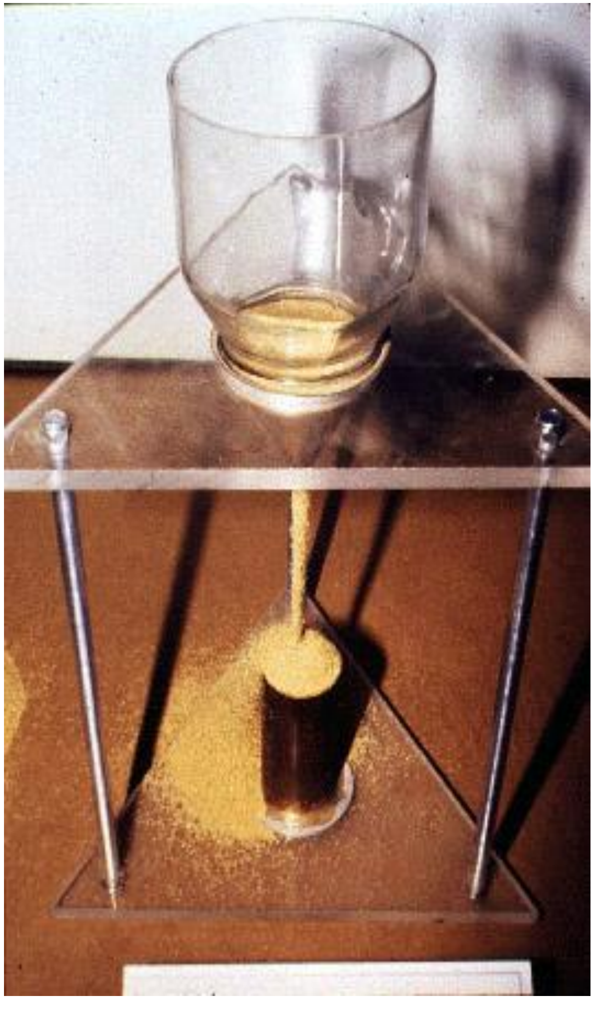
Percent Crushed Particles

0% Crushed **100% with 2 or More Crushed Faces**

Fine Aggregate Angularity

Natural sands:
typically 37 to 44

Manufactured sands:
typically 42 to 52



Asphalt Mixture Behavior

THEORY

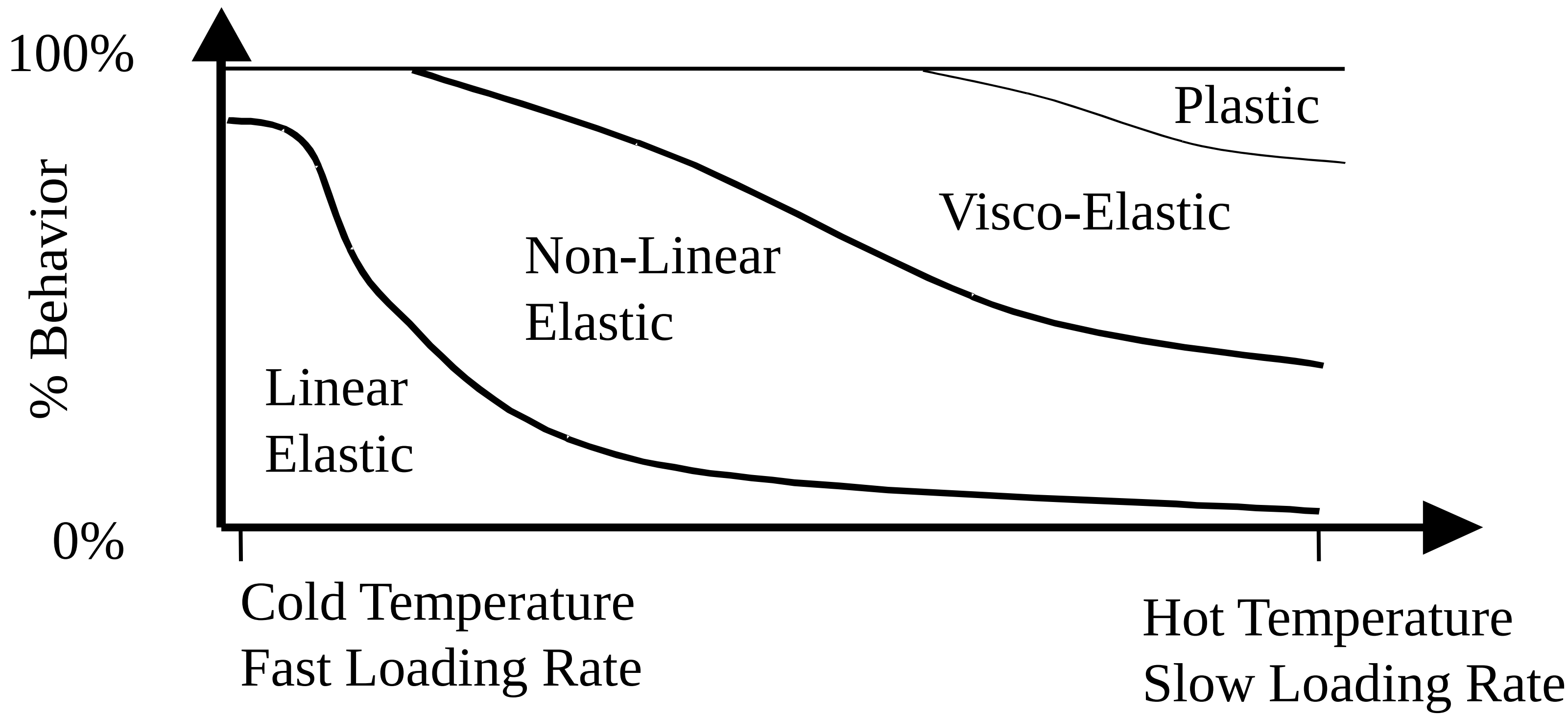
Asphalt Mixture Properties

- Linear Elastic
- Non-linear Elastic

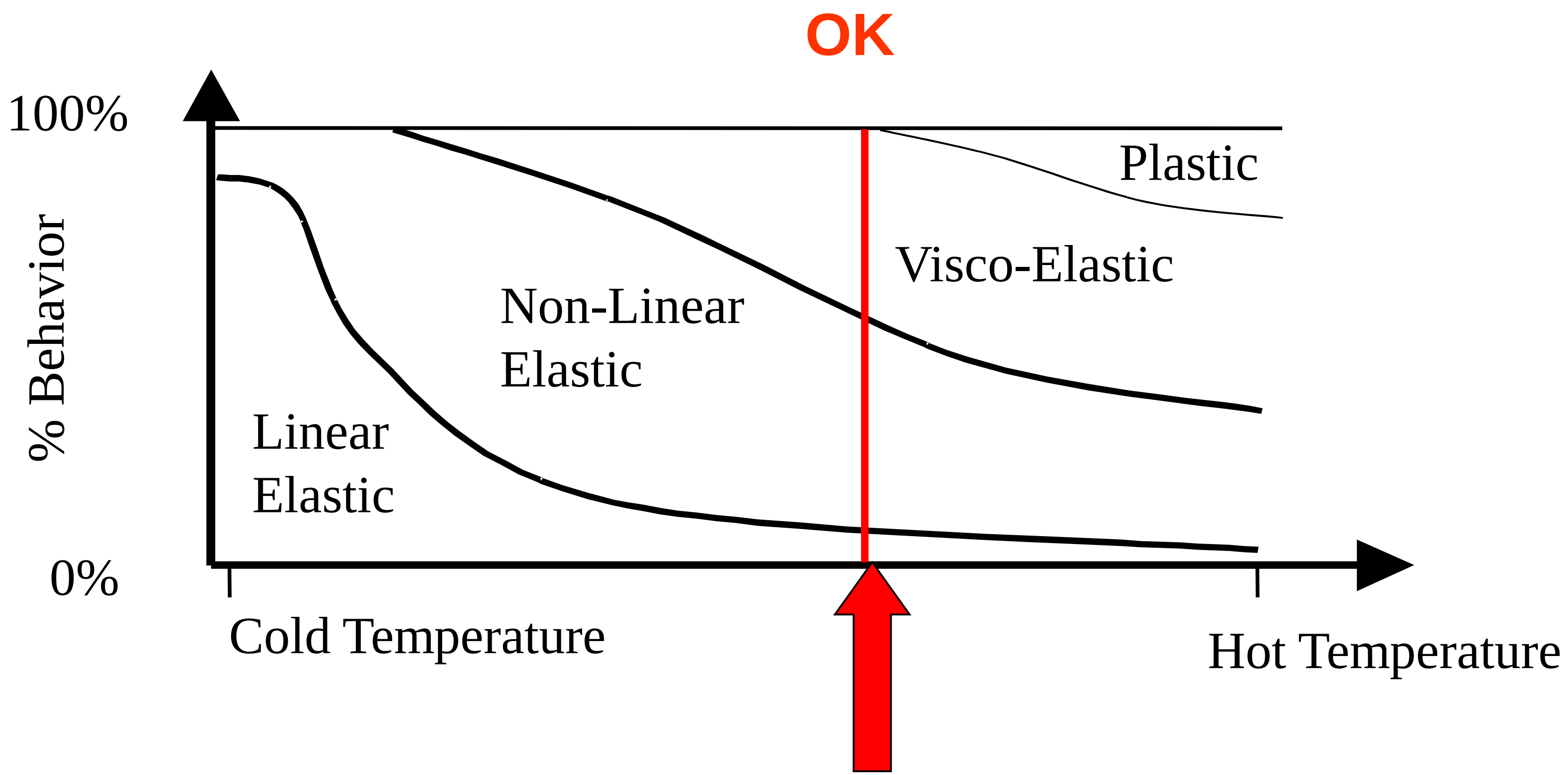
- Visco-elastic

- Plastic

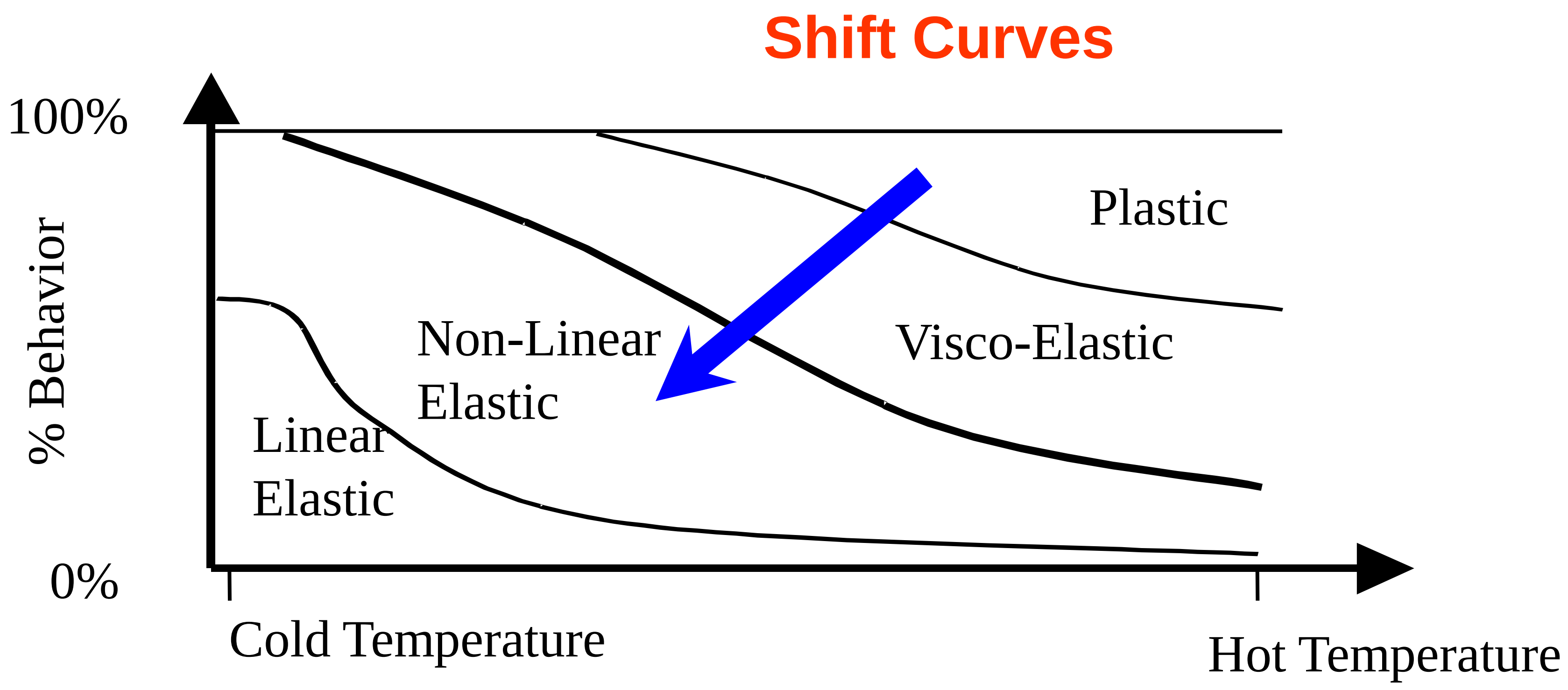
MIX PROPERTIES



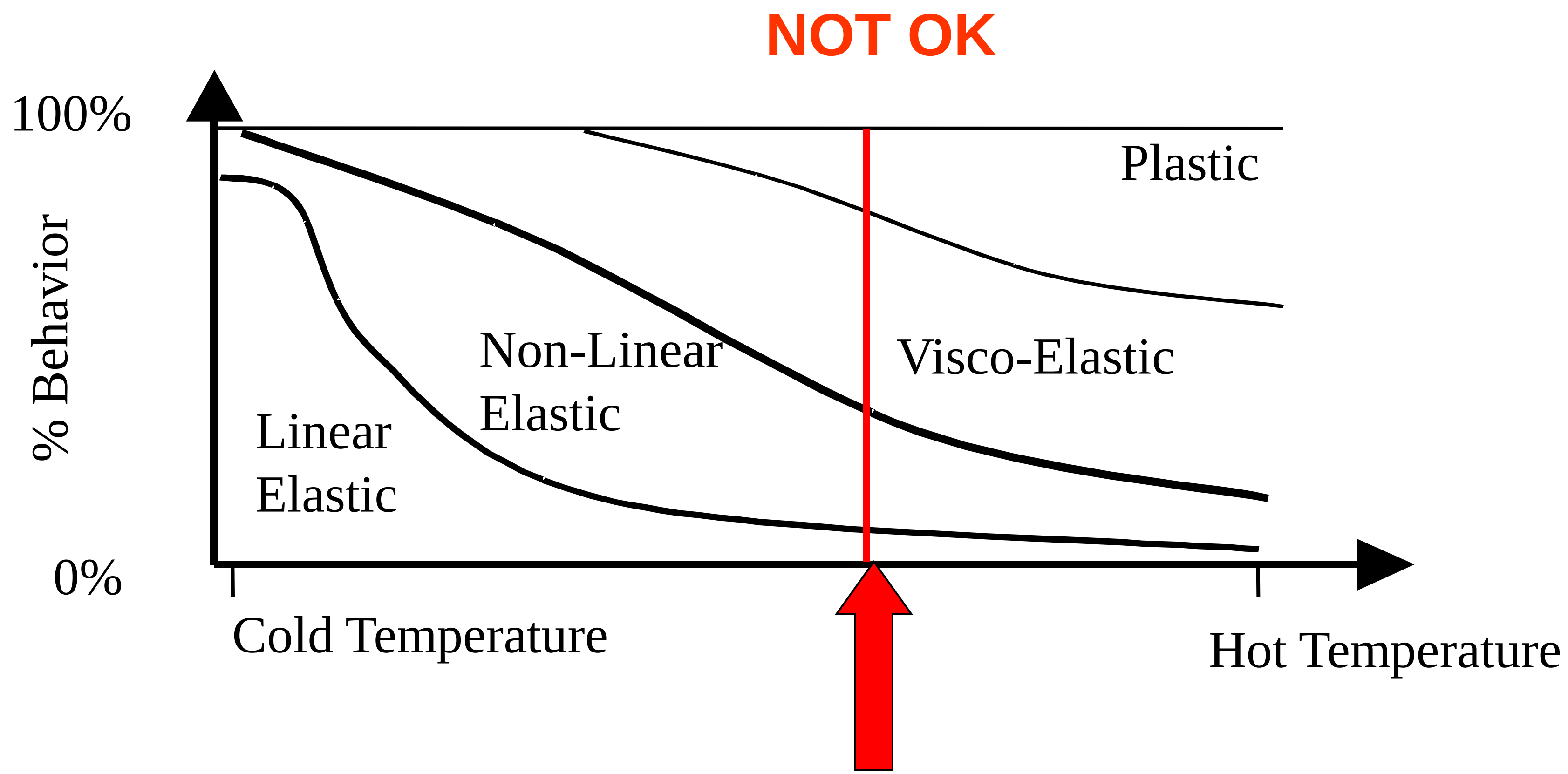
Rut Resistance



Low Air Voids



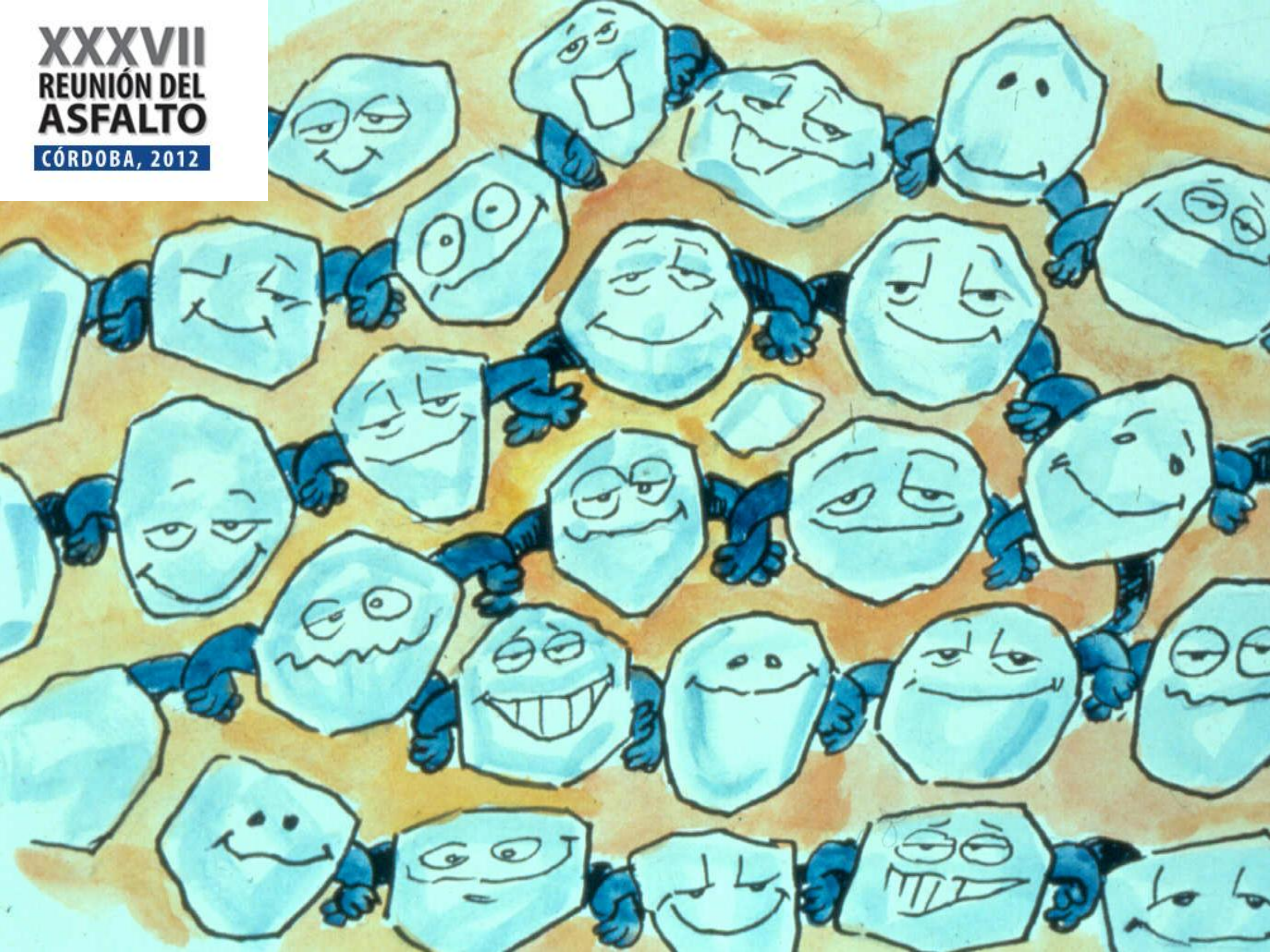
Rut Resistance



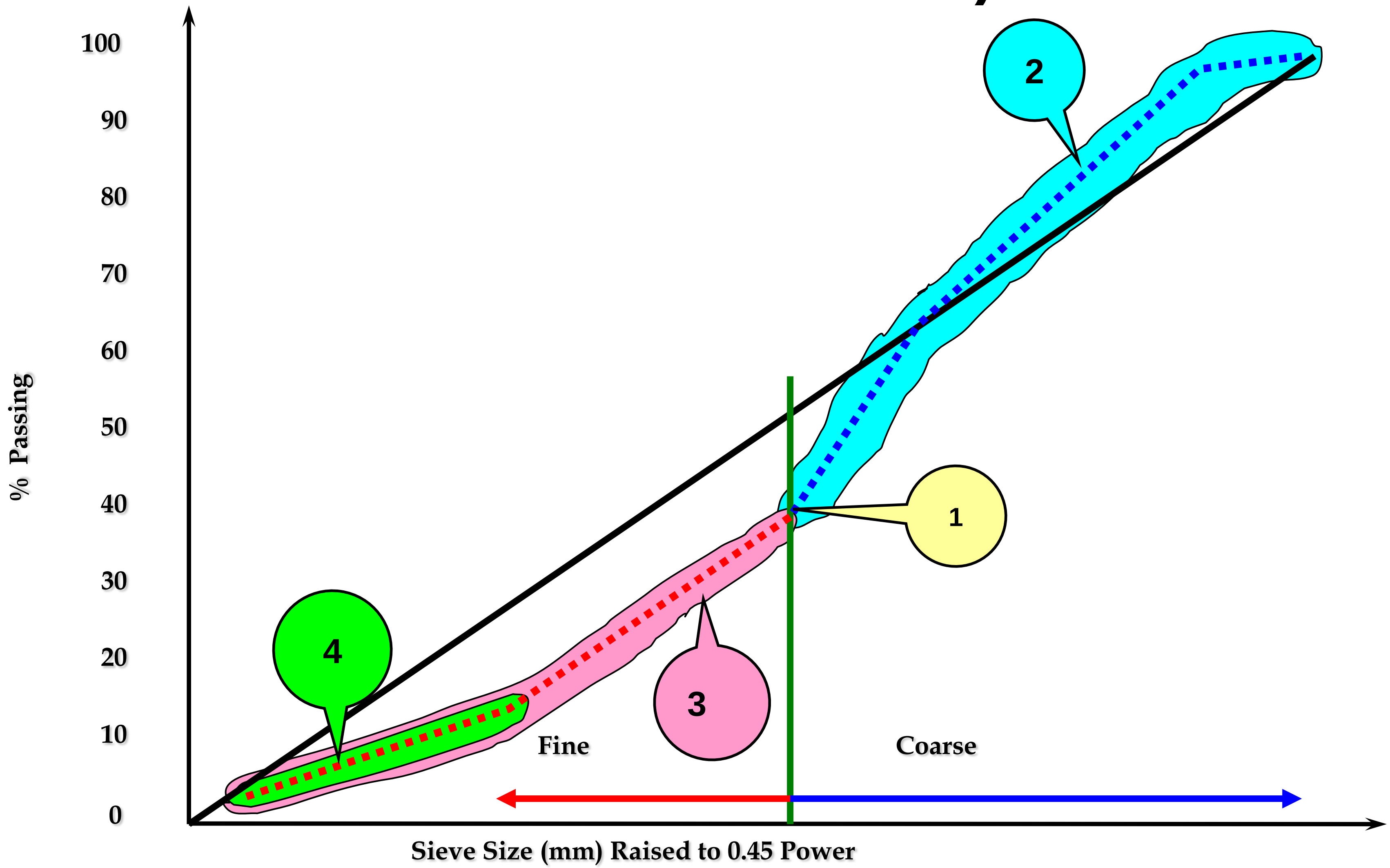
Asphalt Mixture Performance

PRACTICE

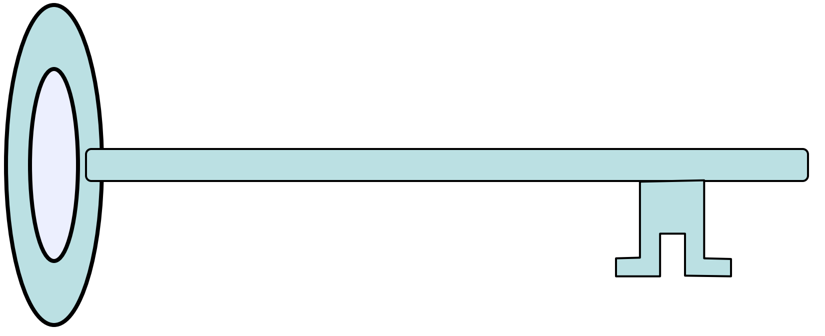
Rut Resistant



Gradation (Bailey Method)



Aggregates in Hot Mix

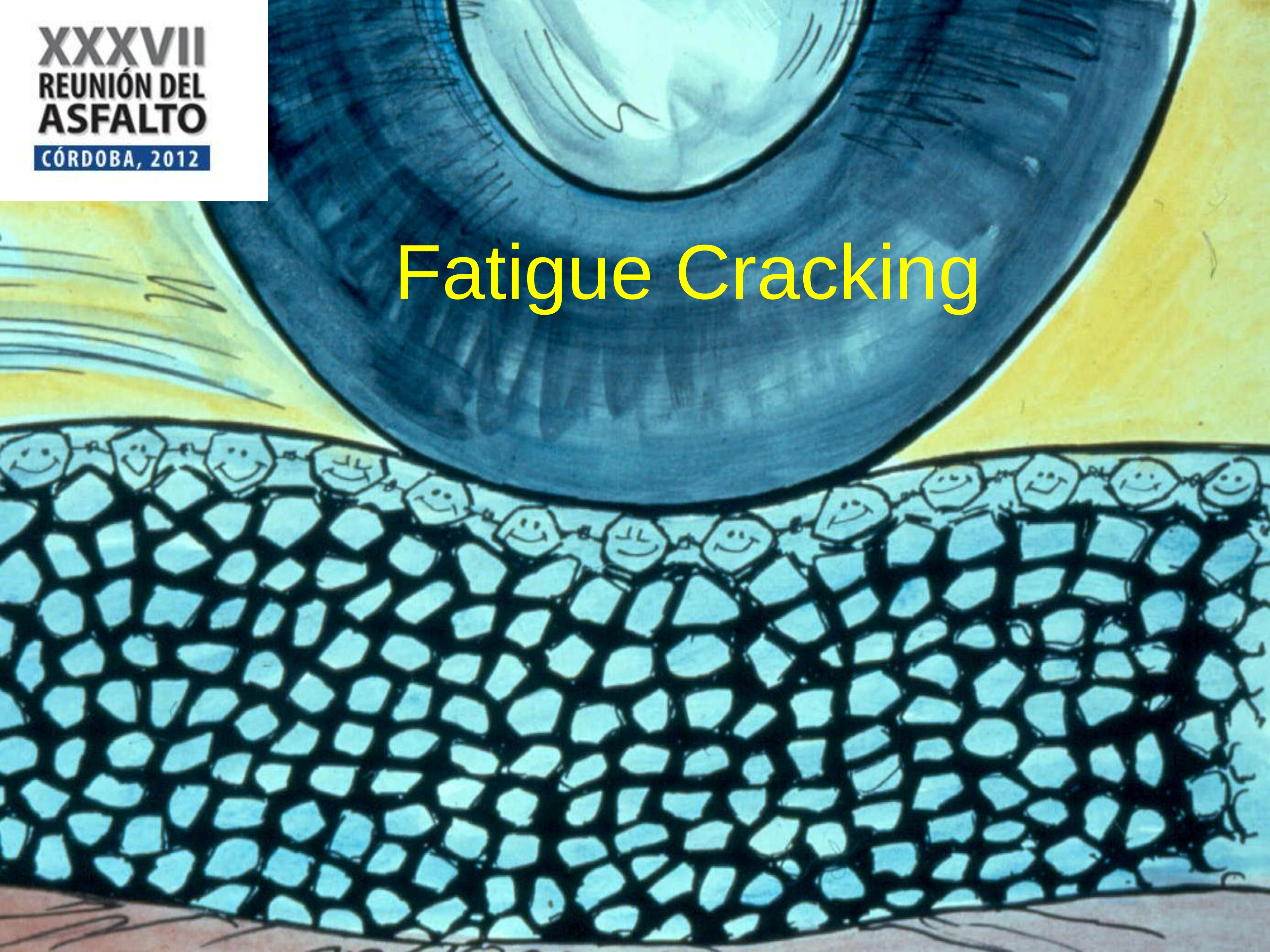


- KEY to non-rutting pavements
  - – Crushed aggregate, coarse and fine
  - – Adequate void properties

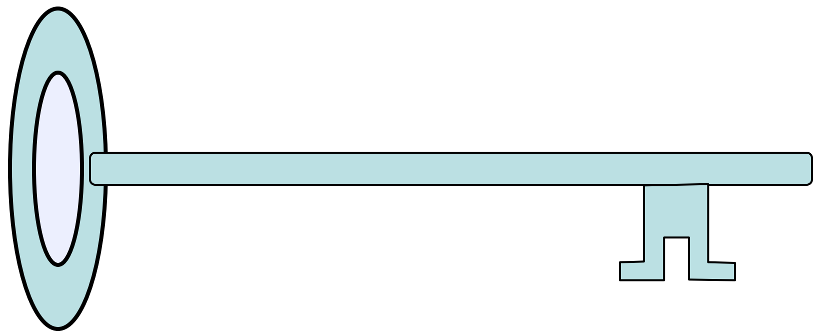
LOW TEMPERATURE CRACKING

- Effected by
  - PG low temp grade

Fatigue Cracking

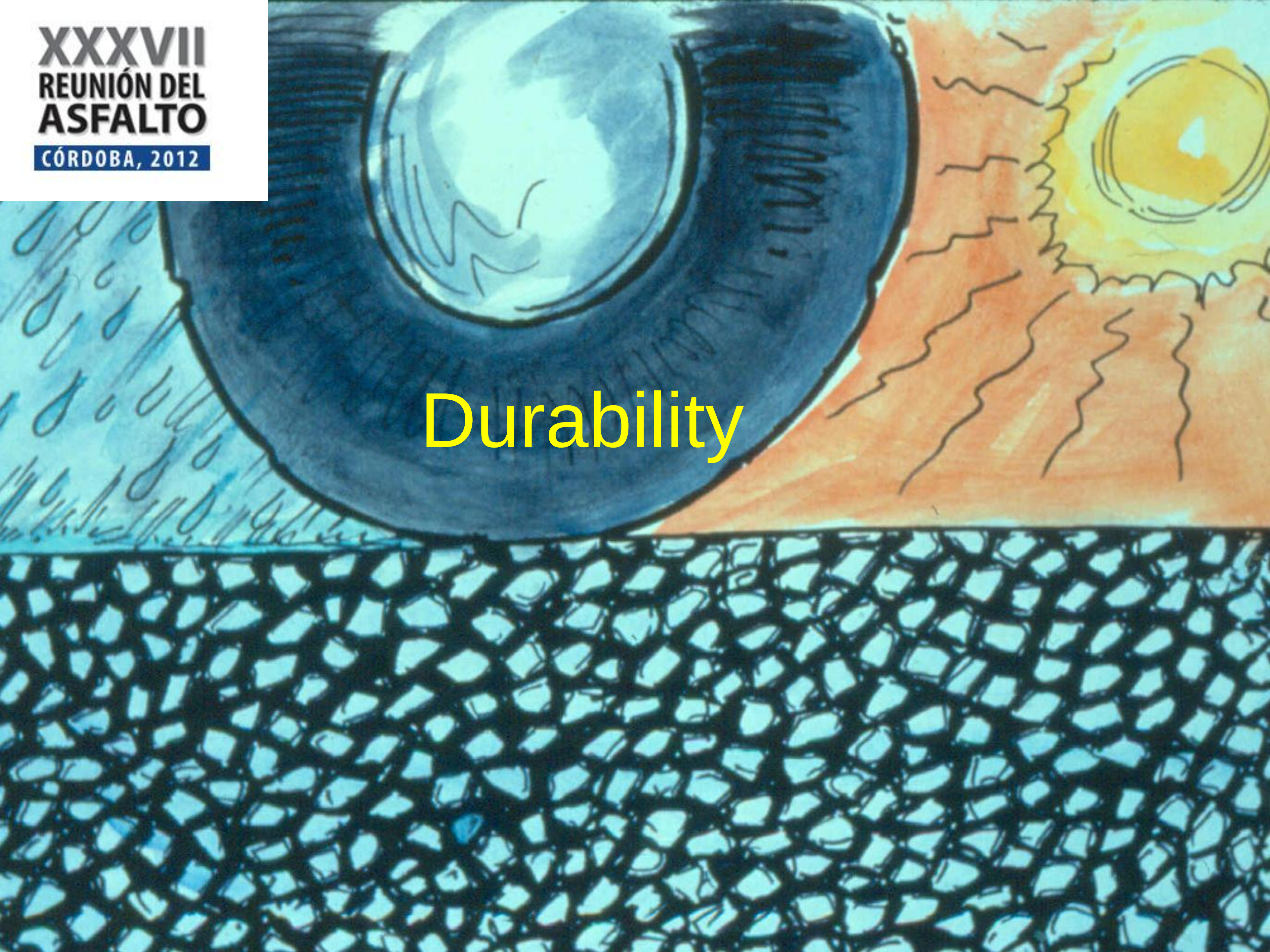


Asphalt in Hot Mix

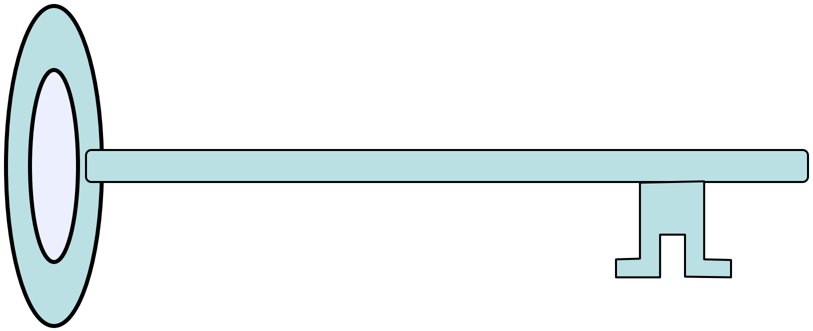


- KEY to fatigue resistant pavements
  - – Sufficient asphalt
  - – Sufficient thickness

Durability



Asphalt in Hot Mix



- KEY to durable pavements
  - Sufficient asphalt
  - Sufficient density

HMA Performance Properties

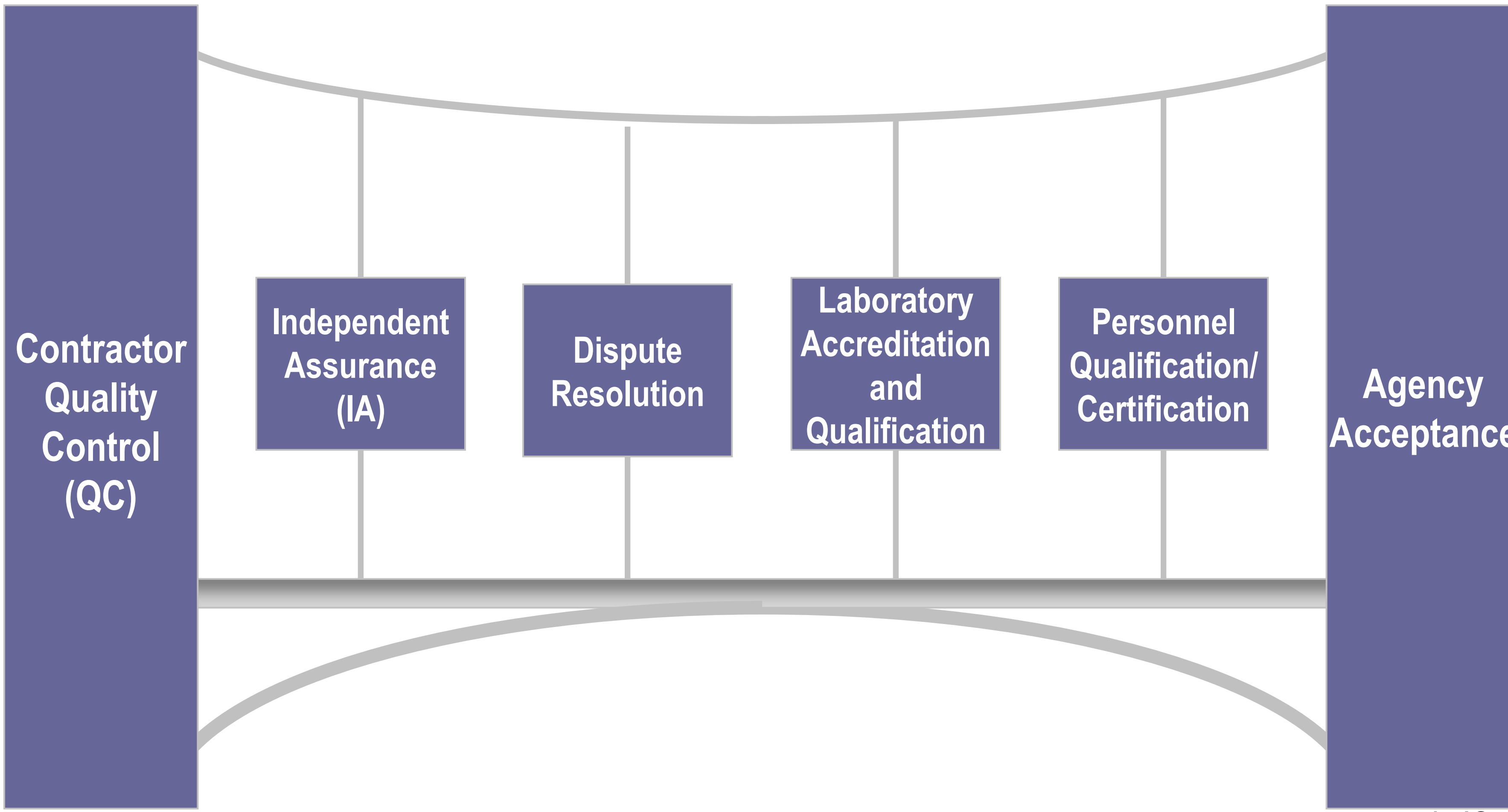
- Air voids (lab)
- Asphalt content
- In-place density
- Crush faces
- Binder grade

- Rutting
- Fatigue Cracking
- Low Temperature Cracking

HMA Acceptance Properties

- Manufacturing Properties
  - Asphalt binder grade
  - Asphalt content
  - Air voids (laboratory)
  - Voids in Mineral Aggregate
- Installation Properties
  - In-place density

Core Elements of a Quality Program



Contractor Responsibility for Quality Control

- Under a QA program, responsibility for QC is assigned to the contractor

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Scope of QC Activities

- QC Key Activities:
  - Materials production and transportation
  - Field placement processes
- QC Processes:
  - Sampling and testing
  - Inspection
  - Storage

Quality cannot be tested nor inspected into an HMA pavement. It must be built in through the implementation of Quality Control and Acceptance programs.

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AASHTO Sub-committee on Materials

"Developing a Quality Assurance Plan for Hot-Mix Asphalt (HMA)"

Standard R-42

Standard Practice -- R 42

- Presents details necessary to effectively control the ***production and placement*** of Hot-Mix Asphalt (HMA)

- Provides foundation (minimum requirements) for Construction Quality

AASHTO R 42 Contains

- Functions and Responsibilities
- Sampling
- Material Requirements
- Field Adjustments
- **Quality Control Systems**
- HMA Acceptance Procedures
- Dispute Resolution

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Quality Control Systems

- QC Plan for Asphalt Binder Materials
- QC Plan for Aggregate Production
- QC Plan for HMA Production
- QC Plan for Roadway Operations

Quality <u>CANNOT</u> be tested nor inspected into an HMA pavement. It must be <u>BUILT IN</u> through the implementation of Quality Control and Acceptance programs.

Aggregates

- **Stockpile gradation**
  - **Stockpiling**
- **Blended aggregate**
  - **Cold bin loading**
  - **Plant calibration**
- **Moisture content**
  - **Plant calibration**

Testing Plan

- **Binder Content**
- **Gradation**
- **Moisture Content**
- **Bulk Specific Gravity**
- **Maximum Specific Gravity**

Asphalt Binder Content

- **Options include**
  - **Ignition Oven**
  - **Extraction**
  - **Nuclear**

Gyratory Specimens

- **Agency Acceptance**
  - **1/1000t - Base & Inter**
  - **1/600t - Surface**
- **HMA (Certification)**
  - **First 250t & each 1000t for Base & Inter**
  - **First 250t & each 600t for Surface**

HMA Bulk Specific Gravity AASHTO T166

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Maximum Specific Gravity AASHTO T209

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Mixture Temperature

- **Verify plant mix temperatures are consistent**

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Quality Control Limits

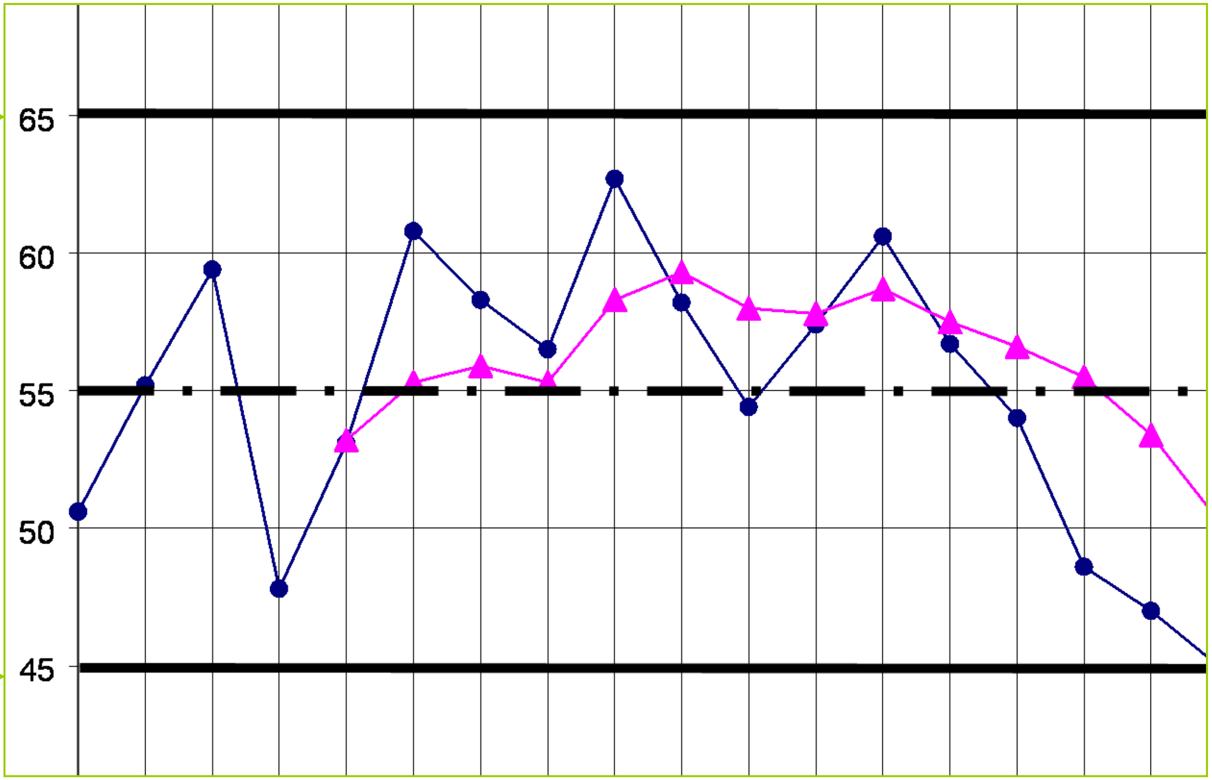
Parameter	Control limit (single test)
Aggregate Stockpile	¾ in. – No. 200
Blended Aggregate	¾ in. – No. 200
Binder content-mixture	± 0.7
VMA @ N_{des}, % (QC/QA HMA)	± 1.0
VMA @ N_{100}, Min % (SMA)	17.0
Target Air Voids % (Dense graded mixtures, SMA)	± 1.0

Control Charts

Control Limit

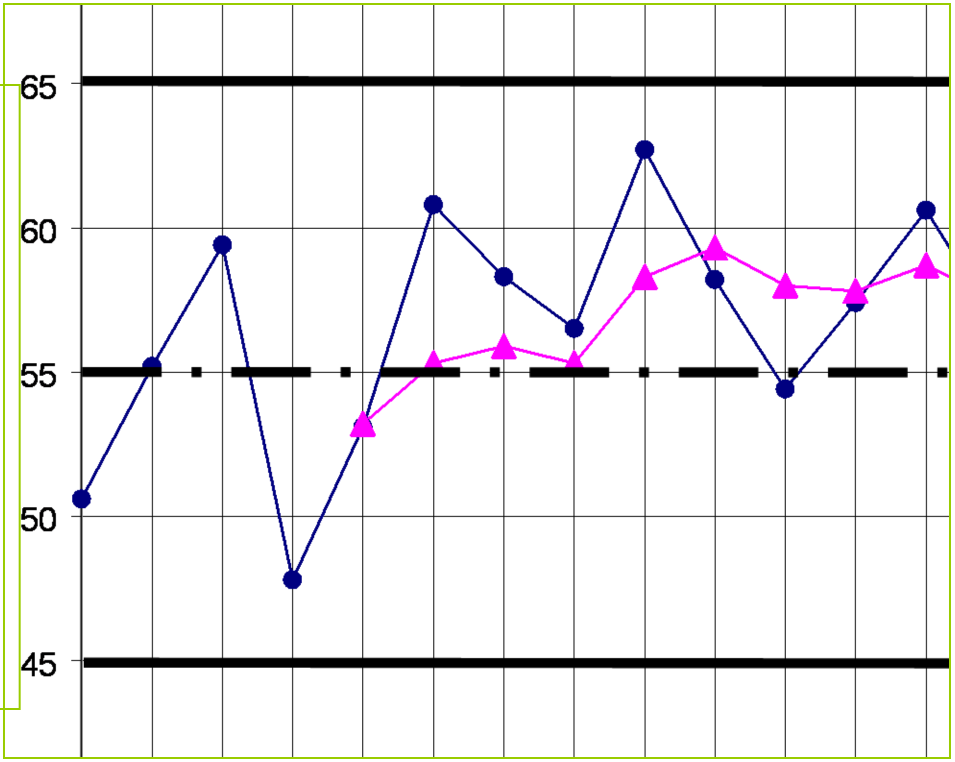
Target

Control Limit



Control Charts

- **Per mixture**
  - **Asphalt Binder Content**
  - **Air Voids**
  - **VMA**



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AASHTO Sub-committee on Materials

Standard - R 9

Hot Mix Asphalt Acceptance Sampling Plans For Highway Construction

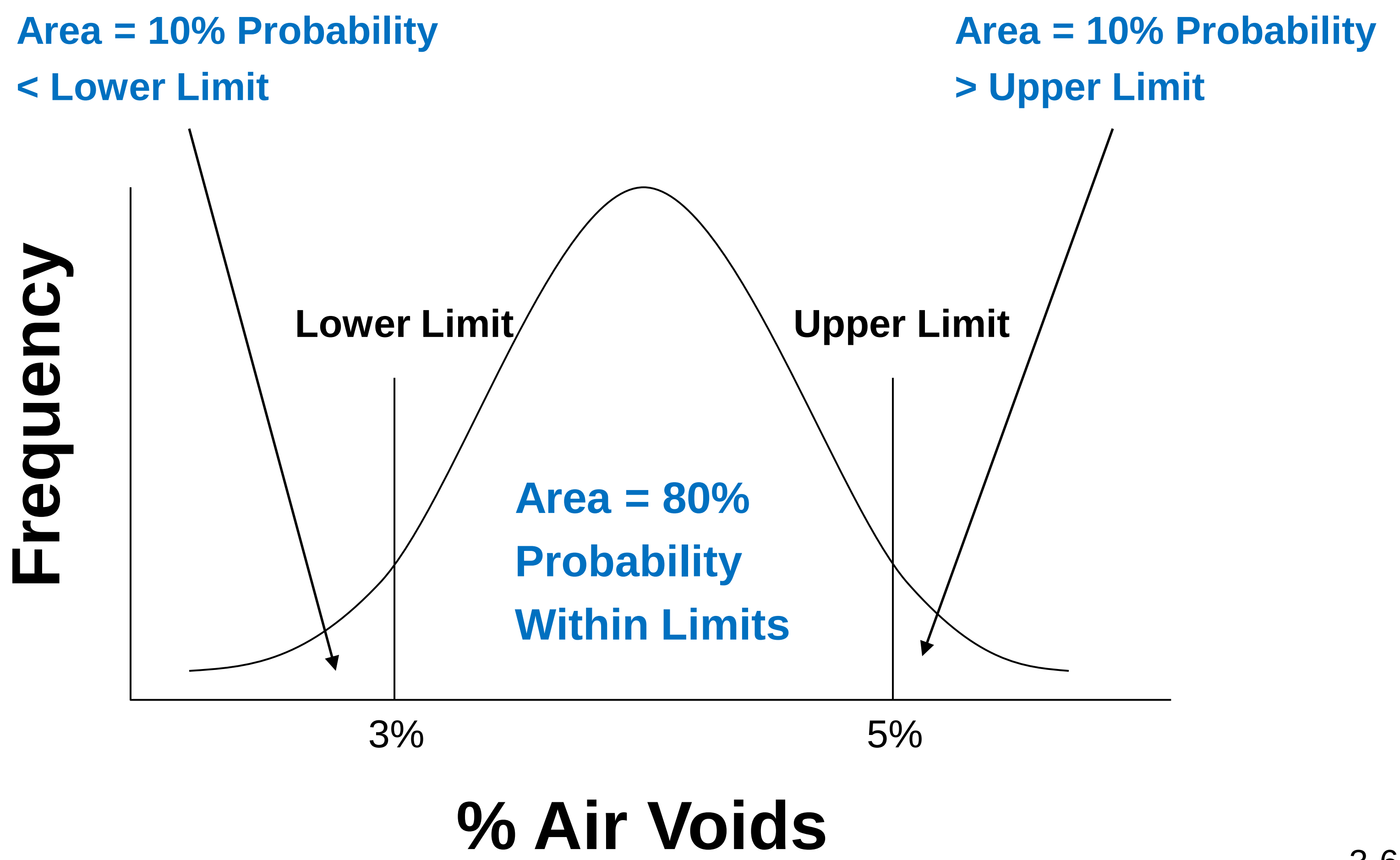
Standard Practice -- R 9

- ***1.2 "Purpose of Acceptance Plan***—

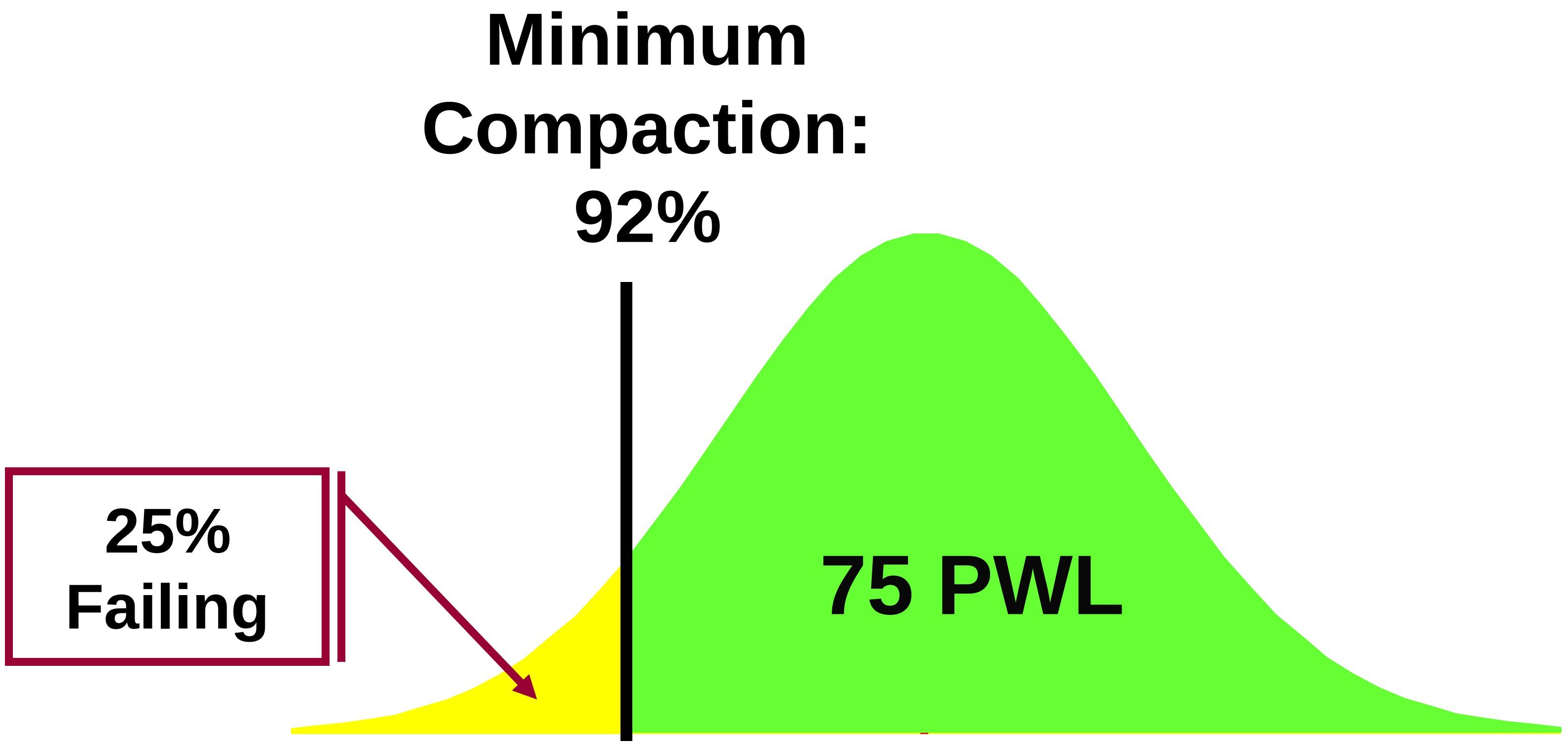
  Guidelines in the preparation of **statistically based acceptance plans using statistical and quality assurance (QA) principles**.

- Preferred Method is
  Percent within Limits (PWL)
  - Statistical evaluation using mean and standard deviation

PWL with Two Limits

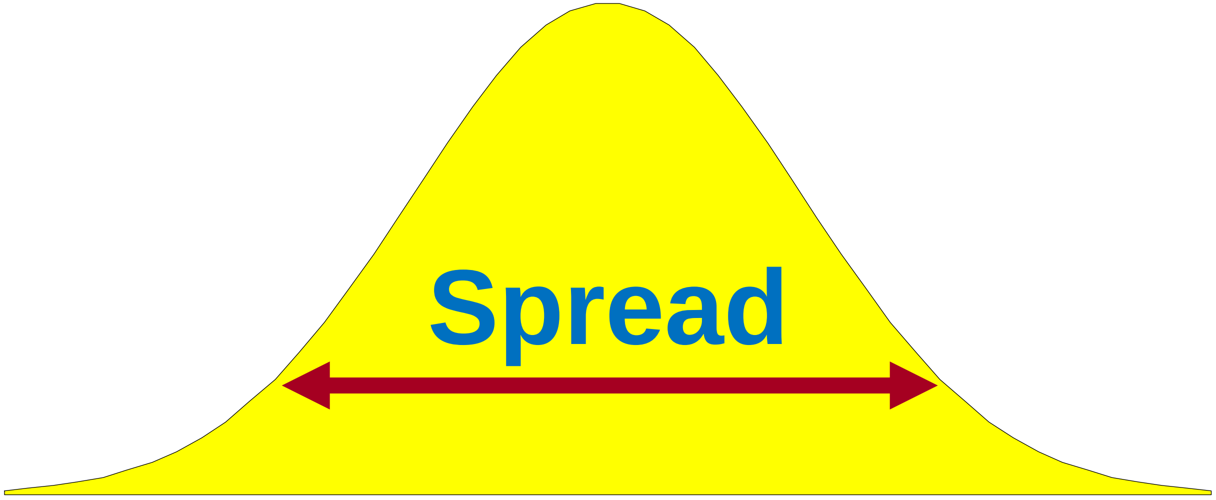


PWL with One Limit

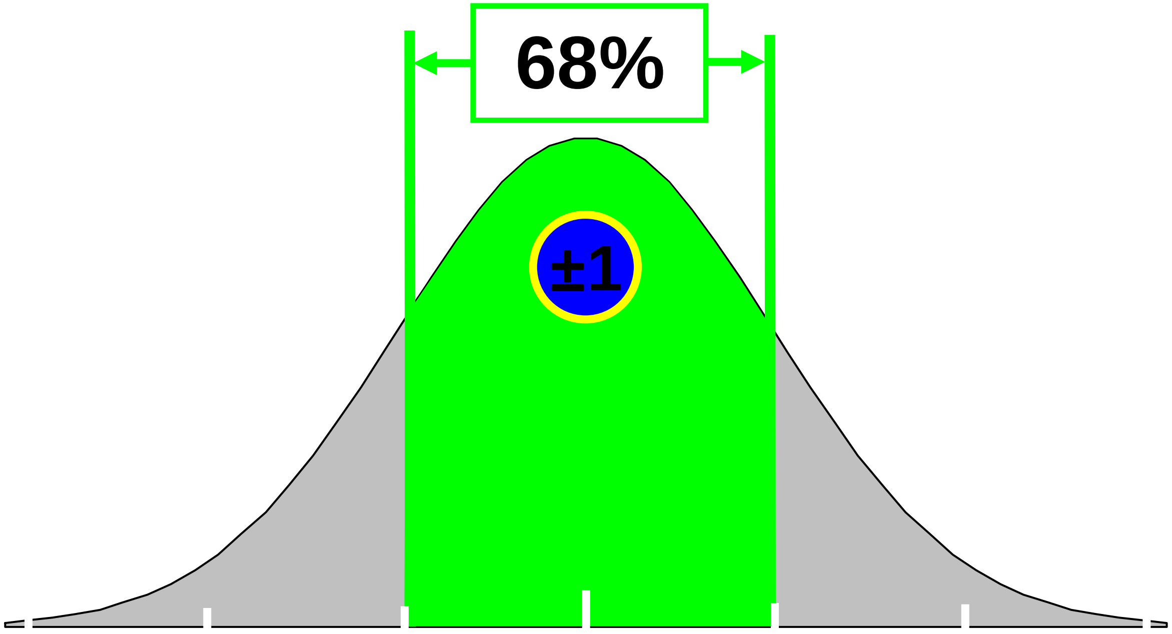


Standard Deviation

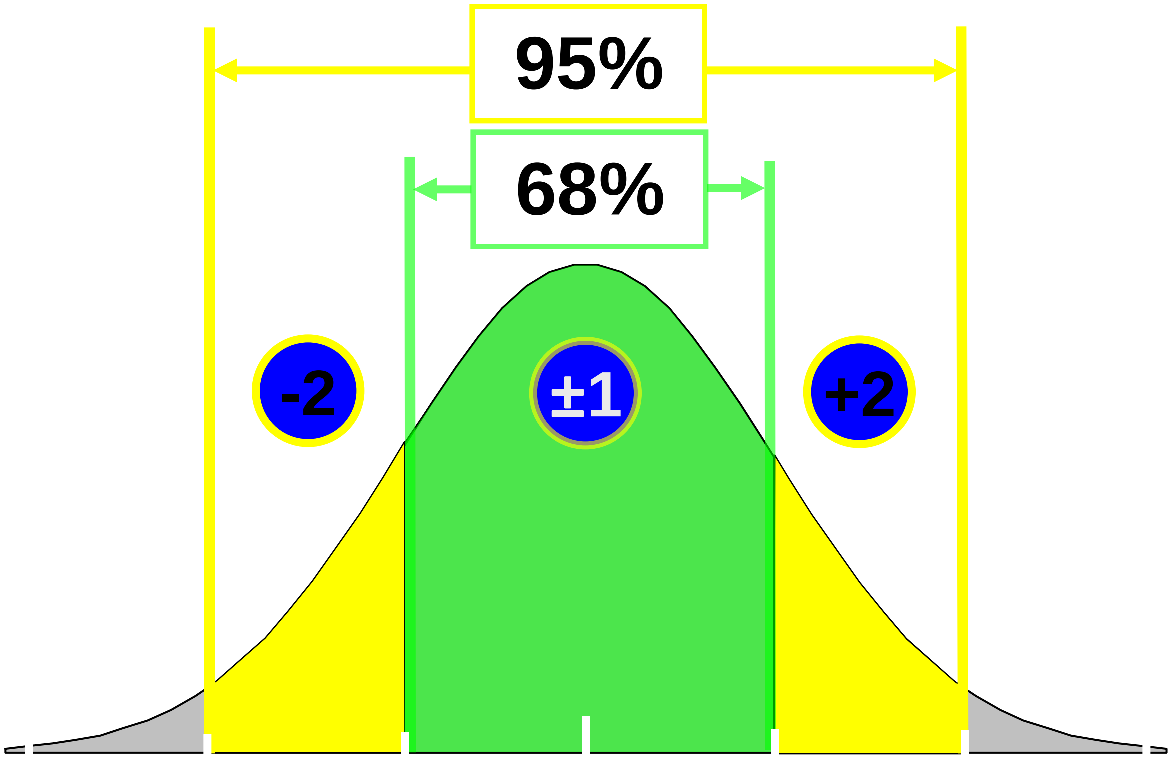
- A measure of the variability (i.e. spread) of data



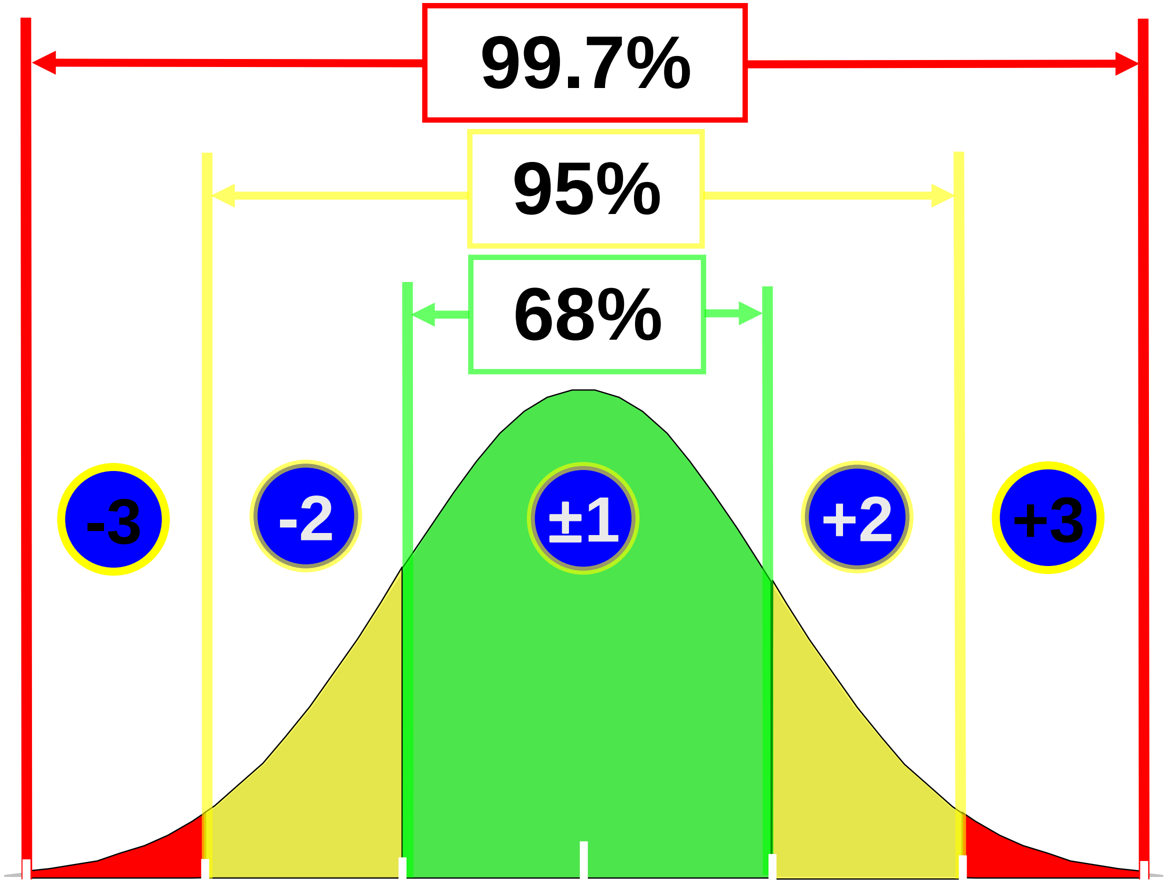
Data within ± 1 Standard Deviation



Data within
: 2 Standard Deviations



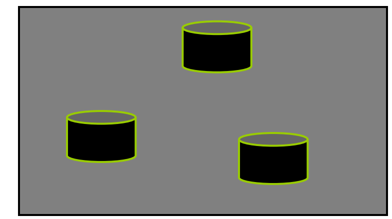
Data within
± 3 Standard Deviations



Steps for Estimating PWL

1. Obtain random samples

Lot



AC_1 AC_2 AC_3

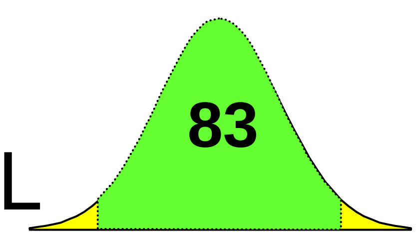
2. Compute
   - Mean ($\bar{x}$)
   - Standard deviation (s)

$\bar{x}$, s

Q

3. Compute quality index (Q)

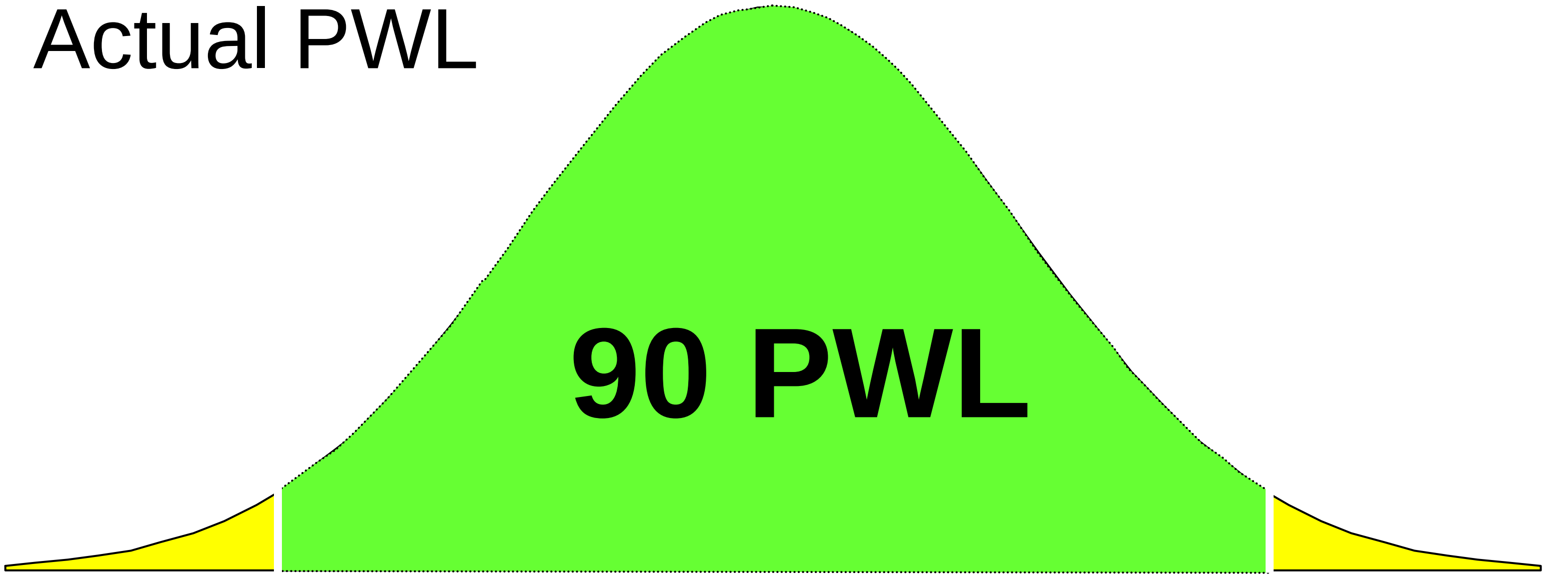
4. Convert Q to “estimated” PWL



LSL USL

Example

- Actual PWL



Example (cont'd)

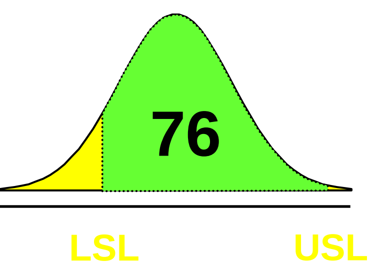
Due to variability…

Lot 1

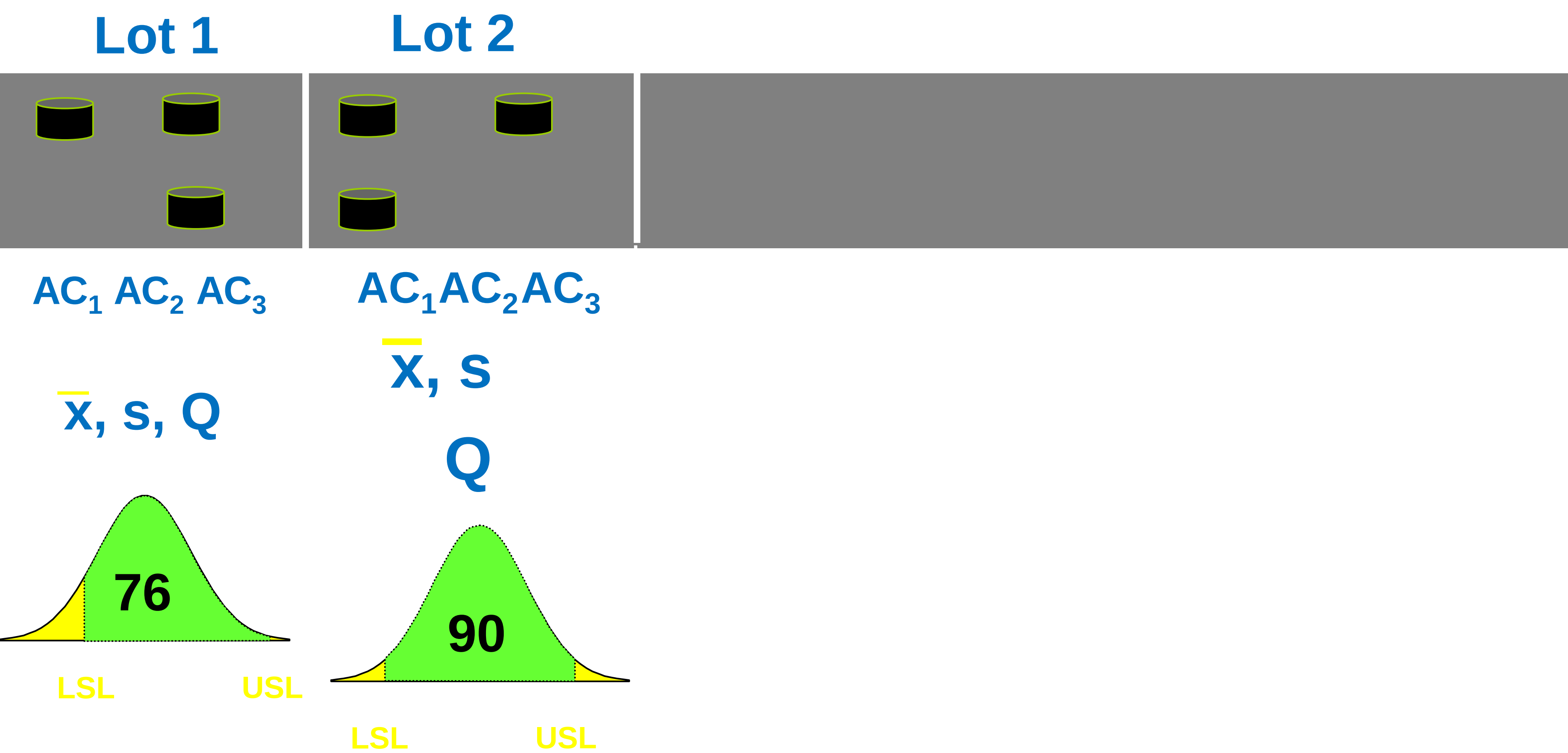
$AC_1 AC_2 AC_3$

$\bar{x}$, s

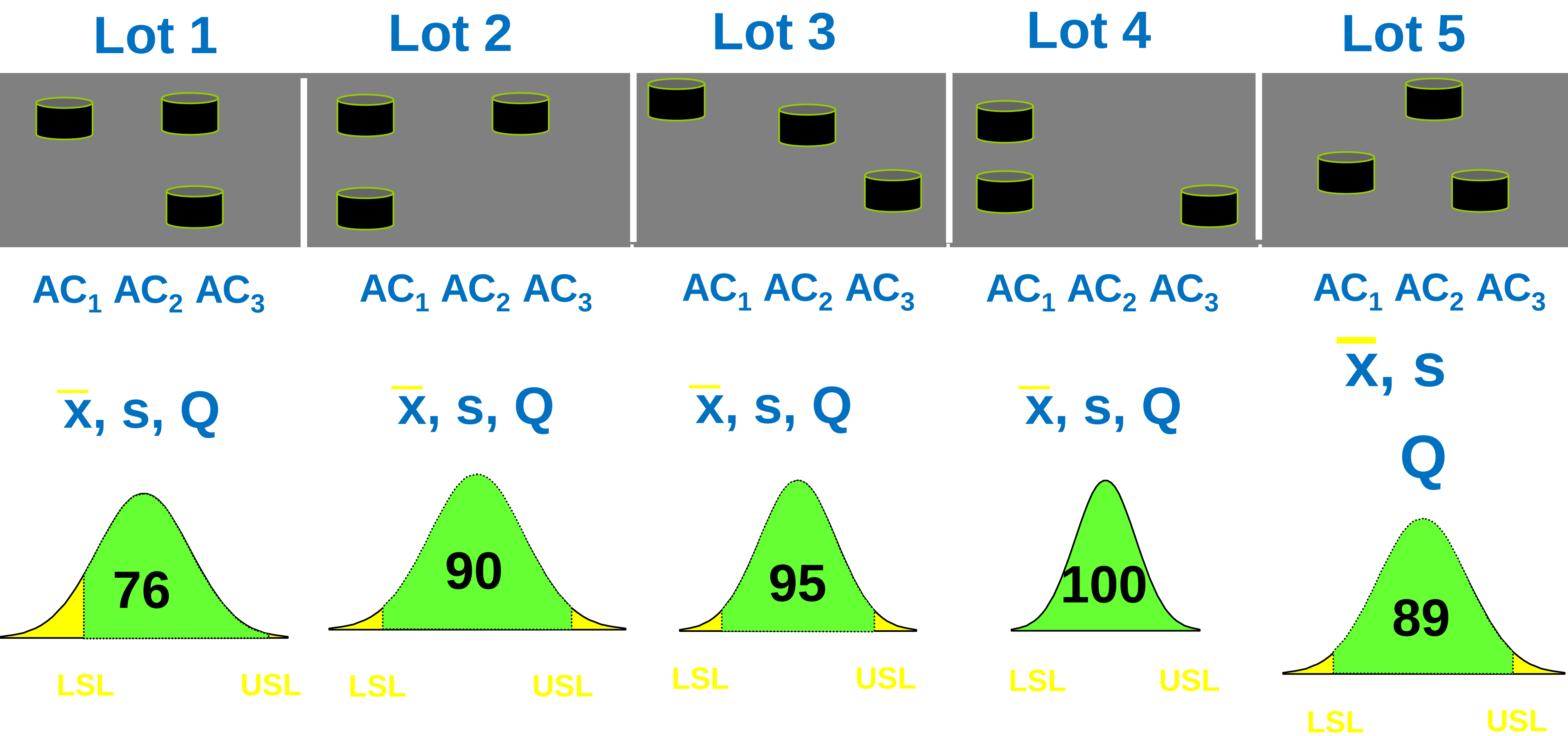
Q



Example (cont'd)



Example (cont’d)



Recommended Criteria

- **Air Voids**: ± 1.2% of the target value for the mixture type, 90 PWL for full pay

- **VMA**: - 0.5 % and + 2.0% of the minimum design value for the mixture type,
  90 PWL for full pay

- **Pavement Density**: minimum of 92% of the mixture TMD, 90 PWL for full pay

- **Binder Content**: ± 0.4% of the target value for the mixture type, 90 PWL for full pay

Example Pay Factor

- **Binder Content**: 35% of pay factor

- **Air Voids**: 25% of Pay Factor

- **VMA**: 10% of Pay Factor

- **Pavement Density**: 30% of Pay Factor

PWL Positive Qualities

- Consistency is rewarded
- Uniformity in construction and materials helps in pavement service life
- PWL encourages greater understanding of materials – cause and effect

PWL Negative Qualities

- Complex calculations to get pay factor
- Penalty possible even if all tests are within the specified limits
  - High standard deviation

PWL

- Make contractor think different about production of HMA mixtures from raw materials to plant production to lay down operation.
- Contractor will learn a lot about the cause and effects of all their QC decisions

Summary

- History of Mix Design
- Development of Superpave Mix Design
- Volumetric Properties to Control Mechanical Properties
- Acceptance Method for Volumetric Properties