SUPERPAVE MIX DESIGN

Superpave Gyratory Compaction and Mixture Requirements

- Section objectives
  - –Describe the Superpave gyratory compactor
  - –Review the Superpave mixture requirements
  - –Summarize the moisture sensitivity test

<u>Final Result</u>

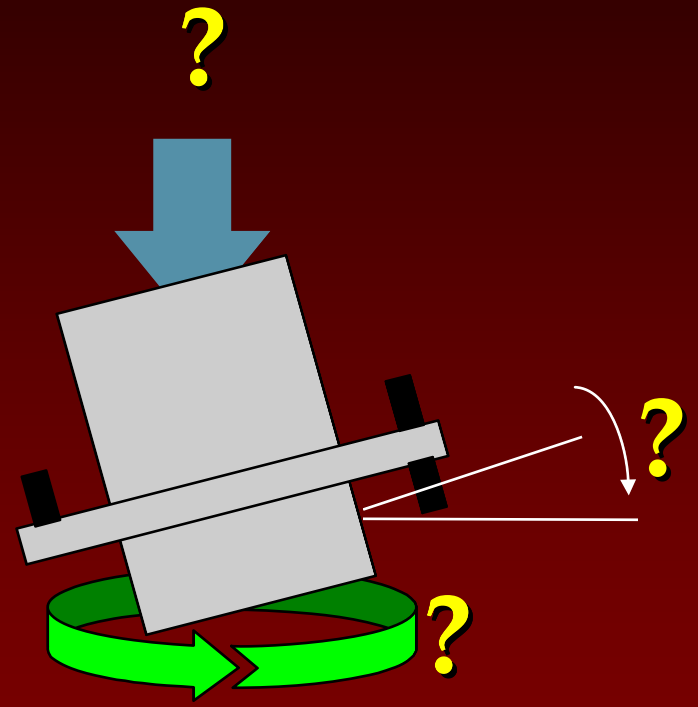
Participant will know the principles of the SGC and what mix criteria are included in the Superpave system

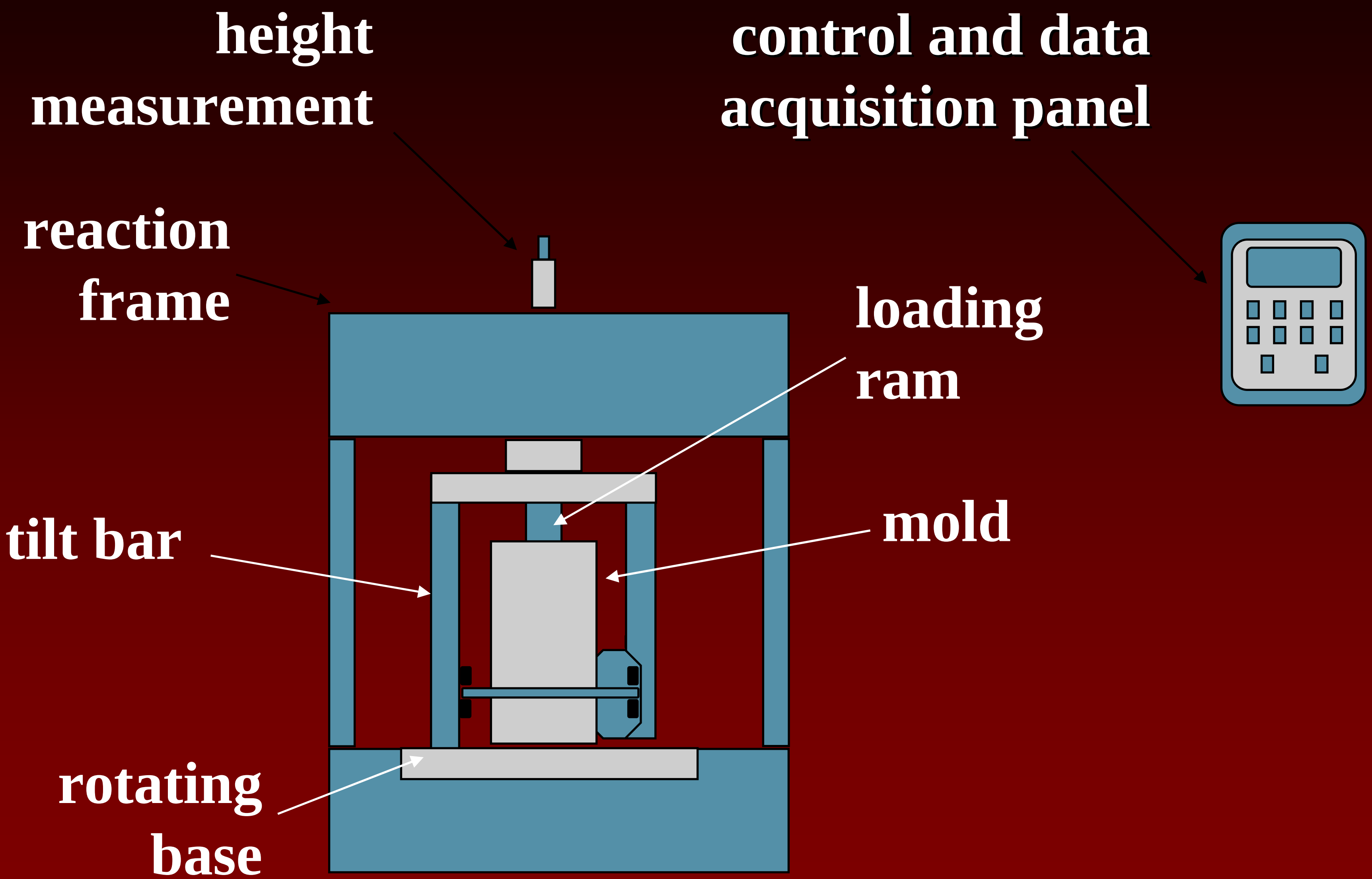
Goals of Compaction Method

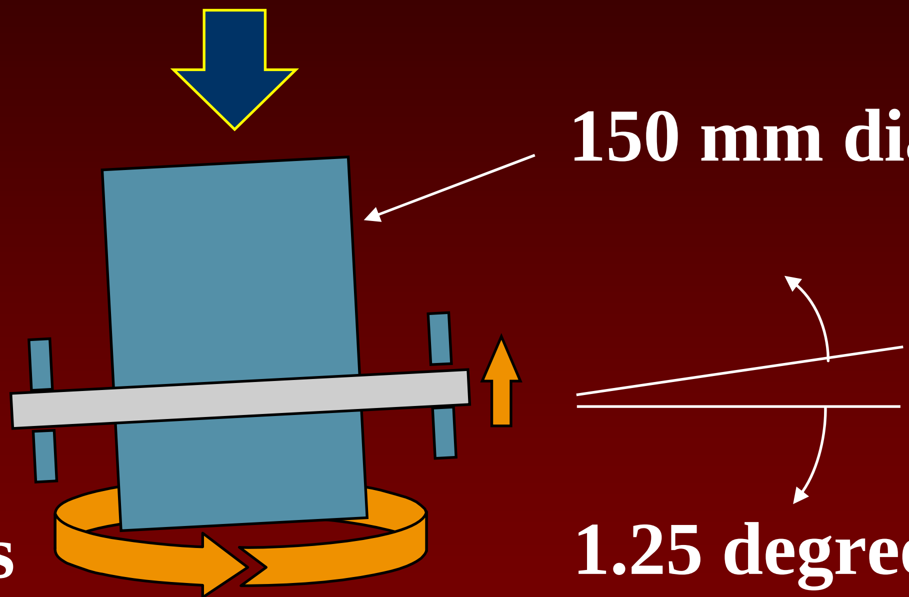
- Simulate field densification
  - traffic
  - climate
- Accommodate large aggregates
- Measure of compactability
- Conducive to QC

Superpave Gyratory Compactor

- Basis
  - Texas equipment
  - French operational characteristics
- 150 mm diameter
  - Up to 37.5 mm nominal size
- Height recordation



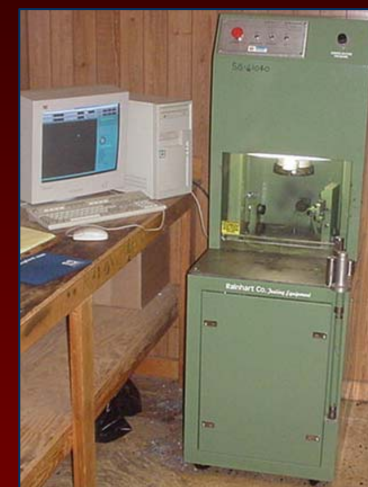

height
measurement
control and data
acquisition panel
reaction
frame
loading
ram
tilt bar
mold
rotating
base


ram pressure
600 kPa
150 mm diameter mold
30 gyrations
per minute
1.25 degrees
(external)

Common SGC Types

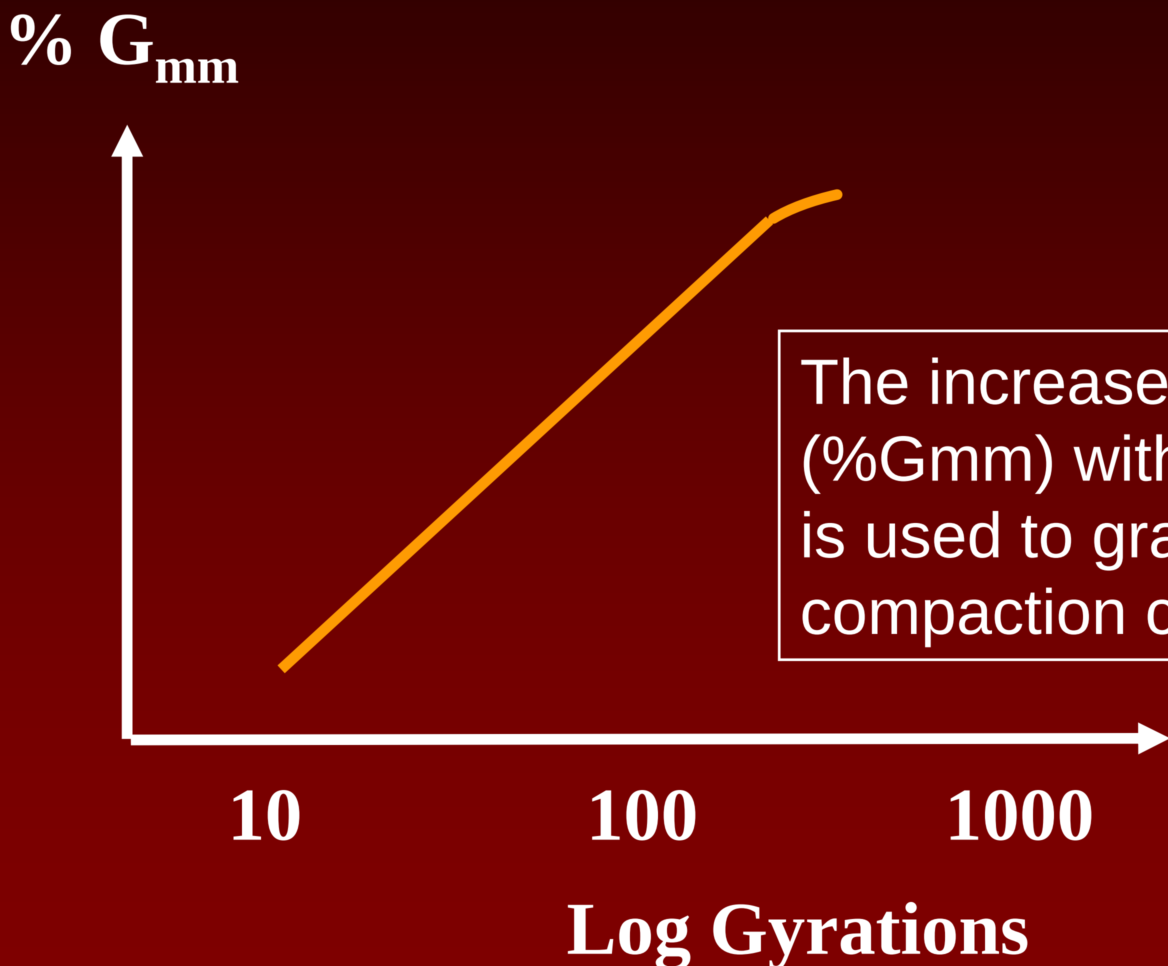






Troxler	Pine	Brovold	Interlaken	Rainhart
4140	AFGC125X	HM-293	GYR-001	144
4141	AFG1A			

SGC Compaction Curve



The increase in density (%Gmm) with each gyration is used to graph this compaction curve.

Gyratory Compaction

- We will evaluate the density of the HMA at two points:
  - $N_{initial}$
  - N_{design}
- These N's represent numbers of gyrations.

Current AASHTO N_{design} Table

Traffic Level	Compaction Level	
	$N_{initial}$	N_{design}
< 0.3	6	50
0.3 to < 3.0	7	75
3.0 to < 30.0	8	100
> 30.0	9	125

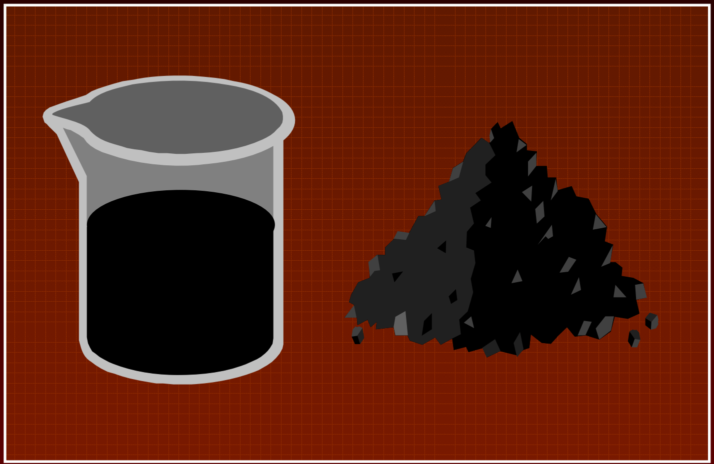
Some States use different N_{design} Tables

Gyratory Compaction

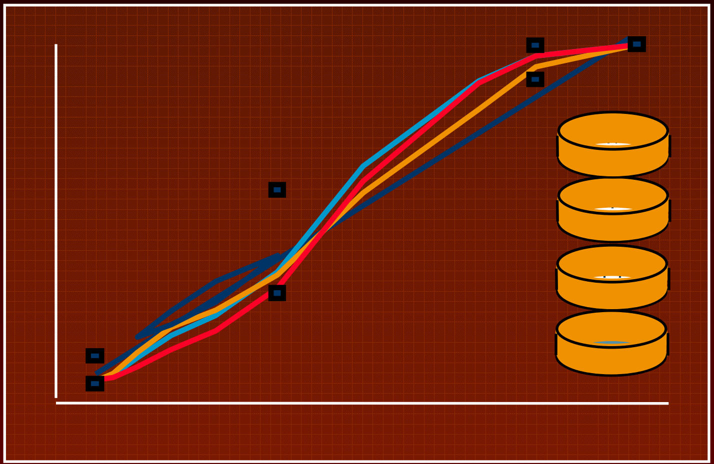
- The density (G_{mb}) @ N_{design} is the most important. This is where we will calculate the volumetric properties.

- $N_{initial}$ and N_{design} are points at which we use to check the compactability and densification of the HMA.

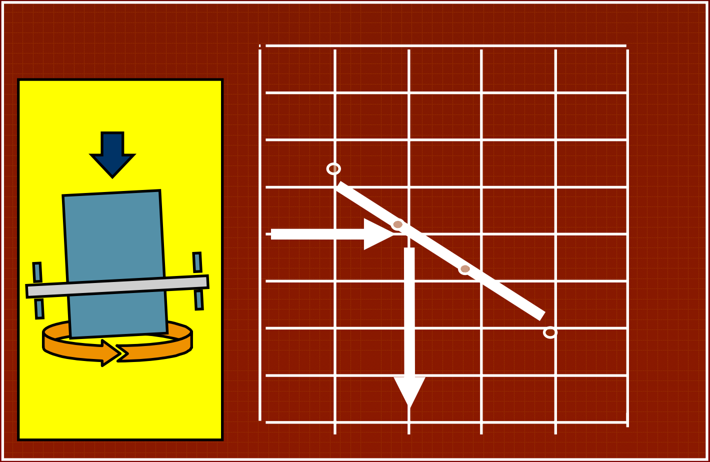
Four Steps for Superpave Mix Design



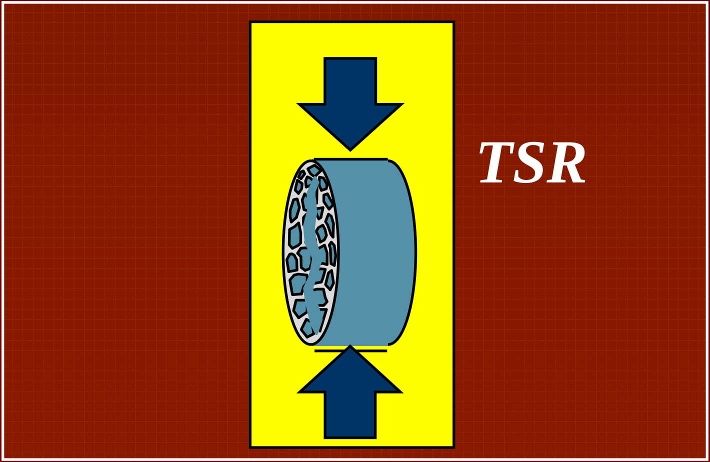
1. Materials Selection



2. Design Aggregate Structure



3. Design Binder Content

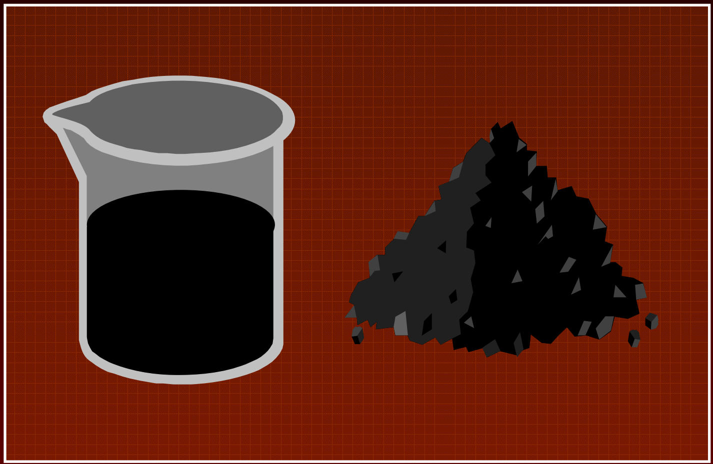


4. Moisture Sensitivity

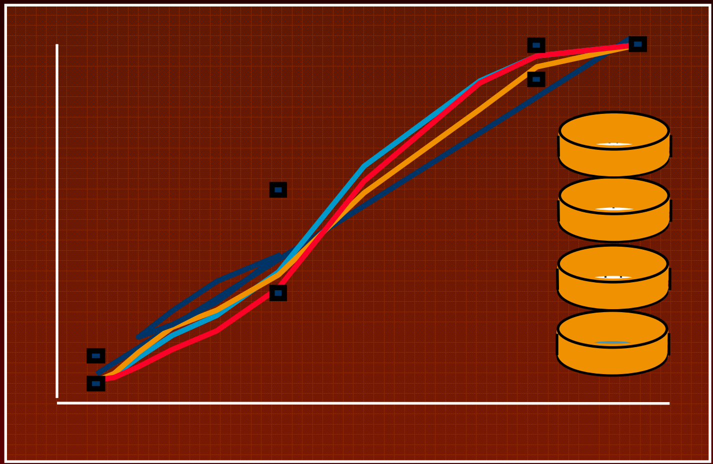
Example Project Data-

- Project on I-43
- Milwaukee, Wisconsin
- 18,000,000 ESAL Design
- Asphalt Overlay - 88 mm total thickness
  - 38 mm - wearing course (12.5 mm NMAS)
  - 50 mm - intermediate course (19 mm NMAS)

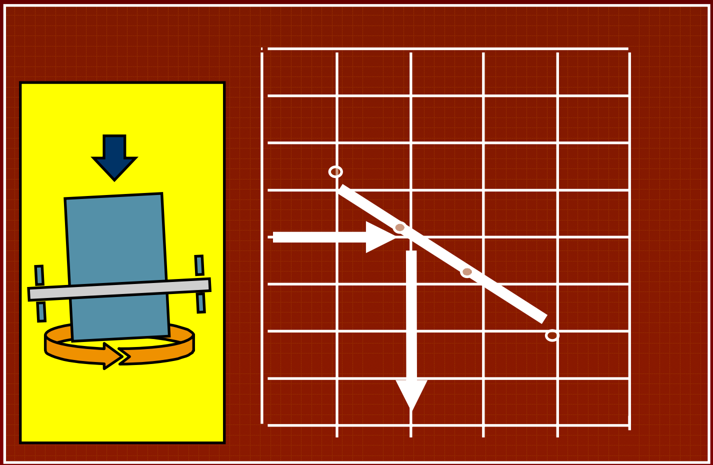
4 Steps of Superpave Mix Design



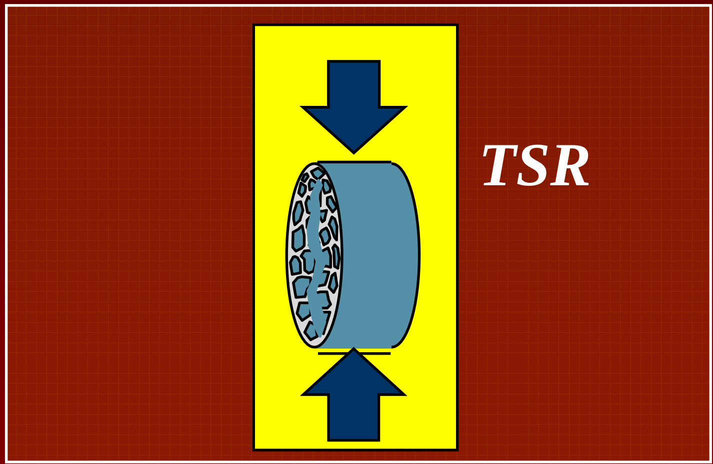
1. Materials Selection



2. Design Aggregate Structure



3. Design Binder Content



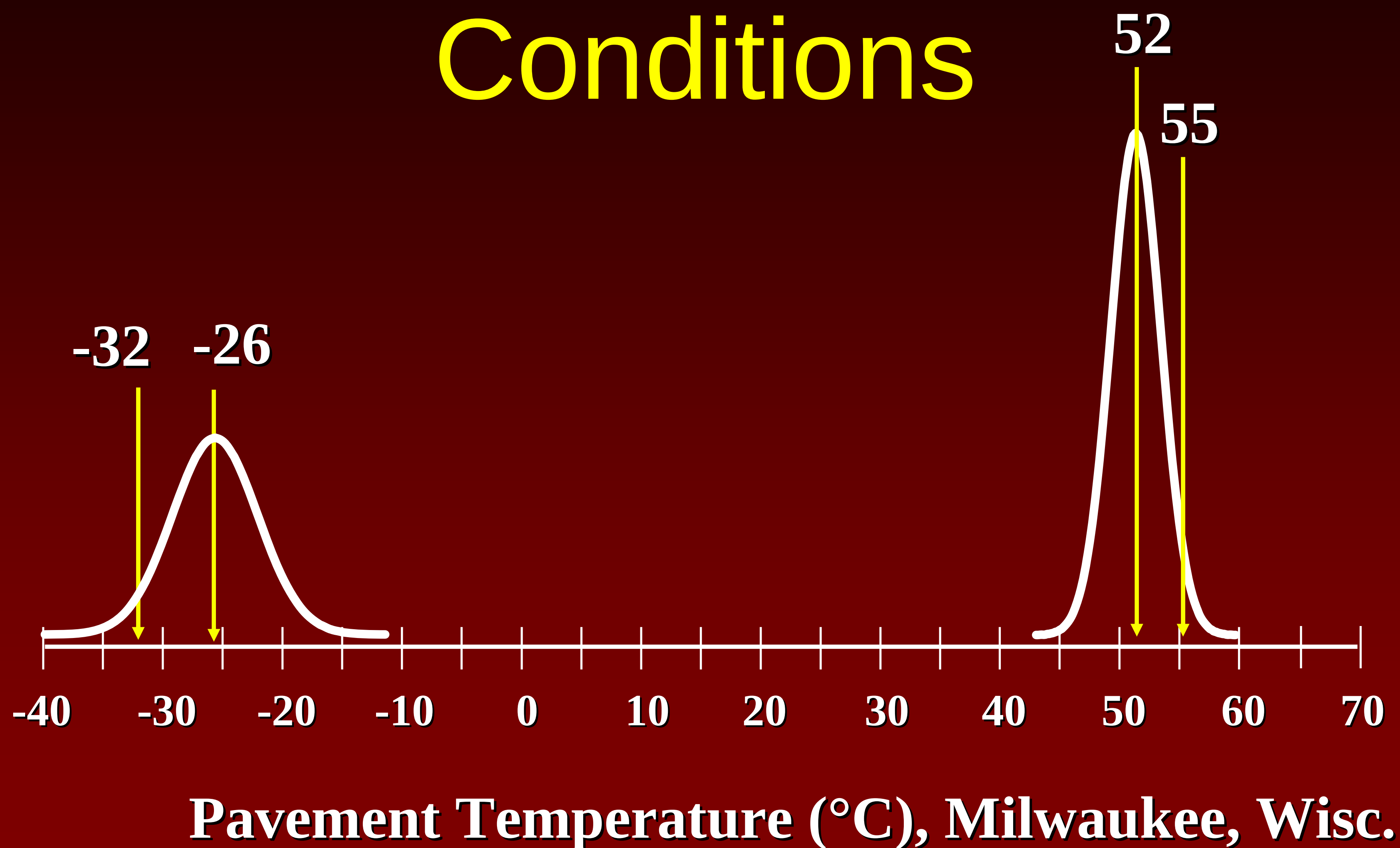
4. Moisture Sensitivity

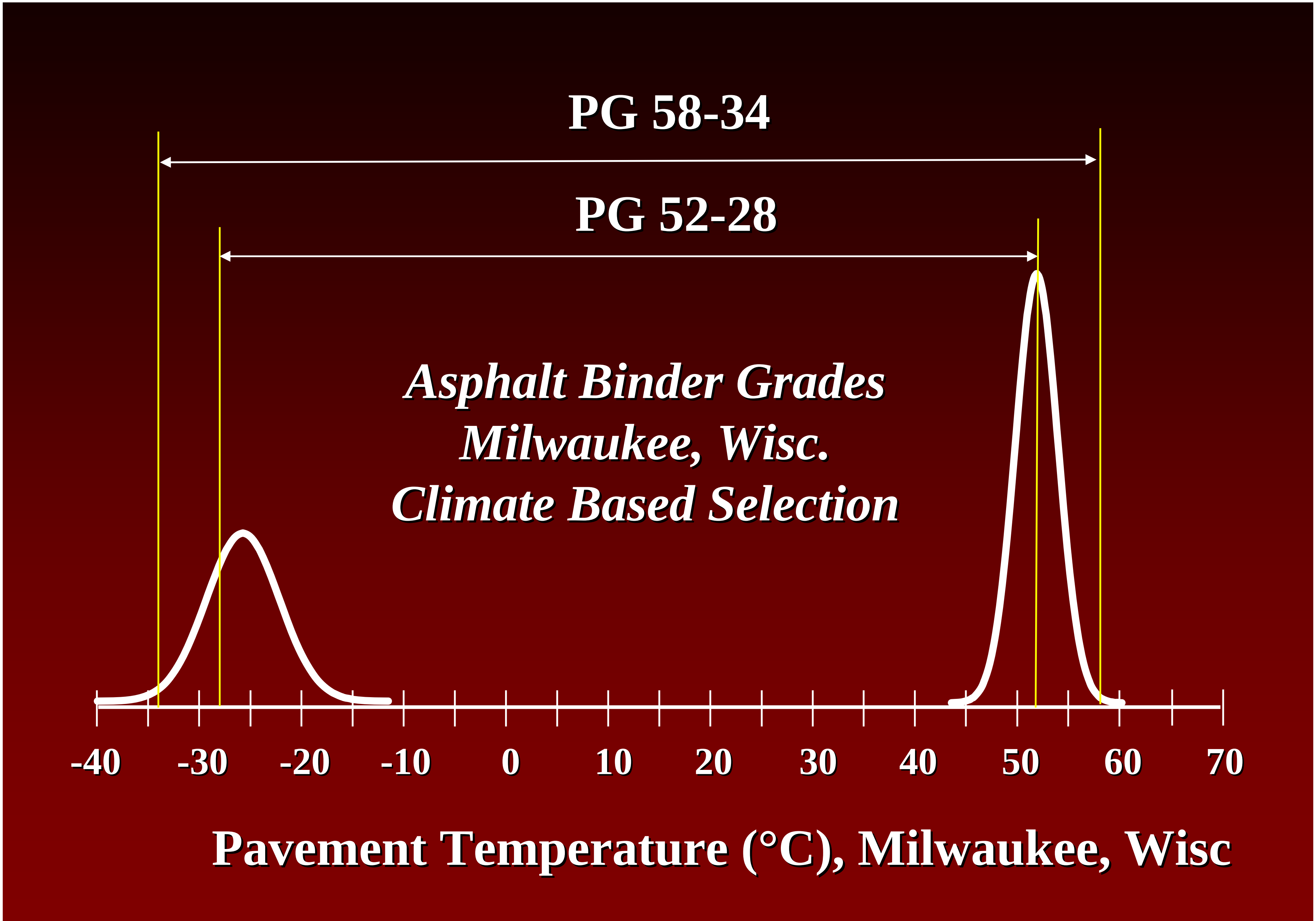
Step 1. Materials Selection

- Binder Selection
  - Binder grade is specified in nearly all cases
  - Selecting the supplier of the binder is most often based on cost.

- Aggregates Selection
  - Choice of aggregates is usually limited to locally available materials

Project Weather Conditions




PG 58-34
PG 52-28
Asphalt Binder Grades
Milwaukee, Wisc.
Climate Based Selection
-40
-30
-20
-10
0
10
20
30
40
50
60
70
Pavement Temperature (°C), Milwaukee, Wisc

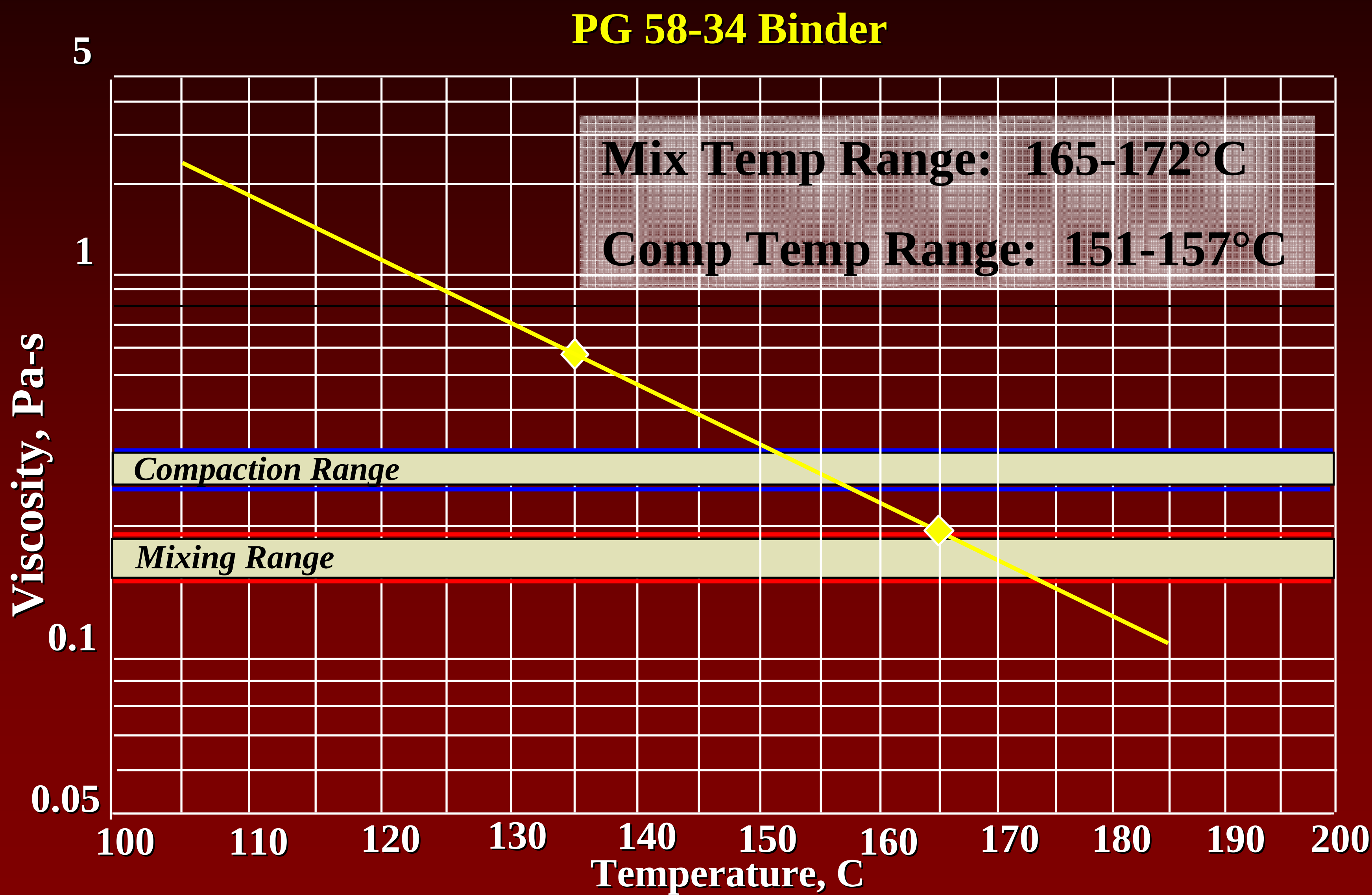
Binder Selection
Milwaukee, Wisc

PG 52-28   PG 58-34

Reliability(%)   50   74.5   99.9   99.6

Selected PG 58-34

Temp-Vis Relationship

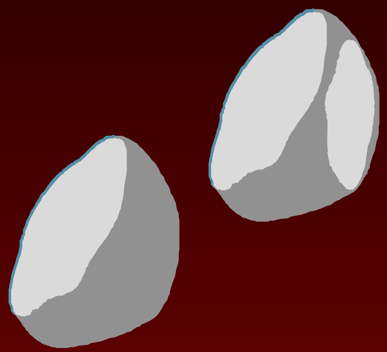


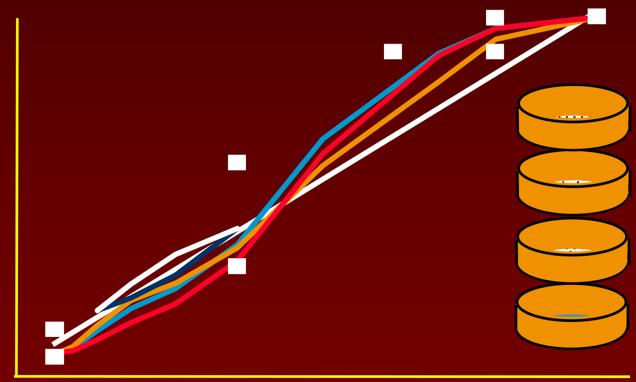
Select Aggregates

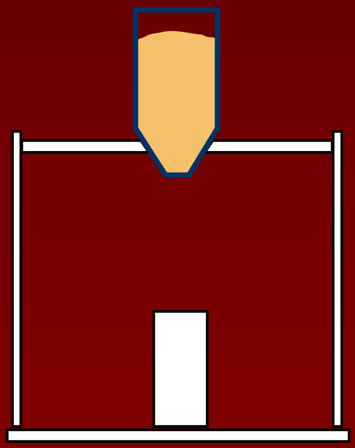
Available Stockpiles

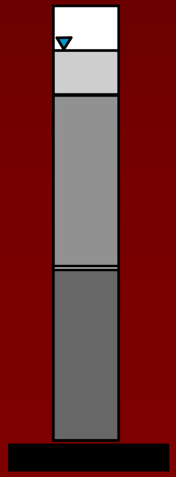
- #1 stone
- 12.5 mm chip
- 9.5 mm chip
- Manufactured sand
- Screen sand

Aggregate Properties





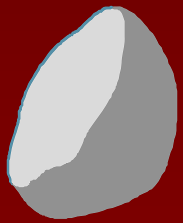


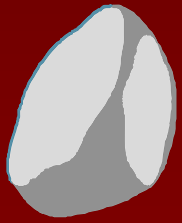


Coarse Aggregate Angularity

Test Results

Aggr.	1+ Frac Faces	Crit.	2+ Frac Faces	Crit.
#1 Stone	92%		88%	
12.5 mm Chip	97%	95% min	94%	90% min
9.5 mm Chip	99%		95%	

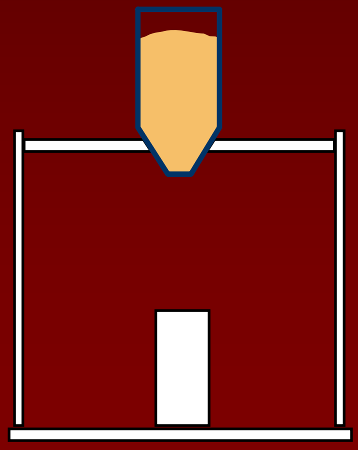




Fine Aggregate Angularity

Test Results

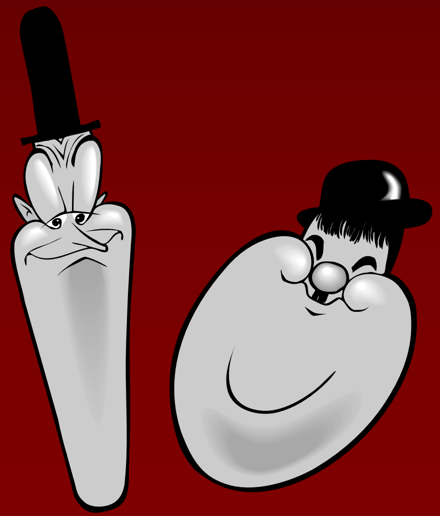
Aggregate	% Air Voids	Criterion
Manufactured Sand	52%	45% min
Screen Sand	40%	



Flat & Elongated Particles

Test Results

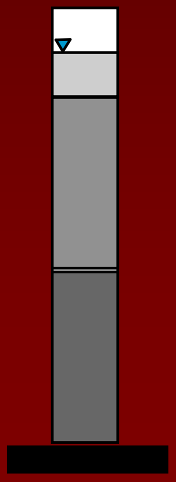
Aggregate	%Flat & Elongated	Criterion
#1 Stone	0%	
12.5mm Chip	0%	10% max.
9.5mm Chip	0%	



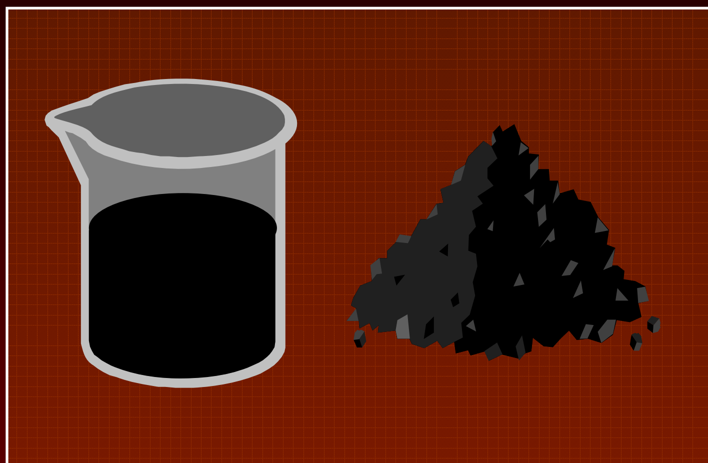
Sand Equivalent

Test Results

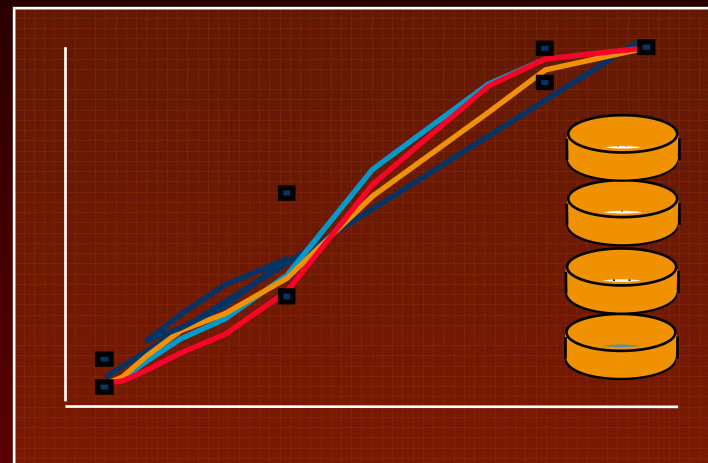
Aggregate	Sand Equivalent	Criterion
Manufactured Sand	47	45 min
Screen Sand	70	



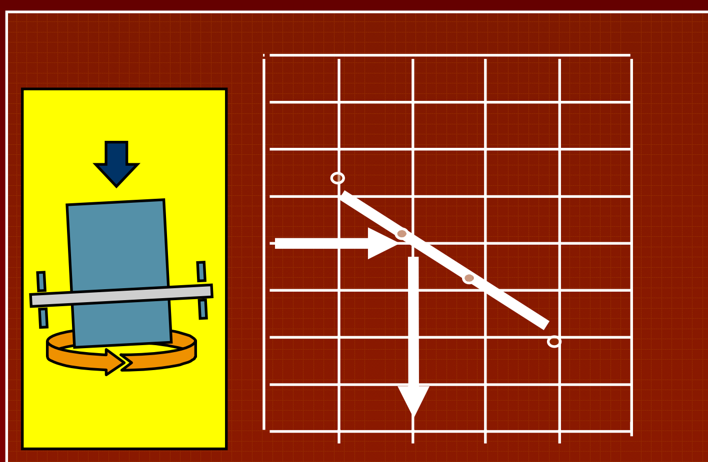
4 Steps of Superpave Mix Design



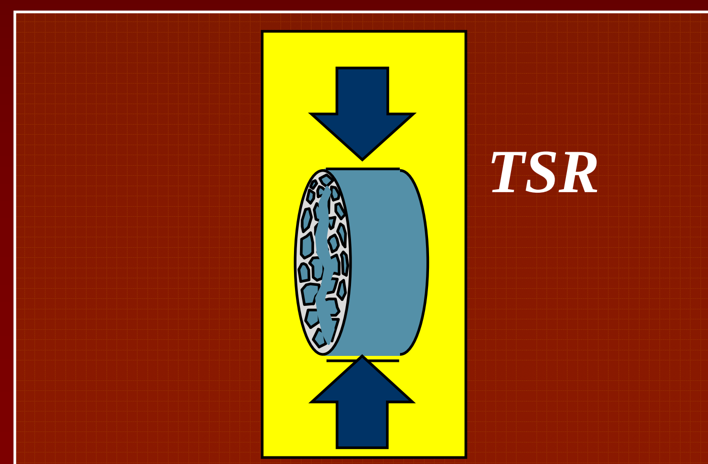
1. Materials Selection



2. Design Aggregate Structure



3. Design Binder Content

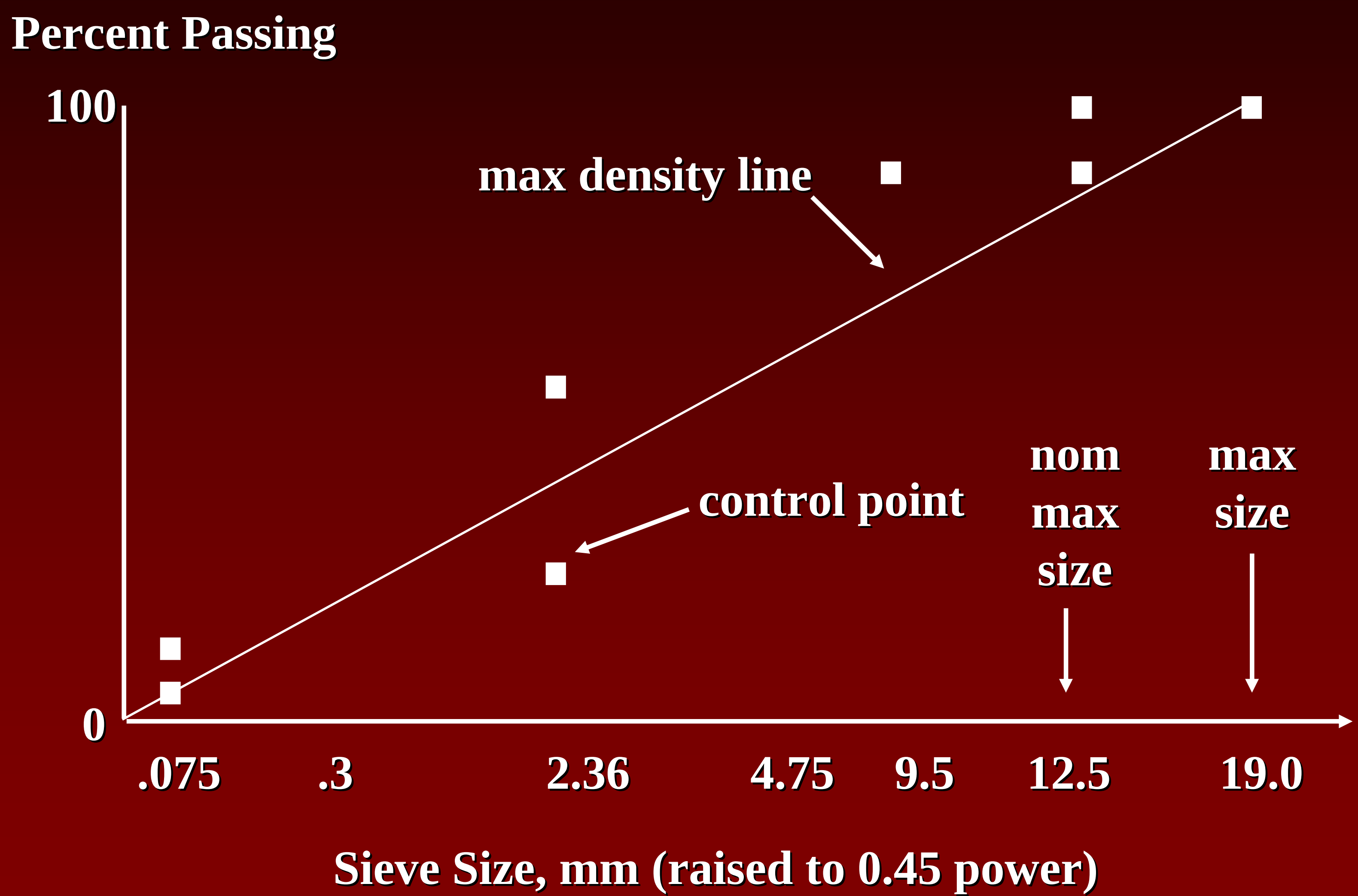


4. Moisture Sensitivity

Selection of Design Aggregate Structure

- Establish trial blends
- Check aggregate consensus properties
- Compact specimens
- Evaluate trial blends
- Select design aggregate structure

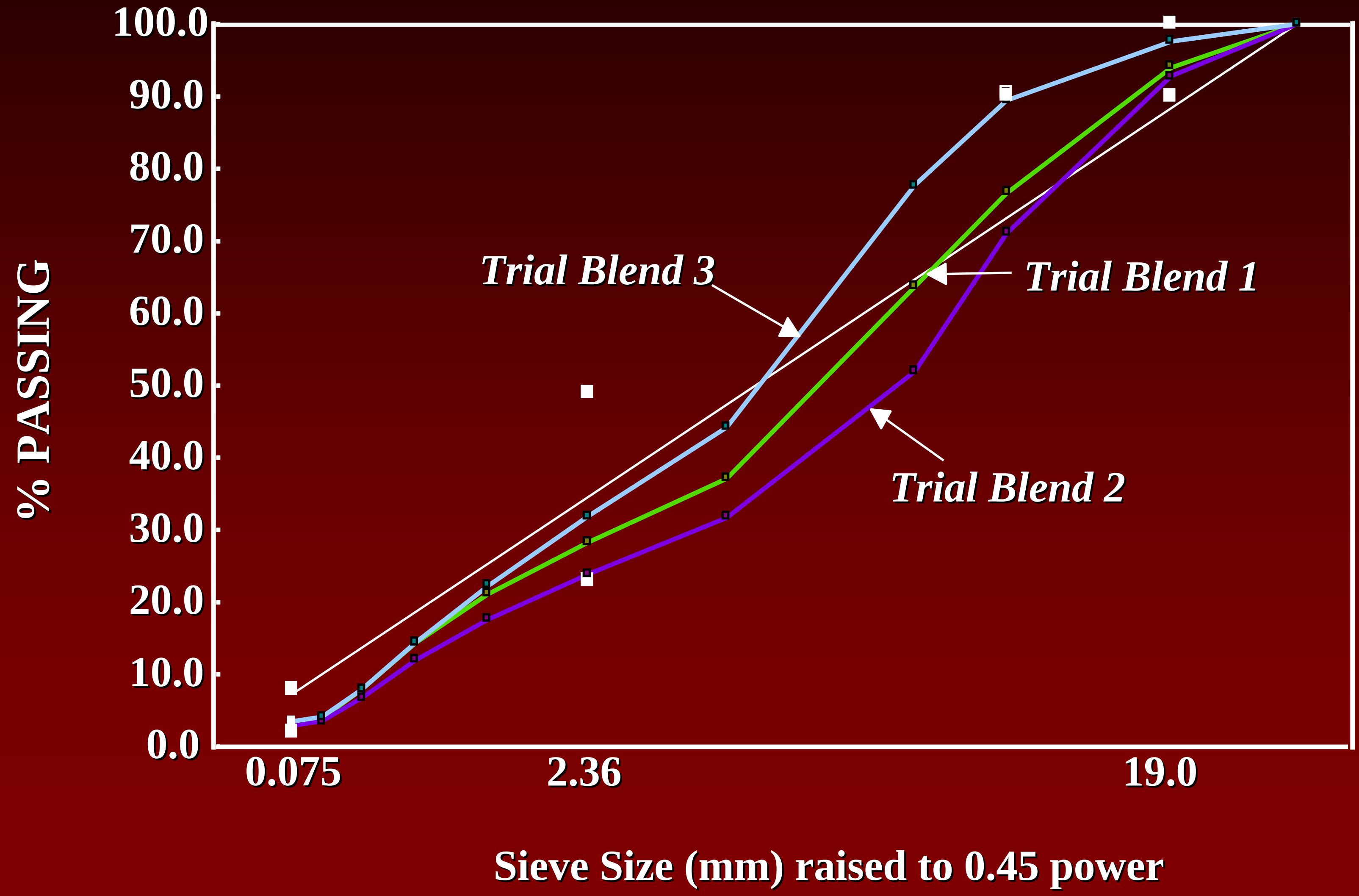
Gradation



Percent Passing
100
0
max density line
control point
nom
max
size
max
size
.075
.3
2.36
4.75
9.5
12.5
19.0
Sieve Size, mm (raised to 0.45 power)

IH-43 Trial Gradations

19.0 mm Nominal Mixture



Example Trial Blends

	Trail Blend 1	Trial Blend 2	Trial Blend 3
#1 Stone	25	30	10
½" Chip	15	25	15
3/8" Chip	22	13	30
Mfg Sand	18	17	31
Scr. Sand	20	15	14

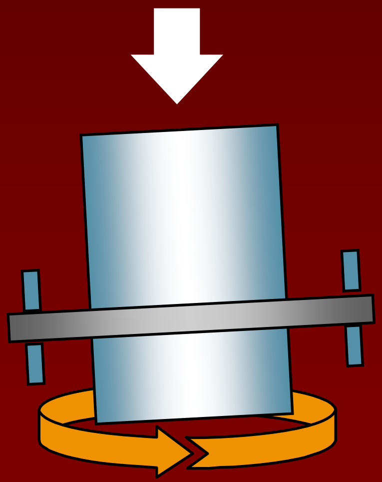
Aggregate Consensus Properties

- Blended aggregate properties are determined

Property	Criteria	Blend 1	Blend 2	Blend 3
Coarse Ang.	95%/90% min.	96%/92%	95%/92%	97%/93%
Fine Ang.	45% min.	46%	46%	48%
Flat/Elongated	10% max.	0%	0%	0%
Sand Equiv.	45 min.	59	58	54
Combined G_{sb}	n/a	2.699	2.697	2.701
Combined G_{sa}	n/a	2.768	2.769	2.767

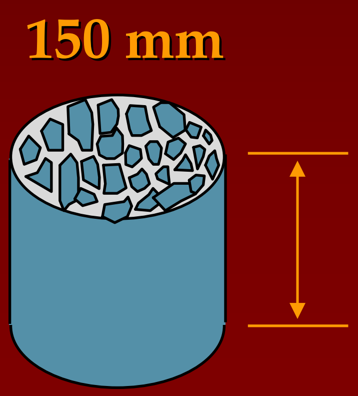
Compact Specimens (Trial Blends)

- Establish trial asphalt binder content
- Establish trial aggregate weight
- Batch, mix, and compact specimens
- Determine N_{ini} and N_{des}
- Determine mixture properties



Specimen Preparation

- Specimen height
  - Mix design - 115 mm (4700 g)
  - Moisture sensitivity - 95 mm (3500 g)
- Loose specimen for G_{mm} (Rice)
  - Sample size varies with NMAS
    - 19 mm (2000 g)
    - 12.5 mm (1500 g)

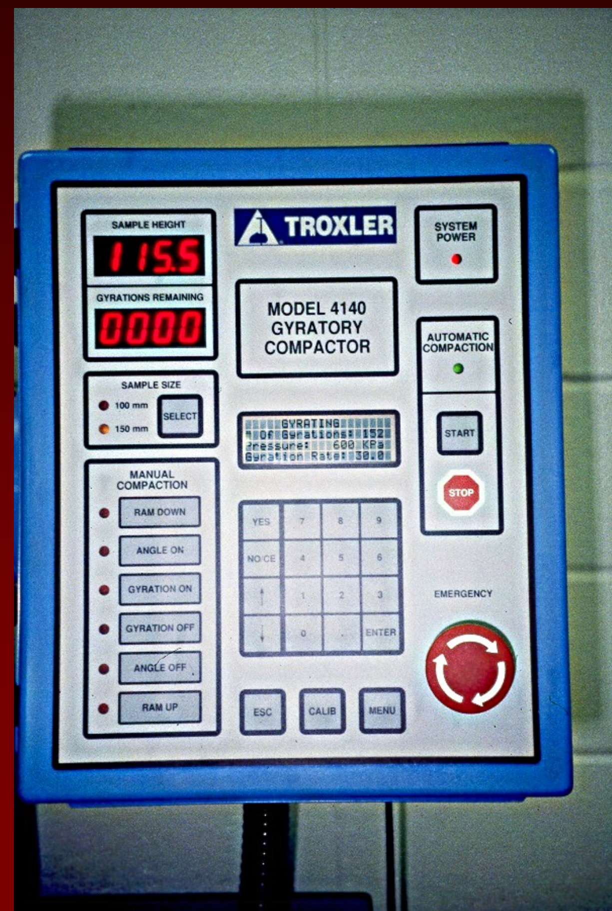


Batching Samples of Trial Blends

Short Term Aging

Two hours at the
compaction temperature

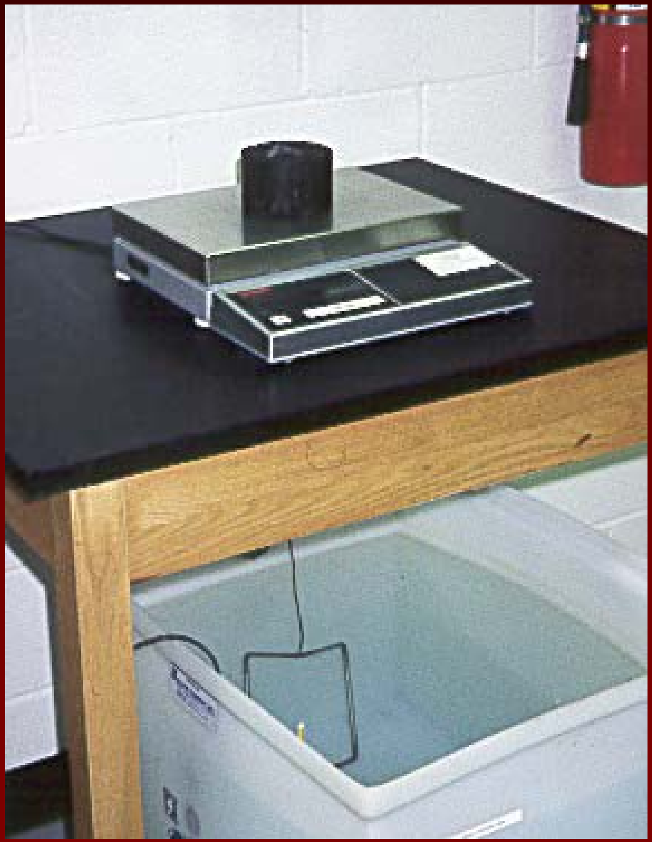

CAUTION

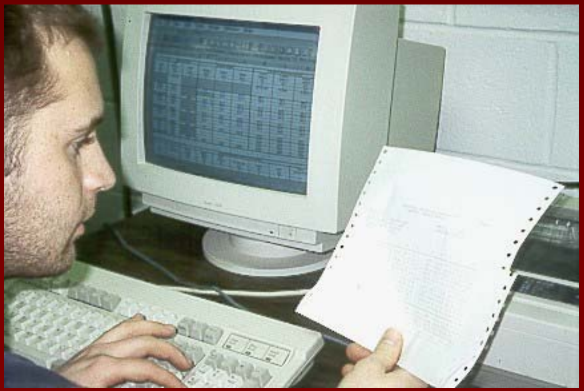

SAMPLE HEIGHT
115.5
GYRATIONS REMAINING
0000
TROXLER
SYSTEM POWER
MODEL 4140
GYRATORY
COMPACTOR
AUTOMATIC COMPACTION
SAMPLE SIZE
100 mm
150 mm
SELECT
GYRATING
START
STOP
MANUAL COMPACTION
RAM DOWN
ANGLE ON
GYRATION ON
GYRATION OFF
ANGLE OFF
RAM UP
YES 7 8 9
NO/CE 4 5 6
1 2 3
0 . ENTER
EMERGENCY
ESC
CALIB
MENU


DANGER
110 VOLTS


2
3.8
1
2
3.8
3
2
3.8
2

Measure G_{mb}, G_{mm} and calculate volumetric properties





Superpave Mixture Requirements

- Specimen height
- Mixture volumetrics
  - Air voids
  - Voids in the mineral aggregate (VMA)
  - Voids filled with asphalt (VFA)
- Dust proportion
- %Gmm @ N_{ini}

Trial Blend Results

Property	1	2	3
Trial Binder Content	4.4%	4.4%	4.4%
$\%G_{mm}$ @ N_{des}	96.2%	95.7%	95.2%
$\%G_{mm}$ @ N_{ini}	87.1%	85.6%	86.3%
%Air Voids	3.8%	4.3%	4.8%
%VMA	12.7%	13.0%	13.5%
%VFA	68.5%	69.2%	70.1%
Dust Proportion	0.9	0.8	0.9

Estimated Volumetric at 4% AV

$P_{be} = P_{bi} – 0.4 \times (4 - V_a)$

P_{be}: estimated design asphalt content

P_{bi}: asphalt content used in trial blends

$VMA_e = VMA_i + C \times (4 - V_a)$

VMA_e: estimated VMA at design asphalt content

VMA_i: initial VMA of trial blend

C= constant: 0.1 when air voids < 4% and 0.2 when air voids > 4%

Volumetric Design Criteria

Traffic ESAL	SGC Criteria		VMA	VFA	Dust / Binder
	N_{ini}	N_{des}			
< 0.3	$\leq$91.5	=96.0	see slide 53	70-80	0.6 -to- 1.2
< 3	$\leq$90.5			65-78	
> 3	$\leq$89.0			65-75	

Compare Trial Blends to Mixture Criteria

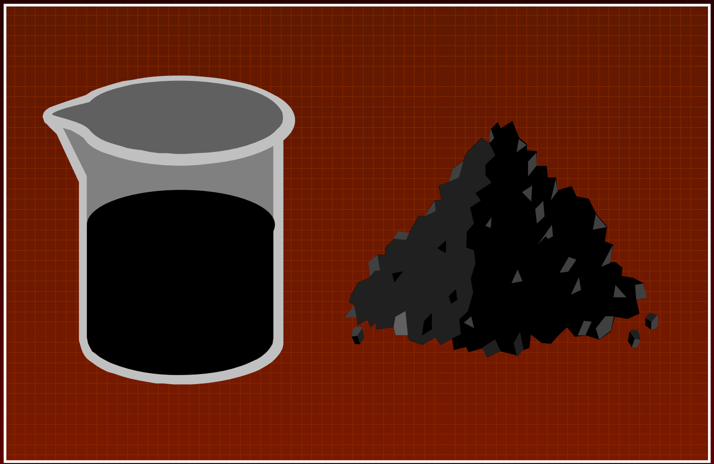
Blend	1	**2**	**3**	Criteria
Binder Content	4.3%	4.5%	4.7%	
%G_{mm} @ N_{ini}	86.9%	85.9%	87.1%	< 89%
%Air Voids	4.0%	4.0%	4.0%	4.0%
%VMA	12.7%	13.0%	13.3%	≥ 13.0%
%VFA	68.5%	69.2%	70.1%	65-75%
Dust Proportion	0.9	0.8	0.9	0.6-1.2

Select Design Aggregate Structure

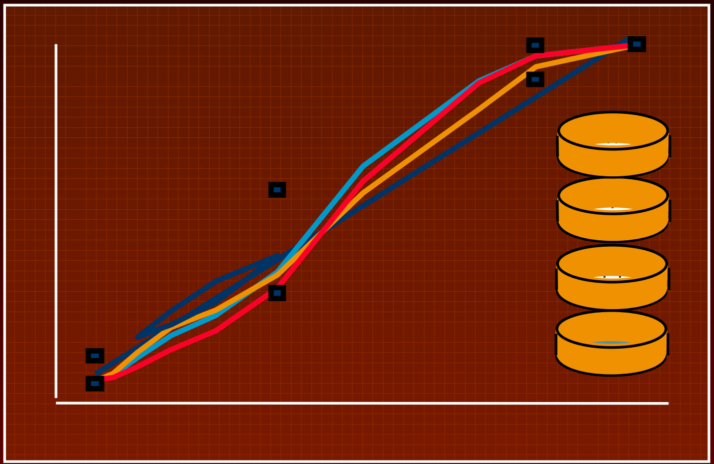
What to do if none of the 3 trial blends are acceptable?

- Recombine aggregates to form further trial blends (i.e., Blend 4, Blend 5, etc.)
- Obtain new materials (aggregates, asphalt binder, modifiers)

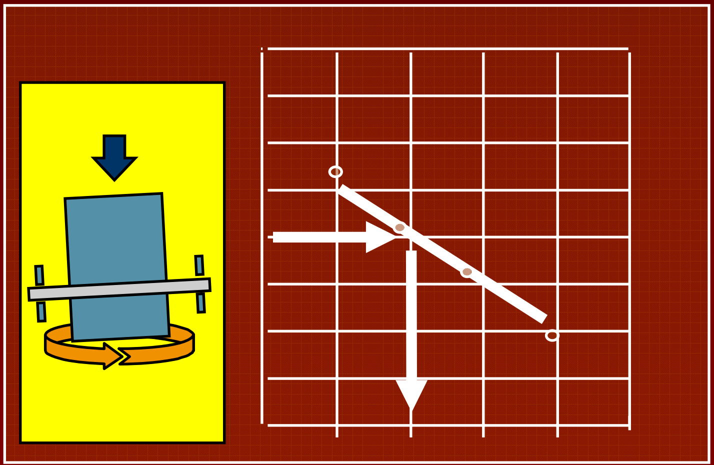
4 Steps of Superpave Mix Design



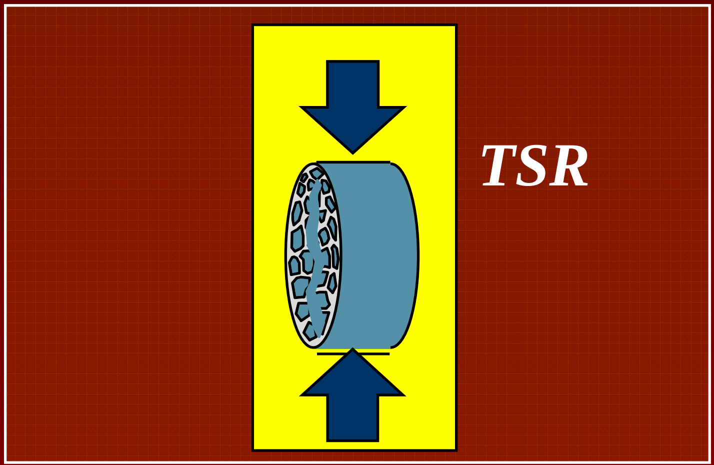
1. Materials Selection



2. Design Aggregate Structure



3. Design Binder Content



4. Moisture Sensitivity

Determining the Design Asphalt Content

- The selected trial blend becomes the design aggregate structure.
- Batch, mix, and compact more samples with this gradation with four asphalt contents.
- Determine volumetric properties
- Select P_b at 4.0% air voids and check other volumetric properties.





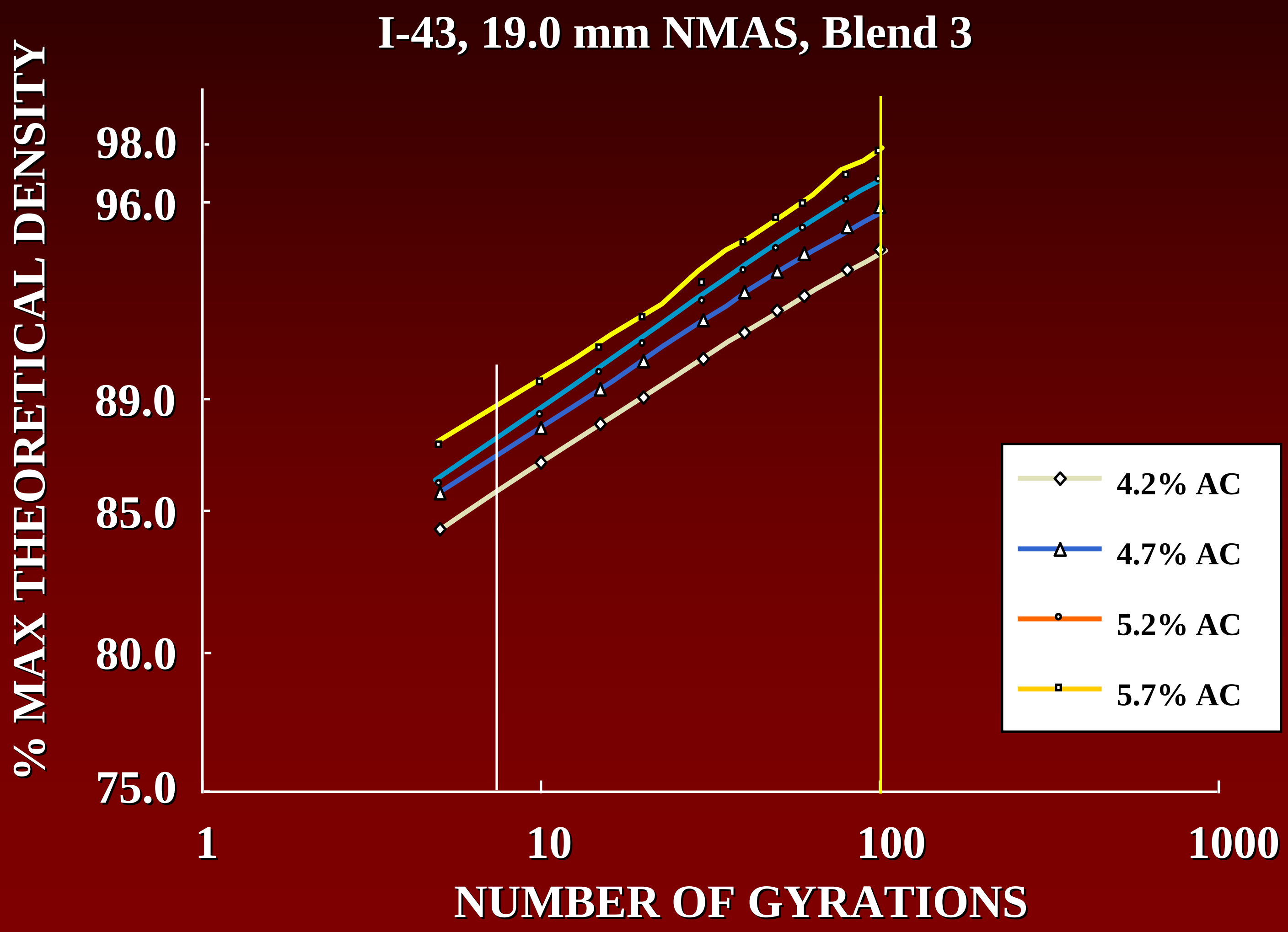


3.8 1
4.3 1
4.8 1
5.3 1
3.8 2
4.3 2
4.8 2
5.3 2
3.8 3
4.3 3
4.8 3
5.3 3

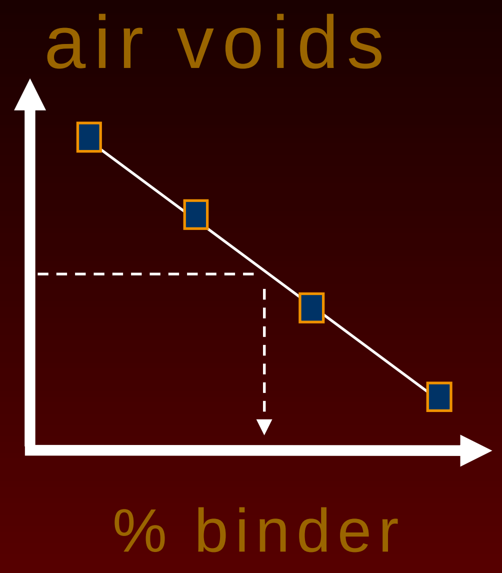
Design Binder Content Samples

Binder Content	4.2%	4.7%	5.2%	5.7%
$\%G_{mm}$ @ N_{ini}	85.7%	87.1%	87.4%	88.6%
$\%G_{mm}$ @ N_{des}	94.6%	96.1%	97.1%	98.2%
%Air Voids	5.4%	3.9%	2.9%	1.8%
%VMA	13.3%	13.1%	13.3%	13.5%
%VFA	59.4%	70.2%	78.2%	86.7%
Dust Proportion	1.0	0.9	0.8	0.7

Densification Curves



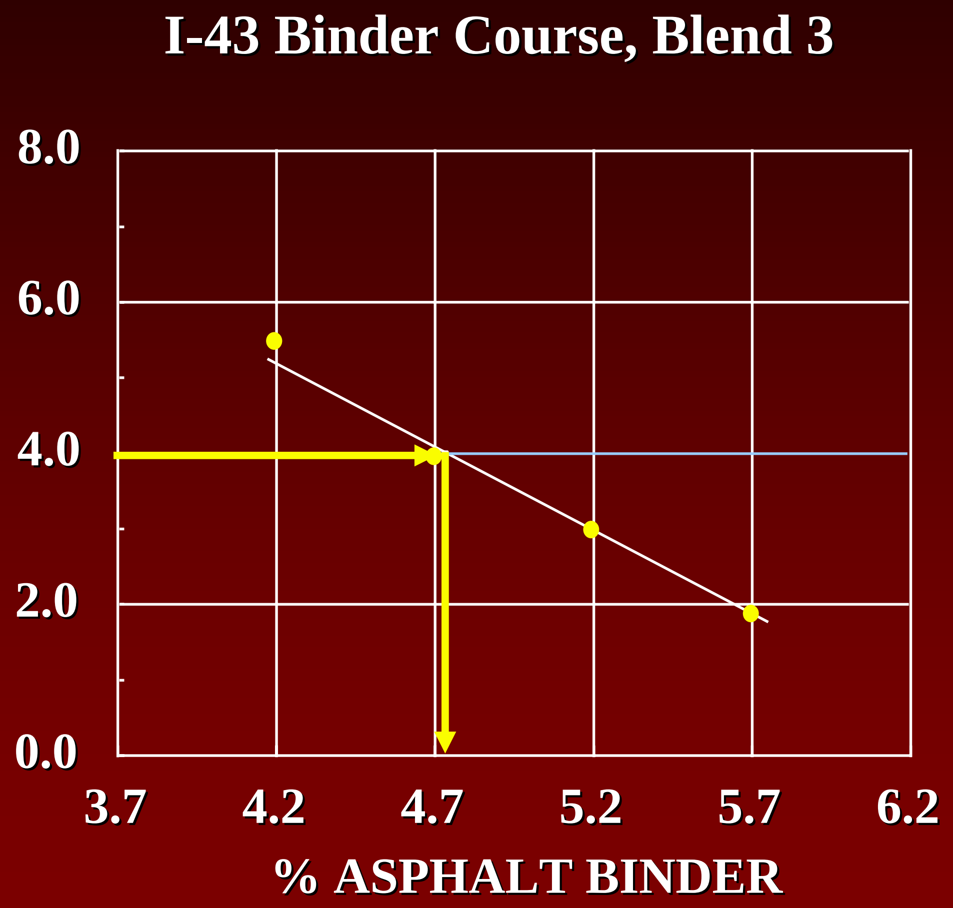
Mix Air Voids Requirement



4% at N_{des}
Regardless of the Traffic Level

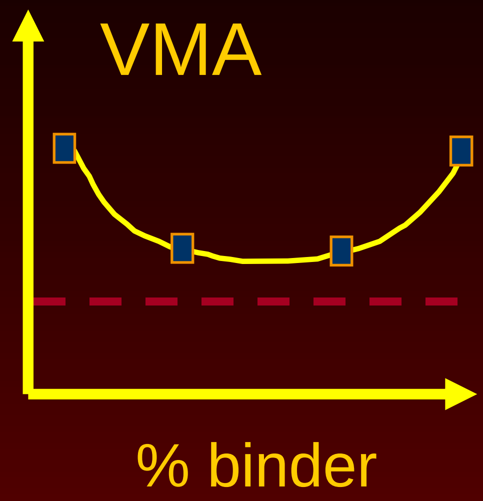
Air Voids - Example Mix Design

Air Voids = 4%



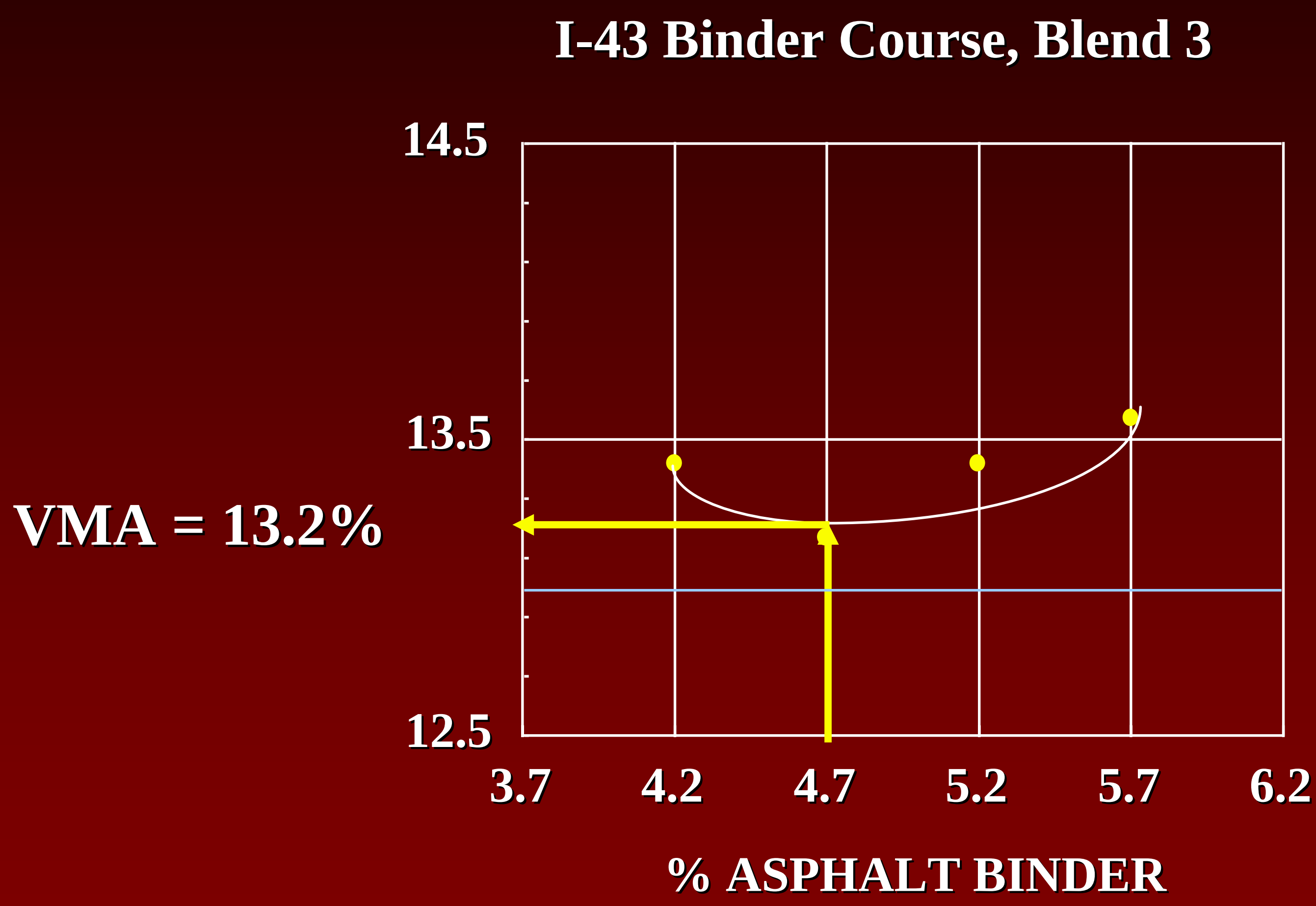
Mix VMA Requirements

Voids in the Mineral Aggregate



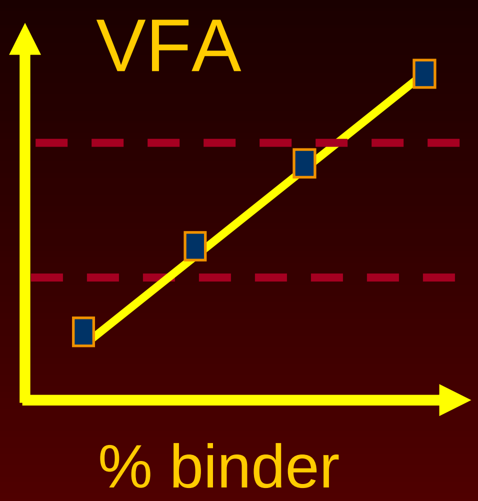
NMAS, mm	Minimum VMA, %
9.5	15.0
12.5	14.0
19.0	13.0
25.0	12.0
37.5	11.0

VMA – Example Mix Design



Mix VFA Requirements

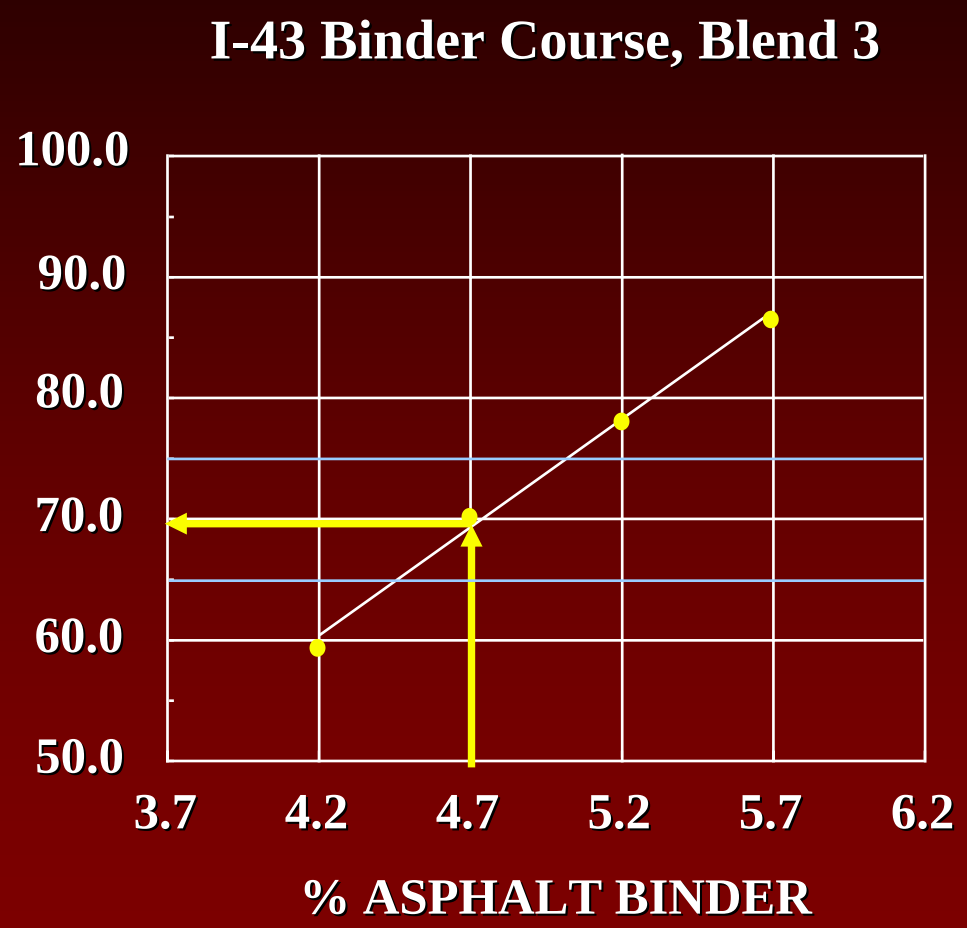
Voids Filled with Asphalt



Traffic 10^6 ESALs	Range of VFA, %
< 0.3	70 - 80
< 1	65 - 78
< 3	65 - 75
> 3	65 - 75

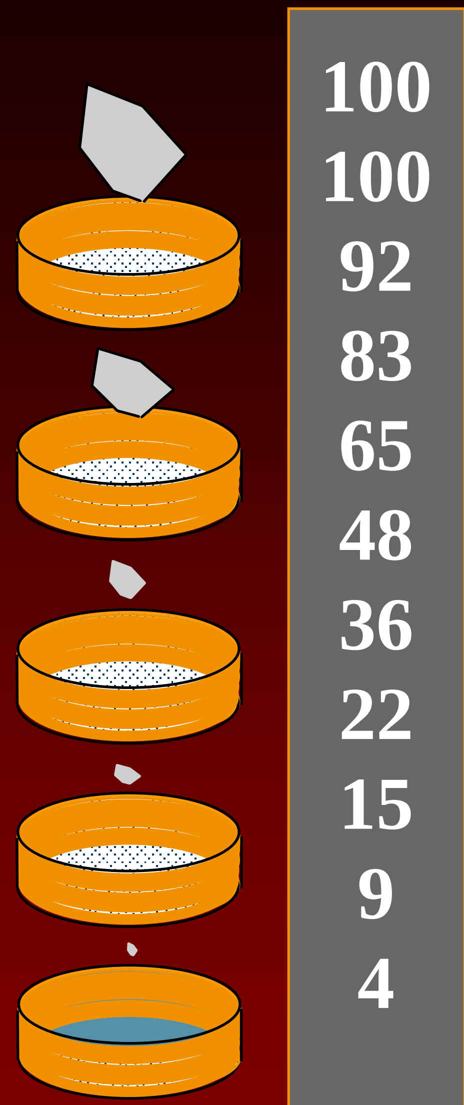
VFA – Example Mix Design

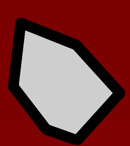
VFA = 70%



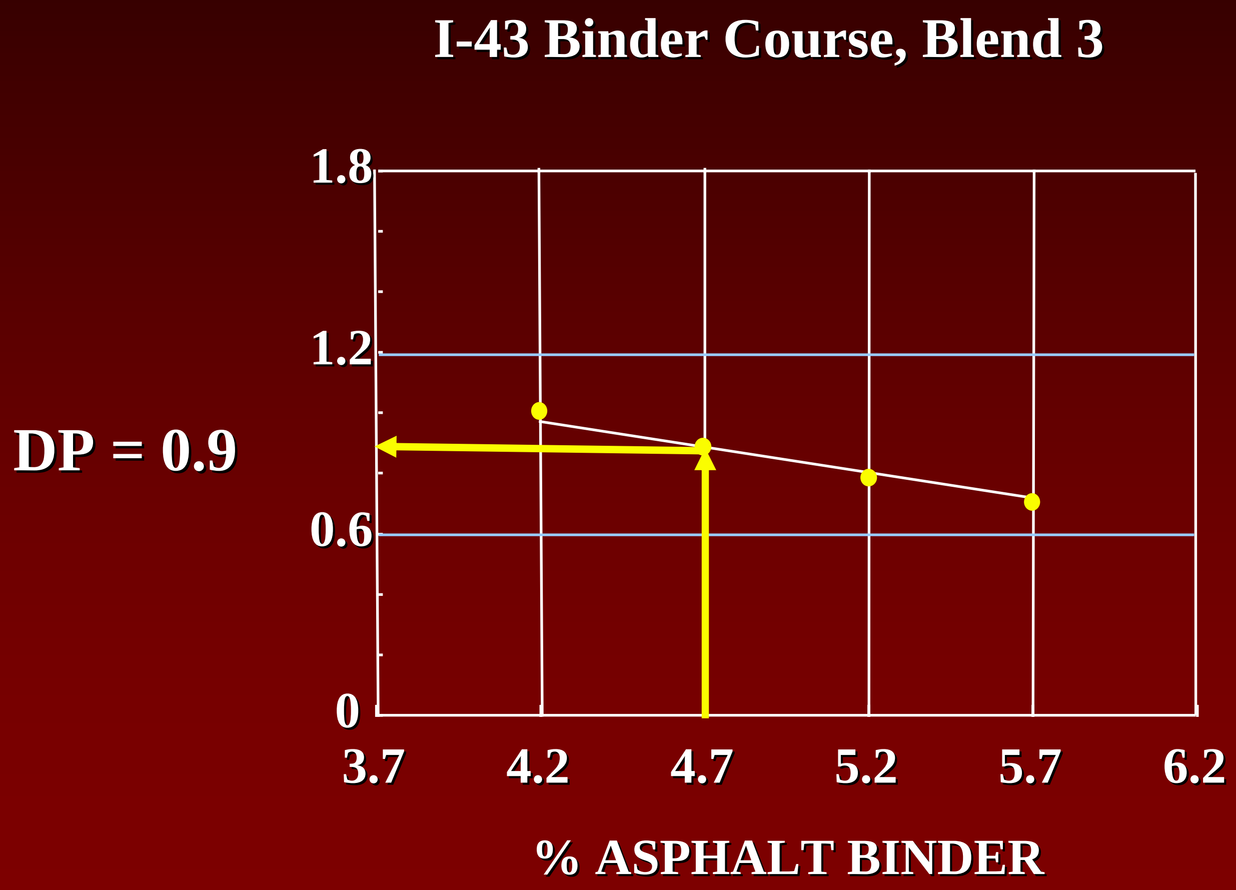
Mix Requirement for Dust Proportion

$$0.6 \le \frac{\%\ \text{weight of}\ -\ 0.075\ \text{material}}{\%\ \text{weight of}\ \textit{effective}\ \text{asphalt}} \le 1.2$$



 **Unabsorbed binder in mix**

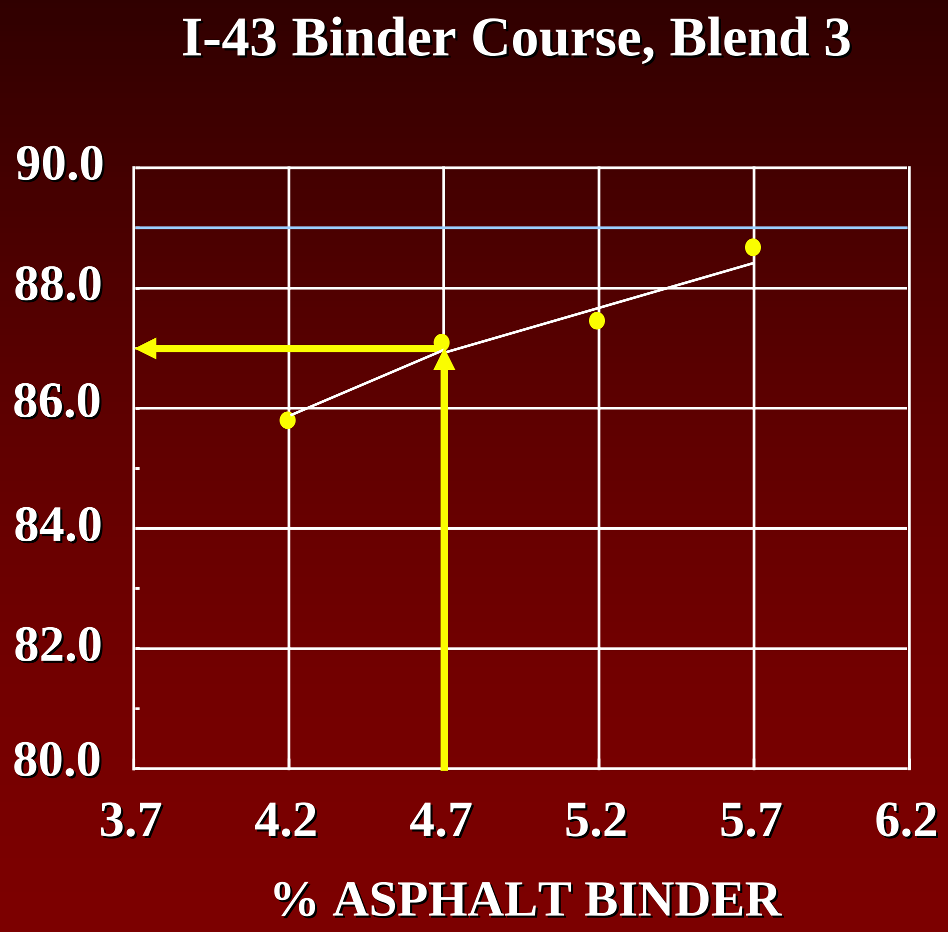
Dust Proportion – Example Mix Design



%G_{mm} @ N_{ini}

%G_{mm} @ N_{ini}

= 87.1%

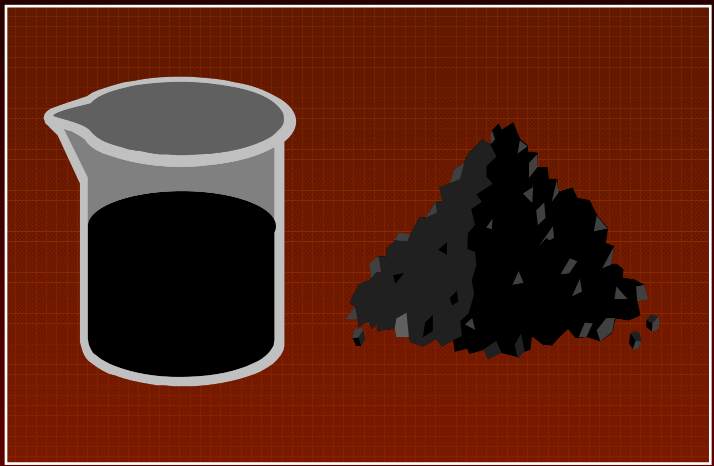


Select Design Asphalt Binder Content

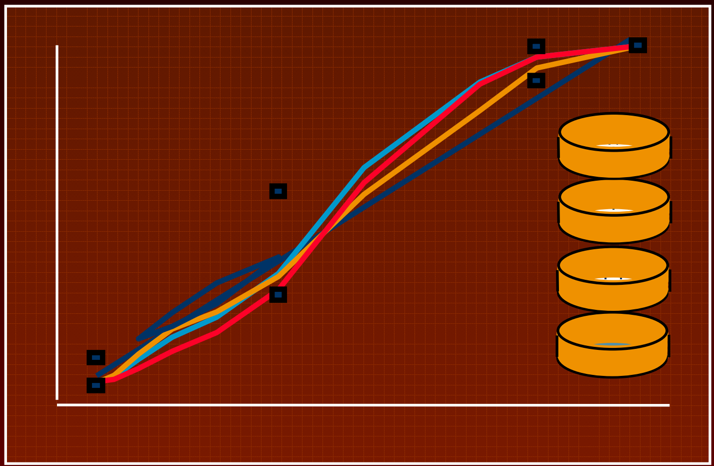
Summary of Mixture Properties @ 4.7% AC

Property	Result	Criteria
%Air Voids	4.0%	4.0%
%VMA	13.2%	$\geq$13.0%
%VFA	70%	65-75%
D/A Ratio	0.9	0.6-1.2
$\%G_{mm}$ @ N_{ini}	87.1%	<89%

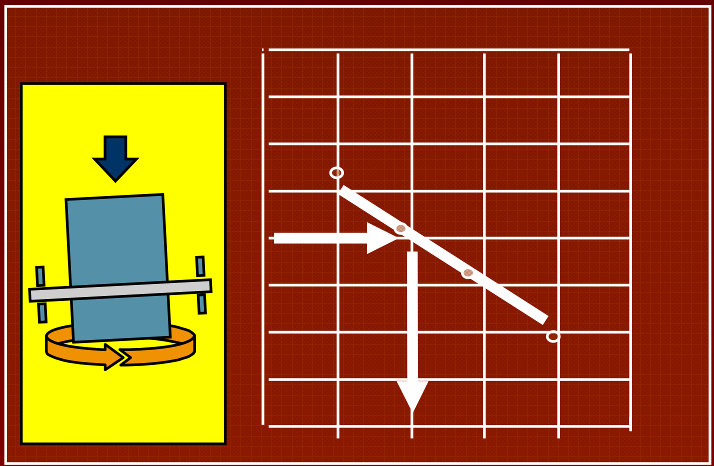
4 Steps of Superpave Mix Design



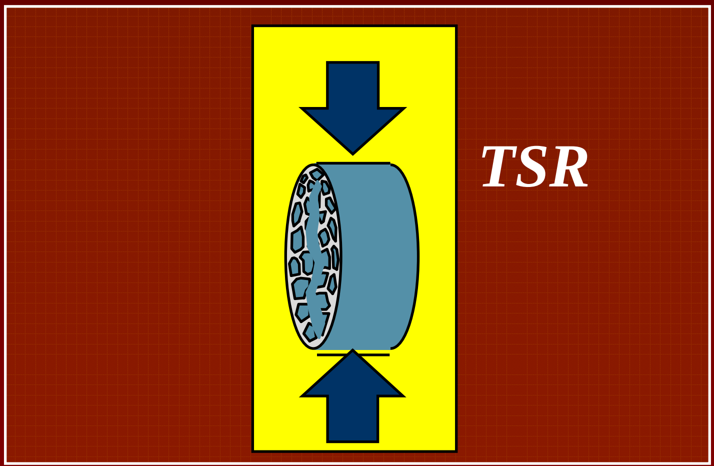
1. Materials Selection



2. Design Aggregate Structure



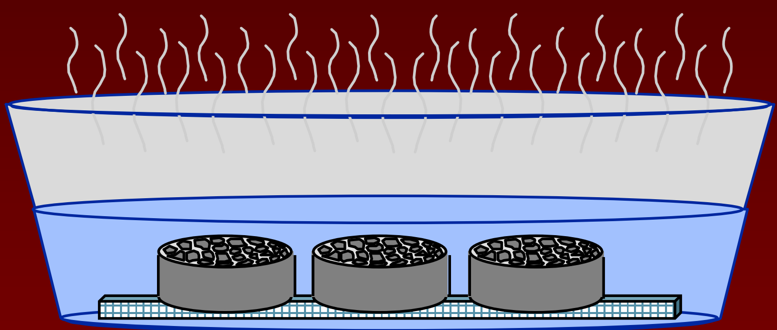
3. Design Binder Content



4. Moisture Sensitivity

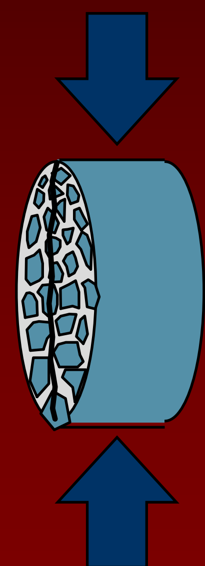
Moisture Sensitivity
AASHTO T 283

- Measured on proposed aggregate blend and asphalt content



3 Conditioned Specimens

3 Dry Specimens



80 % minimum

Tensile Strength Ratio

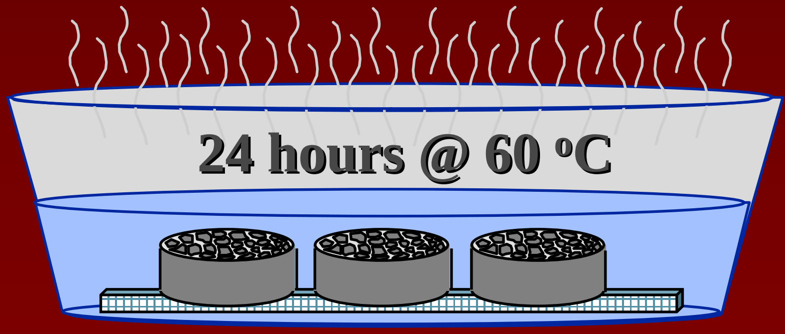
AASHTO T 283 Conditioning

- Short term aging
  - Loose mix 16 hrs @ 60°C
  - Comp mix 72-96 hrs @ 25°C
- Two subsets with equal voids
  - One “dry”
  - One saturated

AASHTO T 283 Conditioning

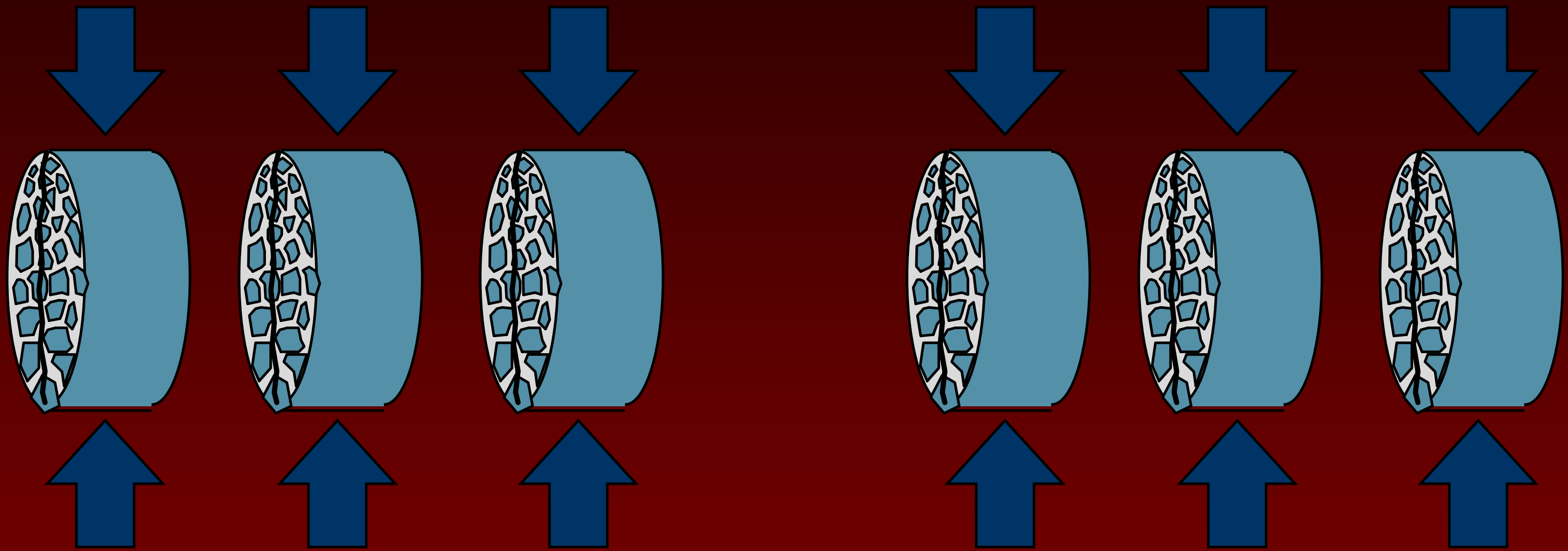
- Optional freeze cycle

- Hot water soak



AASHTO T 283 Test Procedure

51 mm / min @ 25 ºC



Avg Dry Tensile Strength   **Avg Wet Tensile Strength**

$$\text{TSR} = \frac{\text{Wet}}{\text{Dry}} \geq 80\ \%$$

Calculate %TSR

$$\%TSR = 100 * \frac{\text{Wet Strength}}{\text{Dry Strength}}$$

$$= 100 * \frac{721 \text{ kPa}}{872 \text{ kPa}} = 82.6\%$$

Criterion is 80% minimum. Design asphalt mixture exceeds the minimum requirement.

Design Asphalt Mixture

- Aggregate:
  - – 10% #1 Stone
  - – 15% 12.5mm Chip
  - – 30% 9.5mm Chip
  - – 31% Manuf. Sand
  - – 14% Screen Sand
- Asphalt Binder:
  - – 4.7% PG 58-34

- Aggregate Gradation:

25 mm	100%
19.0 mm	97%
12.5 mm	89%
9.5 mm	77%
4.75 mm	44%
2.36 mm	32%
1.18 mm	22%
0.6 mm	15%
0.3 mm	8%
0.15 mm	4%
0.075 mm	3.5%

Questions – does it all make sense?