SHRP LEVEL I MIX DESIGN

Presented by

Prof. Hamad I. Al-Abdul Wahhab

Civil Engineering Department
King Fahd University of Petroleum & Minerals
Dhahran, Saudi Arabia

LEVEL I MIX DESIGN

Step I: Design of aggregate structure

Step II: Design of asphalt content

LEVEL I MIX DESIGN FLOW CHART

Select aggregate based
on Specification criteria

⇩

Prepare three trail gradations

⇩

Calculate an initial asphalt
trail content for each gradation

⇩

Evaluate compacted trial gradations and select one

⇩

Compact specimen at 4 AC contents
ound the trail asphalt content for the selected gradati

Aggregate Specific Gravities

Aggregate	Bulk Sp. Gravity	Apparent Sp. Gravity
#1 Stone	2.703	2.785
1/2”	2.689	2.776
3/8”	2.723	2.797
Manuf. Sand	2.694	2.744
Screen Sand	2.79	2.731

Coarse Aggregate Angularity

Aggregate	1 + Fractured Faces	Criterion	2 + Fractured Faces	Criterion
#1 Stone	95 %	95 %	91 %	90 %
1/2”	97 %	95 %	94 %	90 %
3/8”	99 %	95 %	95 %	90 %

H.A.W.

Fine Aggregate Angularity

Aggregate	% Air Voids (Loose)	Criterion
Manufactured Sand	62 %	45 % min
Screen Sand	36 %	

H.A.W.

Thin (Flat) And Elongated Particles

Aggregate	% Thin / Elongate	Criterion
#1 Stone	0 %	
1/2"Chip	0 %	10 % max
3/8"Chip	0 %	

H.A.W.

CLAY CONENT (Sand Equivalent)

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

H.A.W.

LEVEL I MIX DESIGN FLOW CHART

Select aggregate based
on Specification criteria

⇩

Prepare three trail gradations

⇩

Calculate an initial asphalt
trail content for each gradation

⇩

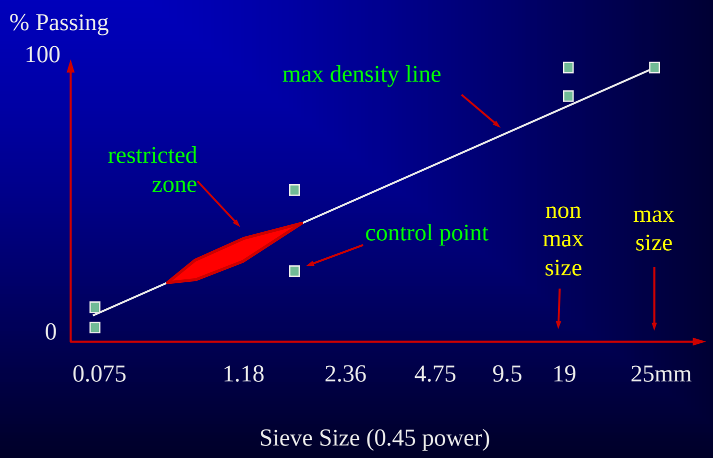
Evaluate compacted trial gradations and select one

⇩

Compact specimen at 4 AC contents
around the trail asphalt content

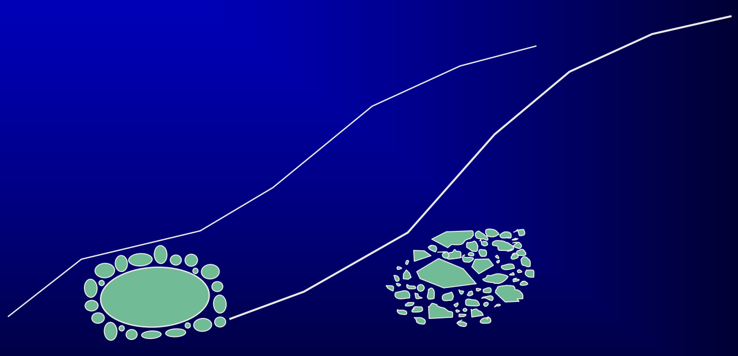
SIVE SIZE	PERCENT PASSING
1 INCH	100
¾ INCH	98 -100
½ INCH	80 - 91
3/8 INCH	77-87
No. 4	58-71
No. 8	45-56
No. 30	24-35
No. 100	9-18
No. 200	4-6

Design Aggregate Structure



H.A.W.

Design Aggregate Structure



H.A.W.

Table A-1. 37.5 mm (1 1 /2 in.) NOMINAL MAXIMUM SIZE

SIEVE SIZE	CONTROL POINT (PERCENT PASSING)	
	MINIMUM	MAXIMUM
75µm (No. 200)	0	6
2 .36 mm (No.8)	15	-
Nominal maximum (37.5 mm) (1 1 / 2)	90	100
Maximum (50.0 mm) (2 in.)	100	-

Table A-2. 25.4 mm (1 in.) NOMINAL MAXIMUM SIZE

SIEVE SIZE	CONTROL POINT (PERCENT PASSING)	
	MINIMUM	MAXIMUM
75µm (No. 200)	1	7
2 .36 mm (No.8)	19	-
Nominal maximum (25.4 mm) (1 in.)	90	100
Maximum (37.5 mm) (1 1/2 in.)	100	-

Table A-3. 19.0 mm (3/4 in.) NOMINAL MAXIMUM SIZE

SIEVE SIZE	CONTROL POINT (PERCENT PASSING)	
	MINIMUM	MAXIMUM
75µm (No. 200)	2	8
2 .36 mm (No.8)	23	-
Nominal maximum (19.0 mm) (3/4 in)	90	100
Maximum (25.4 mm) (1 in.)	100	-

H.A.W.

Table A-4. 12.5 mm (1/2 in.) NOMINAL MAXIMUM SIZE

SIEVE SIZE	CONTROL POINT (PERCENT PASSING)	
	MINIMUM	MAXIMUM
75µm (No. 200)	2	10
2 .36 mm (No.8)	28	-
Nominal maximum (12.5 mm) (1/2 in)	90	100
Maximum (19.0 mm) (3/4 in.)	100	-

H.A.W.

Table A-5. 9.5 mm (3/8 in.) NOMINAL MAXIMUM SIZE

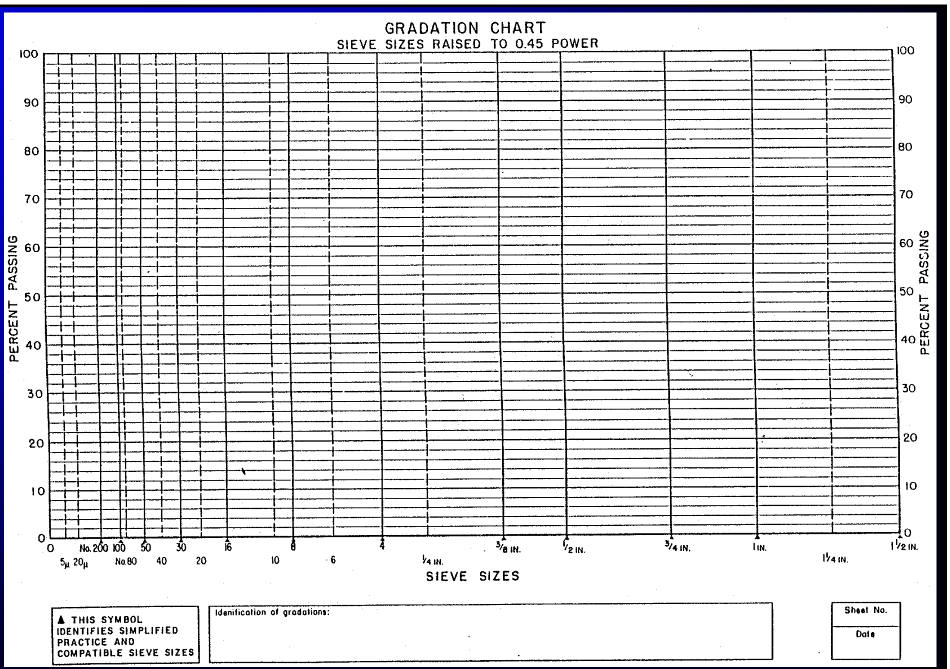
SIEVE SIZE	CONTROL POINT (PERCENT PASSING)	
	MINIMUM	MAXIMUM
75µm (No. 200)	2	10
2 .36 mm (No.8)	32	-
Nominal maximum (9.5 mm) (3/8 in)	90	100
Maximum (12.5 mm) (3/8 in.)	100	-

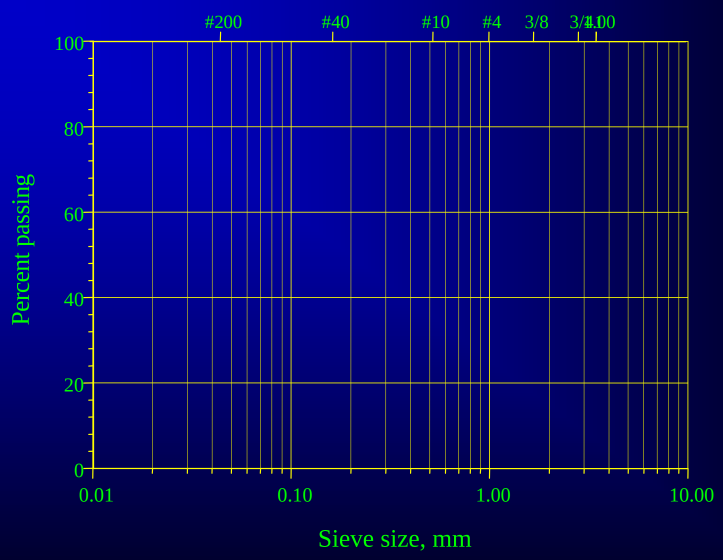
H.A.W.

Table A-6. Boundaries of Aggregate Restricted Zone

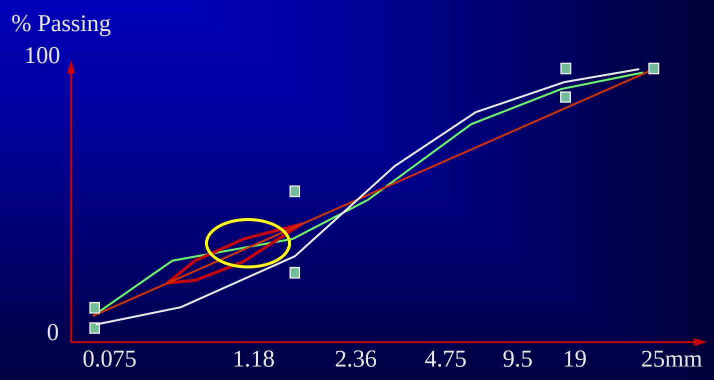
Sieve Size Within Restricted Zone	Minimum & Maximum Boundaries of Sieve Size for Nominal Max. Aggregate Size. (Min. / Max. % Passing)				
	1 ½ in	1 in	¾ in	½ in	3/8 in
4.75mm (No. 4)	34.7 / 34.7	39.5 / 39.5	-	-	-
2.36mm (No.8)	23.3 / 27.3	26.8 / 30.8	34.6 / 34.6	39.1 / 39.1	47.2 / 47.2
1.18mm (No.16)	15.5 / 21.5	18.1 / 24.1	22.3 / 28.3	25.6 / 31.6	31.6 / 37.6
0.60mm (No. 30)	11.7 / 15.7	13.6 / 17.6	16.7 / 20.7	19.1 / 23.1	23.5 / 27.5
0.30mm (No. 50)	10.0 / 10.0	11.4 / 11.4	13.7 / 13.7	15.5 / 15.5	18.7 / 18.7

H.A.W.


GRADATION CHART
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
SIEVE SIZES
No.200 100 50 30 16 8 4 1/4 IN. 3/8 IN. 1/2 IN. 3/4 IN. 1 IN. 1 1/4 IN. 1 1/2 IN.
5μ 20μ No.80 40 20 10 6
▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Identification of gradations:
Sheet No.
Date

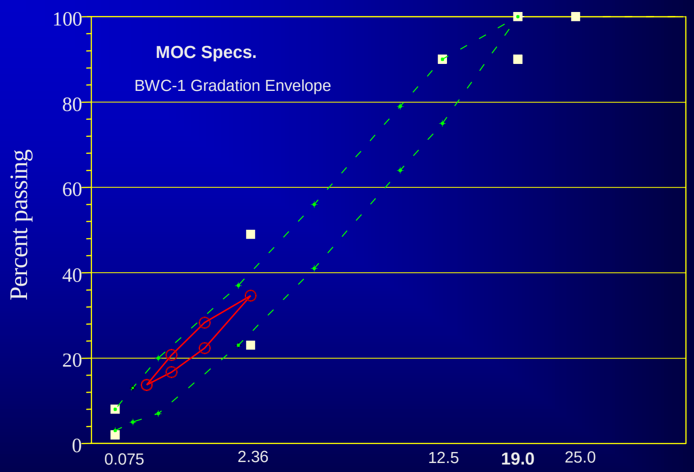

#200
#40
#10
#4
3/8
3/4
1.00
Percent passing
100
80
60
40
20
0
0.01
0.10
1.00
10.00
Sieve size, mm

Design Aggregate Structure



Sieve Size (0.45 power)

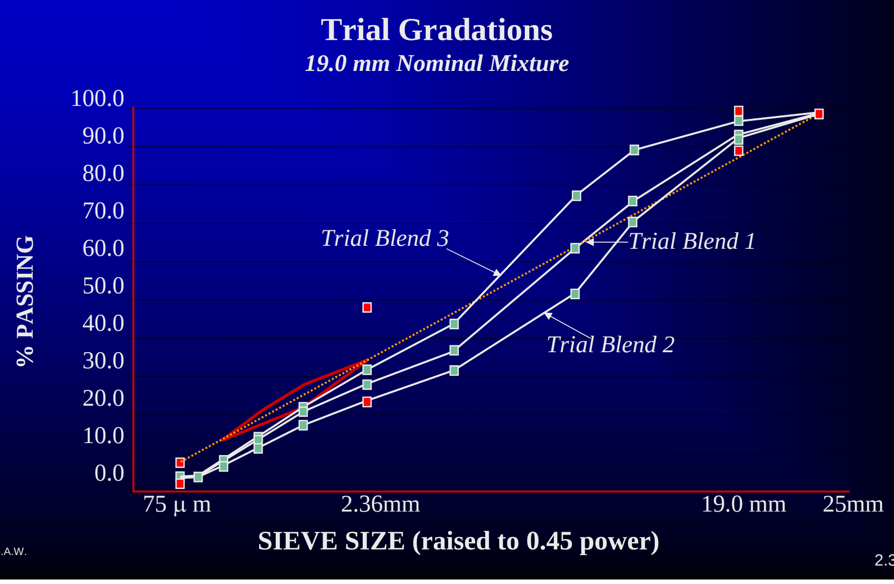
Design Aggregate Structure



Sieve Size (mm) Raised to 0.45 Power

MOC Specification for Wearing Course type BWC-1 with SHRP Restricted Zone and Control Points.

Design Aggregate Structure



H.A.W.

LEVEL I MIX DESIGN FLOW CHART

Select aggregate based
on Specification criteria

⇩

Prepare three trail gradations

⇩

Calculate an initial asphalt
trail content for each gradation

⇩

Evaluate compacted trial gradations and select one

⇩

Compact specimen at 4 AC contents
around the trail asphalt content

H.A.W.

Trial Asphalt Binder

H.A.W.

LEVEL I MIX DESIGN FLOW CHART

Select aggregate based
on Specification criteria

⇩

Prepare three trail gradations

⇩

Calculate an initial asphalt
trail content for each gradation

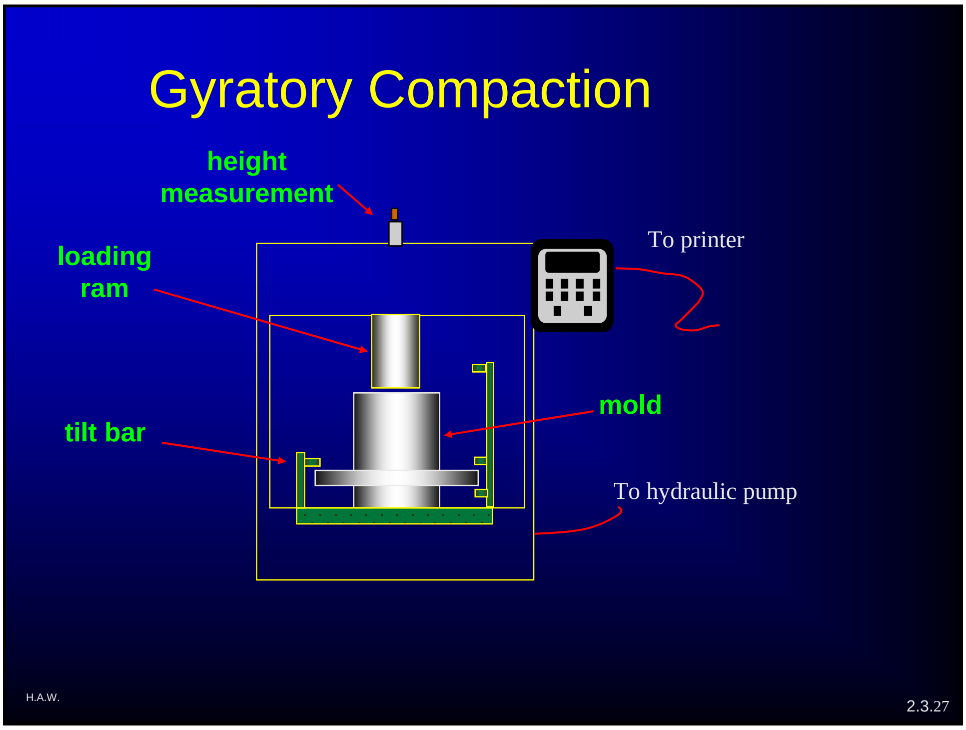
⇩

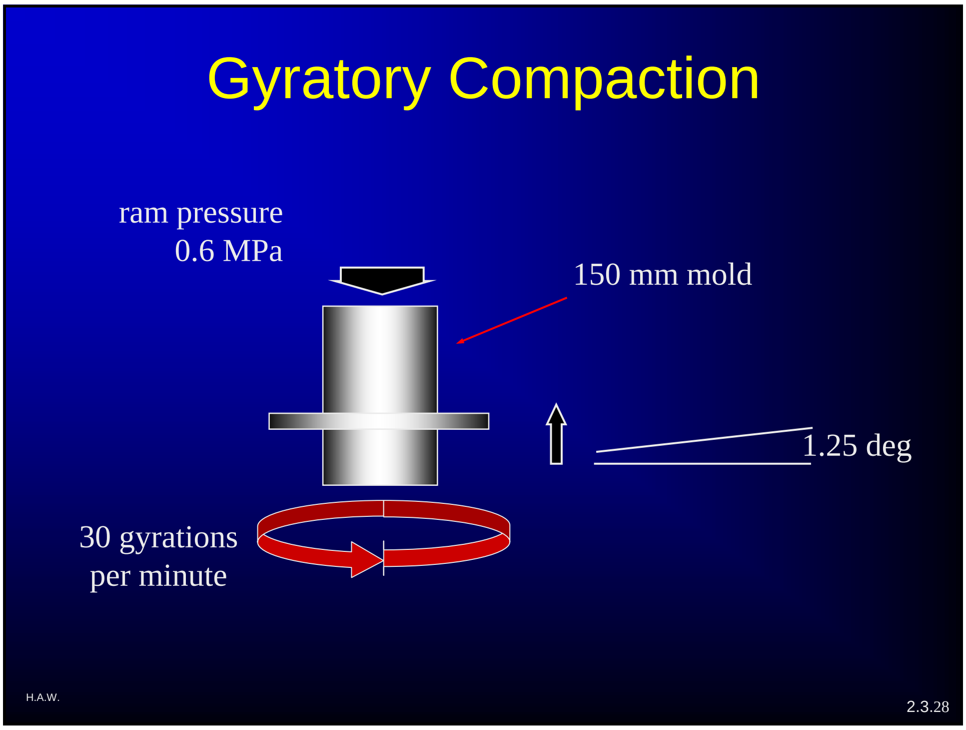
Evaluate compacted trial gradation

⇩

Compact specimen at 4 AC contents
around the trail asphalt content

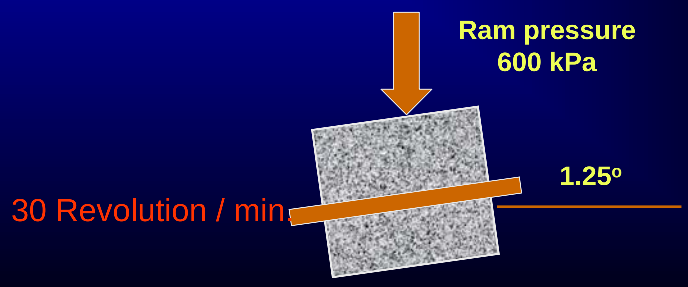
H.A.W.


Gyratory Compaction
height measurement
loading ram
To printer
mold
tilt bar
To hydraulic pump
H.A.W.
2.3.27


Gyratory Compaction
ram pressure
0.6 MPa
150 mm mold
1.25 deg
30 gyrations
per minute
H.A.W.
2.3.28

Compaction

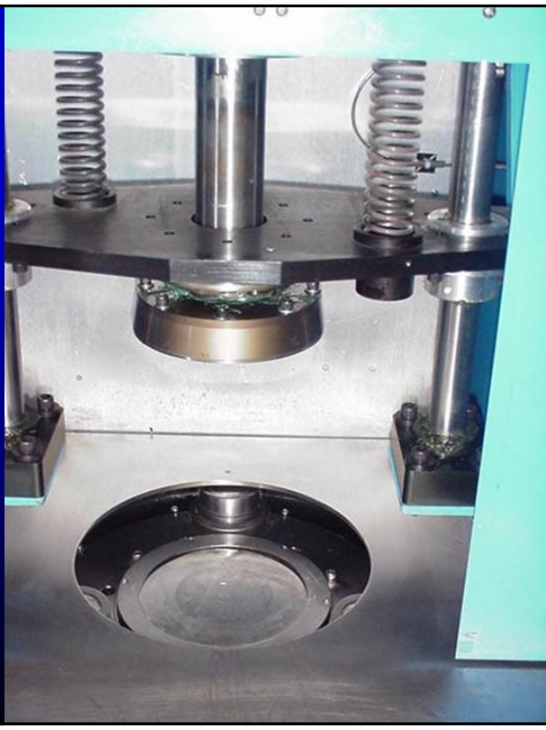
- Gyratory compactor
  - Axial and shearing action
  - 150 mm diameter molds
    - Aggregate size up to 37.5 mm
    - Height measurement during compaction
      - Allows densification during compaction to be evaluated



Compaction

Example of typical full-size compactors.


TROXLER
CAUTION
GYRATORY COMPACTOR



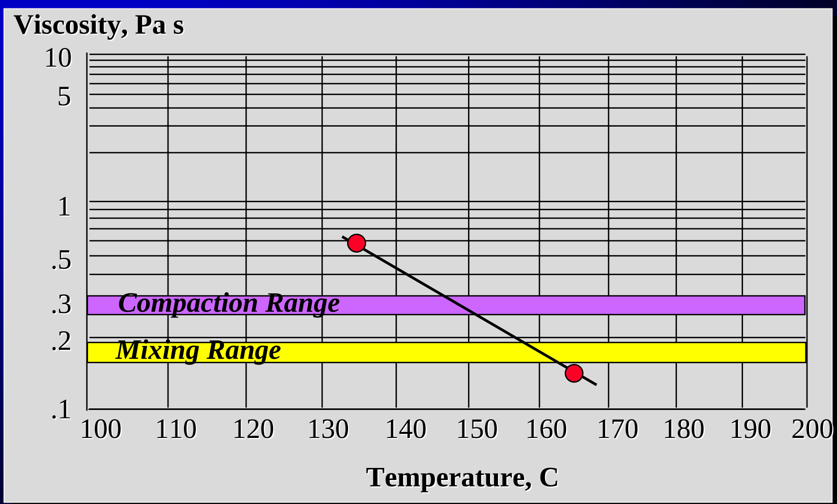

TROXLER

Quality Control

1. Height Measurement (standard height s
2. No. of Revolutions / Minute
3. Ram Pressure (load-cell or proving ring)
4. Gyration angle (digital dial gage)

H.A.W.

Mixing/Compaction Temps



H.A.W.

Mixing

Place pre-heated aggregate in bowl and add hot asphalt

Specimen Preparation

- Specimen Height
  - Mix Design - 115 mm (4700 g)
  - Moisture Sens. - 95 mm (3500 g)

- Loose Specimen for Max. Theor. (Rice)
  - varies with nominal max size
    - 19 mm (2000 g)
    - 12.5 mm (1500 g)

Mixing

Place bowl on mixer and mix until aggregate is well-coated

Short Term Aging

Empty mix into pan and place in oven to simulate short term aging

2 hours for low absorption aggregates
4 hours for high absorption aggregates

Short Term Aging Important

- Allows time for aggregate to absorb asphalt
- Helps minimize variability in volumetric calculations
  - Most terms dependent upon volumes which change with changes in the amount (volume) of absorbed asphalt

H.A.W.

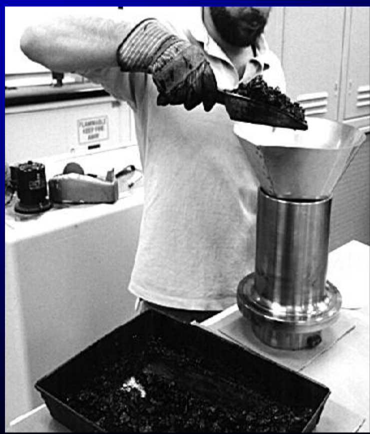
Compaction

After aging, take mix and preheated mold from oven. Place paper in bottom of mold.

H.A.W.

Compaction

Place funnel on top of mold and place mix in mold. Take care not to allow the mix to segregate.



H.A.W.

Compaction

Place another paper on top of mix and place mold in compactor.

H.A.W.

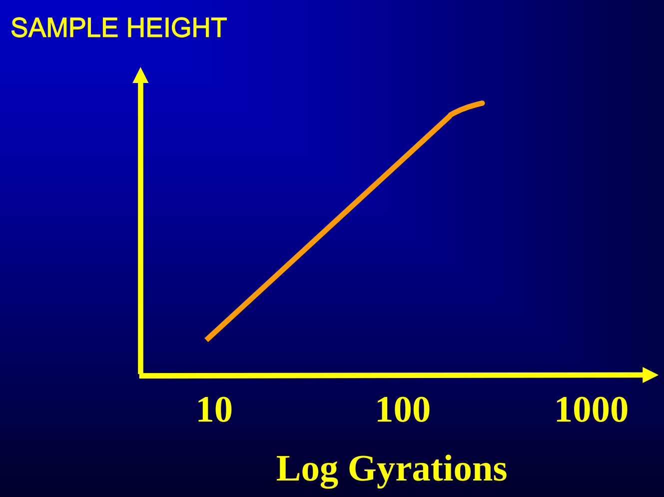
Compaction

Once compaction is finished, extrude sample from mold.

Compaction

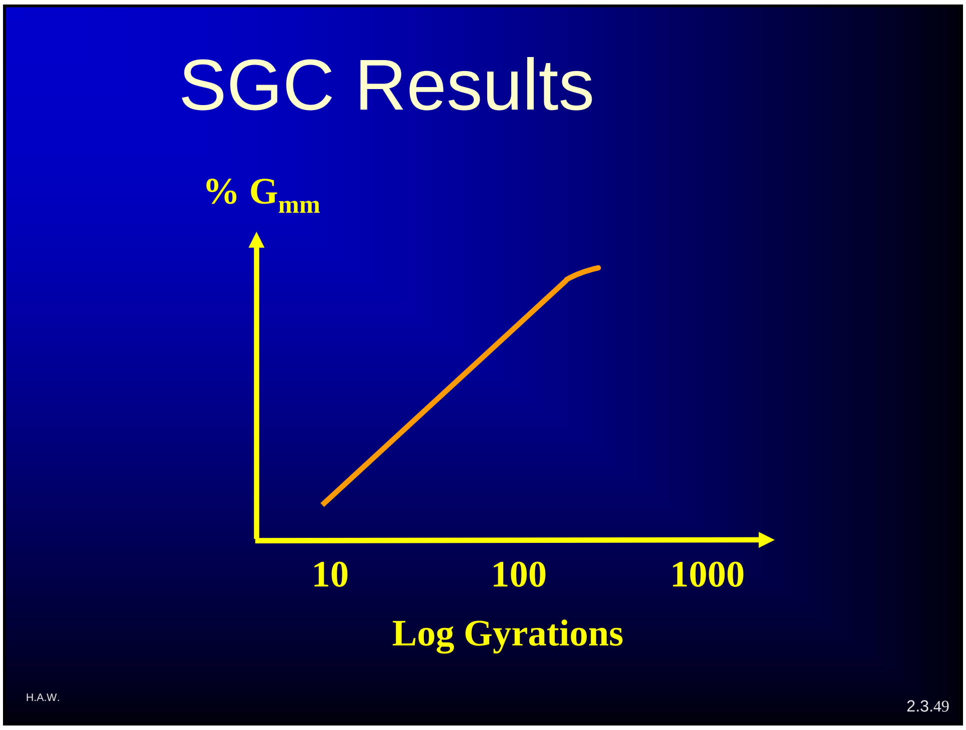
Remove the paper and label samples.

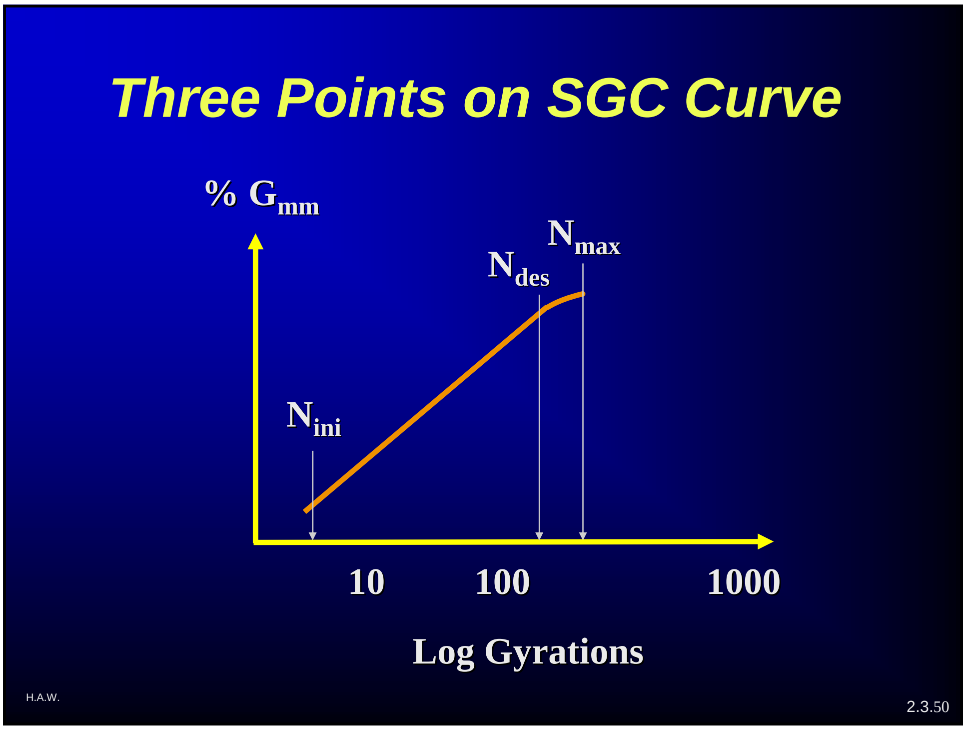
SGC Results



Bulk SG of The Mix = Sample Weight / Sample Height x πr^2

$$\% G_{mm} = (\text{Bulk SG of The Mix} / G_{mm}) \times 100$$


SGC Results
% G_{mm}
10
100
1000
Log Gyrations
H.A.W.
2.3.49


Three Points on SGC Curve
% G_{mm}
N_{max}
N_{des}
N_{ini}
10
100
1000
Log Gyrations
H.A.W.
2.3.50

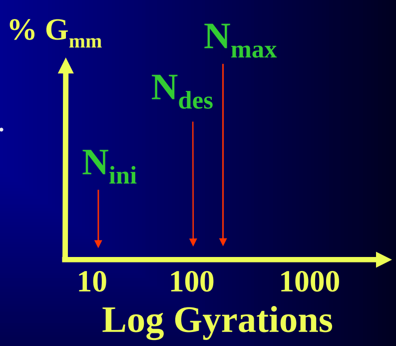
New Superpave N_{design} Table From AASHTO PP-28

Design ESAL[1] (Millions)	Gyratory Compaction Parameters			Typical Road Description [2]
	$N_{initial}$	N_{design}	N_{max}	
< 0.3	6	50	75	Application would include roadways with very light traffic volumes such as local roads, county roads and city streets where truck traffic is prohibited or at a very minimal level
0.3 to < 3	7	75	115	Application would include many collector roads or access streets. Medium trafficked city streets and majority of county roadways would be applicable to this level.
3 to < 30	8	100	160	Application would include many two lanes, multilane and divide partially or completely controlled access roadways. Among these are medium to highly trafficked city streets, highway and some rural interstates.
> 30	9	125	205	Application includes the vast majority of the US interstate system, both rural and urban in nature. Special application such as truck weighing stations or truck climbing lane on two lane roadways would be applicable to this level.

(1) Design ESAL's are anticipated project traffic level expected on the design lane over a period. Regardless of the design the roadway, determine the design ESAL's for 20 years and choose the appropriate N_{design} level.

Design Compaction

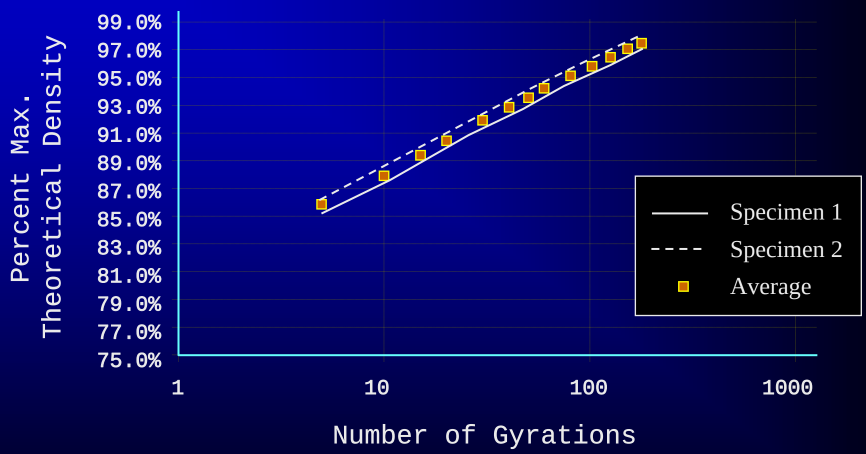
- N_{des} based on
  - average design high air temp.
  - traffic level
- $\text{Log } N_{max} = 1.10 \text{ Log } N_{des}$
- $\text{Log } N_{ini} = 0.45 \text{ Log } N_{des}$



General SUPERPAVE Compaction Requirements	
Compaction Level	Required Density (% of theoretical maximum specific Gravity)
N_{init}	< 89
N_{design}	= 96
N_{max}	< 98

Design ESAL's (millions)	**< 39°C**		
	N_{ini}	N_{des}	N_{max}
<0.3	**7**	**68**	**104**
0.3 – 1	**7**	**76**	**117**
1 – 3	**7**	**86**	**134**
3 – 10	**8**	**96**	**152**
10 – 30	***8***	***109***	***174***
30 – 100	**9**	**126**	**204**
>100	**9**	**142**	**233**

19.0mm Nominal, 4.4% AC,Trial Blend 1



Densification Curves for Trial Blend 1

Measure:

Gmm *for loose mixes*

&

Gmb *for each sample after compaction*

Measured % G_{mm} versus Corrected % G_{mm}

G_{mm} = 2.563

# of Gyrations	SPECIMEN 1 G_{mb} (calc)	SPECIMEN 1 $\%G_{mm}$	SPECIMEN 1 $\%G_{mm}$ (corr)	SPECIMEN 2 G_{mb} (calc)	SPECIMEN 2 $\%G_{mm}$	SPECIMEN 2 $\%G_{mm}$ (corr)	Average $\%G_{mm}$ (corr)
5	2.136	83.4%	85.2%	2.154	84.1%	86.2%	85.7%
10	2192	85.5%	87.3%	2.215	86.4%	88.6%	88.0%
15	2.230	87.0%	88.9%	2.250	87.8%	90.1%	89.5%
20	2.254	88.0%	89.9%	2.275	88.7%	91.0%	90.4%
30	2.294	89.5%	91.4%	2.309	90.1%	92.4%	91.9%
40	2.315	90.3%	92.3%	2.334	91.1%	93.4%	92.8%
50	2.334	91.1%	93.0%	2.353	91.8%	94.2%	93.6%
60	2.351	91.7%	93.7%	2.369	92.4%	94.8%	94.3%
80	2.376	92.7%	94.7%	2.393	93.4%	95.8%	95.2%
100	2.392	93.3%	95.4%	2.411	94.1%	96.5%	95.9%
125	2.409	94.0%	96.0%	2.427	94.7%	97.1%	96.6%
150	2.424	94.6%	96.6%	2.440	95.2%	97.7%	97.2%
174	2.436	95.1%	97.1%	2.451	95.6%	98.1%	97.6%
G_{mb} (meas)	2.489	97.1%		2.514	98.1%		

Determine of % Gmm at

N_{init}, N_{design}, and N_{max}

N_{init} = N_8 = 87.1	89%
N_{design} = N_{109} = 96.2	96%
N_{max} = N_{174} = 97.6%	98%

Volumetric Analyses

- Air Voids (P_a)
  - *Gmm and Gmb*
- Voids in the mineral Aggregate (VMA)
  - *Gmb, Gsb*
- Voids Filled with Asphalt (VFA)
  - *P_a and VMA*
- Dust to Effective Asphalt Ratio (D/A)
  - *$0.6 < p200/P_{be} < 1.2$*

H.A.W.

Superpave Mix Design

- VMA requirements:

Nominal max agg size	Min. VMA
9.5 mm	15
12.5 mm	14
19 mm	13
35 mm	12
37.5 mm	11

H.A.W.

Superpave Mix Design

- VFA requirements:
  - **Traffic (millions of ESALs)** Range of VFA

Traffic (millions of ESALs)	Range of VFA
< 0.3	70 to 80
1 to 3	65 to 78
> 3.0	65 to 75

Compaction Summary of Trial Blends

LEVEL I MIX DESIGN FLOW CHART

Select aggregate based
on Specification criteria

⇩

Prepare three trail gradations

⇩

Calculate an initial asphalt
trail content for each gradation

⇩

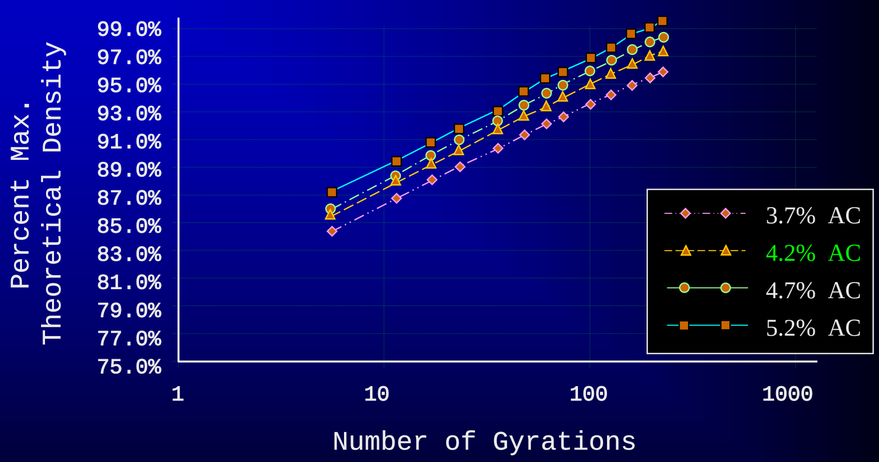
Evaluate compacted trial gradation

⇩

Compact specimen at 4 AC contents
around the trail asphalt content

H.A.W.

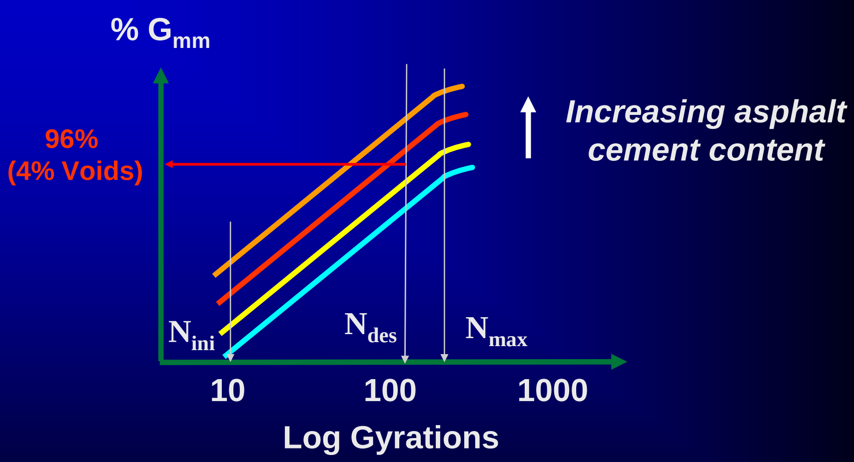
19.0mm Nominal,
Blend 3



Average Densification Curves for Trial Blend 3,
Varying Asphalt Binder Content

H.A.W.

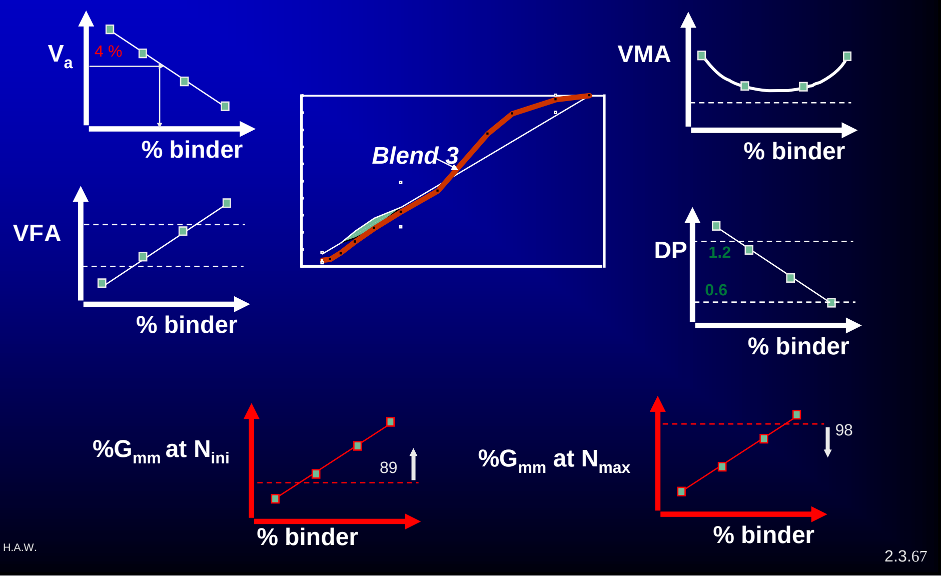
SGC Results



Each line = avg. of two samples

Summary of Blend 2 – Mixture Compaction Properties

Selection of Design Asphalt Binder Content

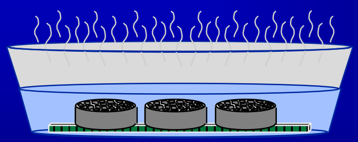


Superpave Mix Design

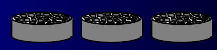
Moisture Sensitivity
AASHTO T 283

- Prepare set of 6 specimens
  - 6 to 8% voids
    - Represents anticipated in-service voids
  - Determine tensile strength of 3 of specimens
  - Condition remaining 3 in water bath (60°C, 24 hr.)
  - Bring to test temperature (25°C) and determine wet (conditioned) tensile strength

3 Conditioned Specimens



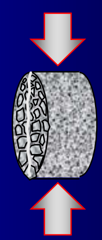
3 Dry Specimens



Vacuum saturate specimens
Soak at 60°C for 24 hours
Soak at 25°C for 2 hours

Moisture Sensitivity
AASHTO T 283

Determine the tensile strengths of both sets of 3 specimens



Calculate the Tensile Strength Ratio (TSR)

$$TSR = \frac{\text{Avg. wet tensile strength}}{\text{Avg. dry tensile strength}}$$

Minimum of 80% needed

Moisture Sensitivity
AASHTO T 283

Average Dry Strength (psi)	126.5
Average Wet Strength (psi)	104.5
% TSR	82.6%

New Superpave N_{design} Table From AASHTO PP-28

Design ESAL[1] (Millions)	Gyratory Compaction Parameters $N_{initial}$	N_{design}	N_{max}	Typical Road Description [2]
< 0.3	6	50	75	Application would include roadways with very light traffic volumes such as local roads, county roads and city streets where truck traffic is prohibited or at a very minimal level
0.3 to < 3	7	75	115	Application would include many collector roads or access streets. Medium trafficked city streets and majority of county roadways would be applicable to this level.
3 to < 30	8	100	160	Application would include many two lanes, multilane and divide partially or completely controlled access roadways. Among these are medium to highly trafficked city streets, highway and some rural interstates.
> 30	9	125	205	Application includes the vast majority of the US interstate system, both rural and urban in nature. Special application such as truck weighing stations or truck climbing lane on two lane roadways would be applicable to this level.

(1) Design ESAL's are anticipated project traffic level expected on the design lane over a period. Regardless of the design the roadway, determine the design ESAL's for 20 years and choose the appropriate N_{design} level.

H.A.W.

Superpave Volumetric Mixture Design Requirements MP2

Design ESAL's[1] (Millions)	Required Density (Percent of Gmm) $N_{initial}$	N_{design}	N_{max}	Voids in Mineral Aggregate (VMA) (Minimum Percent) Nominal Maximum Aggregate Size (mm) 37.5	25.0	19.0	12.5	9.5	Voids Filled with Asphalt (VFA) (Minimum Percent)	Dust-to-Binder Ratio
< 0.3	< 91.5	96.0	< 98.0	11 [4]	12.0	13.0	14.0	15.0	70-80 [3]	0.6-1.6
0.3 to < 3	< 90.5								65-75 [2]	
3 to <10	< 89.0								65-75 [2]	
10 to < 30										
> 30										

(1) Design ESAL's are anticipated project traffic level expected on the design lane over a 20 years period. Regardless of the actual design life of the roadway, determine the design ESAL's for 20 years and choose appropriate N_{design} level.
(2) For 9.5 mm nominal maximum size mixtures the specified VFA range shall be 73% to 76% for design traffic levels > 3 million ESAL'S.
(3) For 25.0 mm nominal maximum size mixtures the specified lower limit of the VFA shall be 66% for design traffic levels <3 million ESAL'S.
(4) For 37.5 mm nominal maximum size mixtures the specified lower limit of the VFA shall be 63% for all design traffic levels

H.A.W.