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## SUPERPAVE MIX DESIGN MANUAL

### I. SCOPE

This manual describes the method for the design of SUPERPAVE Hot Mix Asphalt (HMA) mixtures. This method outlines a complete procedure for the design of Superpave mixtures with and without Reclaimed Asphalt Pavement (RAP) and having an aggregate nominal maximum size not exceeding 19.0 mm.

### II. SIGNIFICANCE

The Superpave Hot Mix Asphalt mixture design system and Performance Graded (PG) Binder specification were developed as a result of research performed during the Strategic Highway Research Program (SHRP). The Superpave mix design system was developed to be a performance based design system which addresses the three principal distresses that effect HMA pavements: rutting, fatigue cracking, and low temperature cracking by identifying the performance properties needed to insure that the in-place HMA will achieve the pavement design life. Superpave HMA will be designed for the specific climate and traffic conditions that they will be exposed to during the life of the pavement.

### III. REFERENCED DOCUMENTS

AASHTO R 30	Mixture Conditioning of Hot Mix Asphalt (HMA).
AASHTO R 35	Superpave Volumetric Design for Hot-Mix Asphalt (HMA)
AASHTO T 11	Material Finer than 75 $\mu\text{m}$ (No. 200) Sieve in Mineral Aggregates by Washing
AASHTO T 27	Sieve Analysis of Fine and Coarse Aggregates
AASHTO T 49	Penetration of Bituminous Materials

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AASHTO T 176	Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
AASHTO T 248	Reducing Field Samples of Aggregate to Testing Size
AASHTO T 304	Uncompacted Void Content of Fine Aggregate
AASHTO T 312	Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the SHRP Gyrotory Compactor.
ASTM D4791	Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
ASTM D5821	Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate
FM 1-T 2	Sampling of Coarse and Fine Aggregates
FM 1-T 84	Specific Gravity and Absorption of Fine Aggregate.
FM 1-T 85	Specific Gravity and Absorption of Coarse Aggregate
FM 1-T 202	Absolute Viscosity of Asphalts
FM 1-T 209	Maximum Specific Gravity of Bituminous Paving Mixtures
FM 1-T 166	Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens
FM 1-T 283	Resistance of Compacted Bituminous Mixtures to Moisture Induced Damage
FM 3-D 5404	Recovery of Asphalt from Solution Using the Rotavapor Apparatus
FM 5-524	Reflux Extraction of Bitumen from Bituminous Paving

### Mixtures

FM 5-544	Quantitative Extraction of Bitumen from Bituminous Paving Mixtures by use of a Non-Chlorinated Solvent
FM 5-563	Quantitative Determination of Asphalt Content from Asphalt Paving Mixtures by the Ignition Method

## IV. DETAILS OF RESPONSIBILITY

### A. CONTRACTOR

#### 1. Documentation

The Contractor is responsible for furnishing the Central Bituminous Laboratory, at the State Materials Office, the following documents:

- a. A completed Superpave Mixture Design from a CTQP Qualified Mix Designer, meeting the specified mixture volumetric criteria as specified in Section 334 of the Florida Department of Transportation Standard Specifications for Road and Bridge Construction (see Figures 1 & 2).
- b. A Pavement Composition Data Sheet (if applicable, see Figure 3).
- c. Material Identification (C-22) Cards included with all samples (see Figure 4).

**NOTE:** If any of the necessary information is missing or not properly filled out, work on the design will be halted until the information is received.

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION  
 STATEMENT OF SOURCE OF MATERIALS AND JOB MIX FORMULA FOR BITUMINOUS CONCRETE

SUBMIT TO THE STATE MATERIALS ENGINEER, CENTRAL BITUMINOUS LABORATORY, 2006 NORTHEAST WALDO ROAD., GAINESVILLE, FLA. 32609

Project No. 111111-52-01 CTQP Qualified Mix Designer Ima Designer  
 Contractor Superpavers Asphalt Contracting Address 5007 N.E. 39th Avenue, Gainesville, FL 32609  
 Phone No. (352) 955-2907 Fax No. (352) 955-2904 E-mail david.webb@dot.state.fl.us  
 Submitted By Best Asphalt Consulting Type Mix Coarse SP-12.5 Recycle Intended Use of Mix Structural  
 Design Traffic Level D Gyration @ N des 100

	TYPE MATERIAL	F.D.O.T. CODE	PRODUCER	PIT NO.	DATE SAMPLED
1.	Milled Material		222222-52-01 Top 2.5" NB & SB KmP. 0.000 - 3.000 /MP. 0.000 - 1.864	Roadway TM-333 44-555	01 / 01 / 2004
2.	67 Stone	43	Superior Aggregates	TM-333 44-555	01 / 01 / 2004
3.	89 Stone	53	Superior Aggregates	TM-333 44-555	01 / 01 / 2004
4.	Screenings	21	Superior Aggregates	TM-333 44-555	01 / 01 / 2004
5.	PG 67-22				
6.					

PERCENTAGE BY WEIGHT TOTAL AGGREGATE PASSING SIEVES										
	Blend	15%	30%	40%	15%	5	6	JOB MIX FORMULA	CONTROL POINTS	RESTRICTED ZONE
	Number	1	2	3	4					
S I E V E	3/4" 19.0mm	100	100	100	100			100	100	
	1/2" 12.5mm	97	70	100	100			91	90 - 100	
	3/8" 9.5mm	94	38	95	100			79	- 90	
S I E V E	No. 4 4.75mm	83	5	38	92			43		
	No. 8 2.36mm	66	4	19	82			31	28 - 58	39.1 - 39.1
	No. 16 1.18mm	58	3	5	69			22		25.6 - 31.6
	No. 30 600µm	47	3	5	48			17		19.1 - 23.1
	No. 50 300µm	28	2	3	28			10		
S I E V E	No. 100 150µm	14	2	3	18			7		
	No. 200 75µm	8.0	1.0	2.0	7.0			3.4	2 - 10	
	G <sub>SB</sub>	2.562	2.393	2.448	2.581			2.467		

No. 200 increased due to expected aggregate breakdown during production.

Best Asphalt Consulting Design No. 04-22

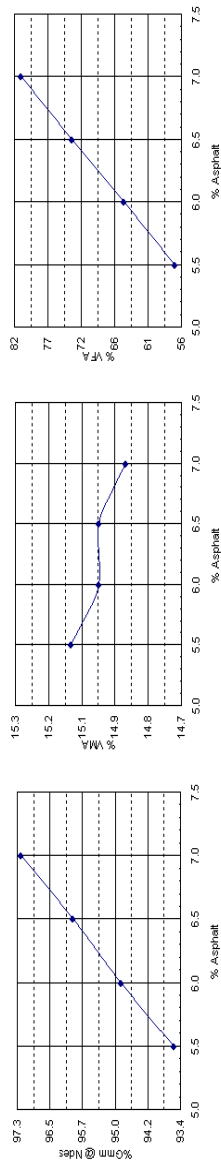
State Materials Engineer \_\_\_\_\_  
 Effective Date \_\_\_\_\_  
 Expiration Date \_\_\_\_\_

Figure 1 – Superpave Mix Design (Front Sheet)

HOT MIX DESIGN DATA SHEET

If you have an internal numbering system to track your mix designs, enter that number here.

P <sub>b</sub>	G <sub>mb</sub> @ N <sub>des</sub>	G <sub>mm</sub>	V <sub>e</sub>	VMA	VFA	P <sub>be</sub>	P <sub>0.075</sub> / P <sub>be</sub>	%G <sub>mm</sub> @ N <sub>hi</sub>	%G <sub>mm</sub> @ N <sub>max</sub>
5.5	2.217	2.370	6.5	15.1	57	4.0	1.3	86.0	95.0
6.0	2.232	2.354	5.2	15.0	65	4.5	1.1	87.0	96.0
6.5	2.244	2.338	4.0	15.0	73	5.0	1.0	88.0	97.0
7.0	2.257	2.322	2.8	14.9	81	5.5	0.9	89.0	98.0



Optimum Asphalt 6.50 %  
 Lab Density 140.0 Lbs/Ft<sup>3</sup> 2244 Kg/m<sup>3</sup>  
 VMA 15.0 %  
 FAA 45 %  
 %G<sub>mm</sub> @ N<sub>des</sub> 96.0  
 NCAT Oven Calibration Factor (-1 To Be Added)(+ To Be Subtracted) -0.10 %  
 Mixing Temperature 310 °F 154 °C  
 Compaction Temperature 300 °F 149 °C  
 Additives Amazing Anti-strip, Gripper 2000 (0001) Antistrip 0.5 %  
 Optimum Asphalt 6.50%  
 Asphalt using 15% Milled Material @ 5.5% = 0.80%  
 PG 67-22 to be added = 5.70%

Figure 2 – Superpave Mix Design (Back Sheet)

State of Florida Department of Transportation  
**Pavement Composition Data Sheet**

Milling Depth : Full Depth

Page: 2 of 2

Date: October 2, 2002		S.R. No.: 40		Notes	
F. P. N.: 238719-1-52-01		From: CR 328			
F. A. P. No.: N/A		To: CR 225A			
County: Marion		Beg. M.P.: 16.300		End M.P.: 19.979	
No. of Lanes: 2					

Core No.	M.P.	Lane	Pavement Layers (in.)						Core Length (ft.)	Percent Passing Sieves							%			
			FC-2	FC-4	S	ST	T-1	acc-2		3/4 in.	1/2 in.	3/8 in.	No. 4	No. 8	No. 16	No. 30		No. 50	No. 100	No. 200
1	19.810	L1	--	1.10	2.90	0.30	0.80	--	5.10	100.00	99.50	98.32	86.09	75.33	65.49	54.76	35.94	13.33	5.27	7.98
3	19.600	L1	--	--	2.50	0.30	0.80	--	3.60											
4	19.300	L1	--	0.40	2.70	--	0.80	--	3.90											
5	18.900	L1	--	0.80	2.00	--	0.90	--	3.70	100.00	100.00	99.63	88.44	76.96	66.41	53.96	34.41	12.79	5.17	7.72
7	18.600	L1	--	0.90	2.10	--	0.80	--	3.80											
8	18.300	L1	--	0.60	2.50	--	0.70	--	3.60											
9	17.900	L1	--	1.00	2.00	--	0.80	--	3.80	100.00	100.00	100.00	90.86	81.55	69.61	56.63	37.45	15.24	7.03	7.87
11	17.600	L1	--	0.90	2.10	--	1.00	--	4.00											
12	17.300	L1	--	0.90	2.10	--	0.80	--	3.80											
14	16.900	L1	0.80	--	3.10	--	--	4.30	8.40	100.00	94.35	84.47	68.07	44.30	35.03	29.88	22.50	11.62	6.73	7.56

Remarks :

Figure 3 - Pavement Composition Data Sheet

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION										675-050-04 MATERIALS 06/02						
PROJECT	<b>111111-1-52-01</b>				PAY ITEM											
MATERIAL NO.			SAMPLE NO.			DATE SAMPLED										
STA FROM				STA TO				SAMP FROM								
RDWY			OFFSET DISTANCE			OFFSET DIRECTION			MAINLINE							
REFERENCE								SOURCE								
PLANT OR PIT NO.																
INTENDED USE						INSP ID	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ROAD	<b>SR - 123</b>		DISTRICT	<b>2</b>		COUNTY	<b>ALACHUA</b>		CONTRACT							
MATERIAL	<b>PRE-BATCHED SAMPLES</b>															
MANUFACTURER	<b>SUPERPAVERS ASPHALT CONTRACTING</b>				DESIGN MIX											
GRADE			BATCH NO.			LOT NO.			LAB NO.							
CONTROL OF CONCRETE																
MATERIAL NO.			P/F			TEST BY CODE			TESTER ID							
DEL TICKET NO.			LOAD			%AIR			SLUMP							
								CONC TEMP			W/C RATIO					
REMARKS	<b>For Coarse SP-12.5 Recycle, TL-D</b>															
	<b>Blend: 15 - 30 - 40 - 15</b>															
	<b>Samples: 6 @ 4600g, 12 @ 1050g, 2 @ (NCAT required weight), 1 bag of RAP</b>															
	<b>Asphalt: PG 67-22 w/0.5% (QPL number of anti-strip)</b>															
	<b>If you have an internal numbering system to track your mix designs, please include that number here.</b>															
CONTACT	<b>Ima Designer</b>				PHONE	<b>(352) 955-2907</b>										
ADDRESS	<b>5007 N.E. 39th Avenue, Gainesville, FL 32609</b>															

**Figure 4 - Material Identification (C-22) Card**

**2. Samples**

**NOTE:** Aggregate submitted for mix design verification should be “split” from aggregate used in the mix design.

- a. Six samples of prebatched aggregate of sufficient mass to result in heights of 115mm ± 5mm when compacted to the required number of gyrations in a Superpave Gyrotory Compactor. Three samples will be compacted to N design and three to N maximum.

- b. Twelve samples of prebatched aggregate at approximately 1050g for maximum specific gravity, and moisture susceptibility testing.
- c. Two samples of prebatched aggregate of sufficient mass as specified in FM 5-563 for ignition oven calibration factor.
- d. One bag of RAP material (30 lbs.), if applicable, for the determination of the RAP bulk specific gravity.
- e. One sample of prebatched aggregate of sufficient mass passing the No. 4 sieve as specified in AASHTO T 176 for sand equivalent testing (do not include RAP material).
- f. One 1-gallon can of asphalt binder, from an approved supplier, labeled with the PG grade, and the Qualified Products List (QPL) number of the chosen anti-strip additive (if applicable).

## V. MATERIALS SAMPLING AND TESTING

### AGGREGATES

1. Obtain a sufficient amount of material to provide a representative stockpile gradation from an approved FDOT aggregate source in accordance with FM 1-T 2. Aggregates shall meet the requirements of Sections 901 and 902 of the Florida Department of Transportation Standard Specifications for Road and Bridge Construction.
2. Dry each aggregate sample to constant weight at  $230 \pm 9^{\circ}\text{F}$ , and reduce to testing size in accordance with AASHTO T 248.
3. Determine the gradation of each aggregate sample by performing a sieve analysis in accordance with AASHTO T 27. A washed gradation is performed on each of the fine aggregates by washing over the No. 200 sieve in accordance with AASHTO T 11. More than one sample should be tested to ensure accurate information.



4. Separate each aggregate into individual size fractions above the No. 8 sieve and store in clean containers. The minus 8 portion of each aggregate is stored in a separate container. The desired fractions shall be the appropriate sieves for the specific mix type involved.
5. The dry bulk specific gravity target for each coarse and fine aggregate can be obtained from the aggregate producer.

**NOTE:** It is important to acquire sufficient aggregate for both the entire mix design and samples for the mix verification process.

**NOTE:** It may be useful to perform the four consensus aggregate tests (coarse aggregate angularity, fine aggregate angularity, flat and elongated particles, and sand equivalency) on each individual aggregate component. This allows greater flexibility when dealing with multiple trial blends. It also informs the designer as to which aggregate(s) do not meet one or more of the consensus properties. The percentage of use for those aggregates not meeting one or more of the consensus properties will be limited in the total aggregate blend.

## **B. ASPHALT BINDER REQUIREMENTS**

1. Asphalt binder shall be a Superpave Performance Graded (PG) binder, on the current QPL, meeting the requirements of Section 916-1.2 of the Florida Department of Transportation Standard Specifications for Road and Bridge Construction. An asphalt binder specific gravity of 1.030 ( $G_b$ ) will be used when determining volumetric properties of the HMA design.

## **C. RECLAIMED ASPHALT PAVEMENT (RAP)**

1. Obtain RAP samples using one of the methods outlined in section 334 of the Florida Department of Transportation Standard Specifications for Road and Bridge Construction.

**NOTE:** Roadway cores shall be washed to remove fines produced by the coring operation.

2. The RAP material should be heated at  $230 \pm 9^\circ\text{F}$  until it is soft enough to break down by hand. Break the RAP material down into small pieces without degrading the aggregate. Dry the RAP material to constant weight at  $230 \pm 9^\circ\text{F}$ . Cool to room temperature stirring frequently to prevent the material from recombining.
3. If a Pavement Composition Data Sheet is not available, assume the responsibility for the determination of binder viscosity. A 3000g sample is sufficient for this purpose.

**NOTE:** Excessive heating of the RAP material may cause the viscosity to increase.

4. Select the appropriate binder based on Table 334-2 of the Florida Department of Transportation Standard Specifications for Road and Bridge Construction.
5. Determine the asphalt content and gradation (percent passing) of the RAP material in accordance with FM 5-544 or FM 5-563. A minimum of 6 samples should be tested to ensure accurate information. Save the uncoated material for further testing.

**NOTE:** The ignition method may produce unfavorable results if not properly calibrated.

**NOTE:** When roadway cores are used in the design process the designer may need to apply a milling factor to the RAP gradation in order to accurately represent the degradation experienced during the milling process.

6. Separate the dried and cooled RAP material into individual size fractions above the No. 8 sieve and store in clean containers. The minus 8 portion is stored in a separate container.

7. Determine the mass of each size fraction and calculate the gradation (percent retained) of the coated RAP material using the following equation. This information will be used to calculate the batch sheets during sample preparation.

0

Sieves	Weight Retained	Percent Retained
3/4"		
1/2"	300.0	3.0
3/8"	300.0	3.0
No. 4	1100.0	11.0
No. 8	1700.0	17.0
- 8	6600.0	66.0

**Figure 5 - Example of RAP Gradation**

$$P_r = \frac{M_r}{M_t} \times 100$$

where:

$P_r$  = percent retained on a particular sieve  
 $M_r$  = measured mass retained on a particular sieve  
 $M_t$  = measured mass of the total sample

example:

$$P_r = \frac{300.0}{10000.0} \times 100 = 3.0$$

$$P_r = \frac{1100.0}{10000.0} \times 100 = 11.0$$

8. Determine the bulk specific gravity of the RAP material using one of the following methods:
  - a. Calculation of the bulk specific gravity value based upon the

effective specific gravity of the aggregate recovered from the RAP, determined on the basis of the asphalt content and the maximum specific gravity.

1. Determine the maximum specific gravity of the RAP material in accordance with FM 1-T 209.

**NOTE:** Ensure fines are not lost in the dry-back process.

2. Extract a sample of the RAP material and estimate the asphalt absorption by determining the percentage of each source of the extracted aggregate through visual inspection and the use of Table 1.

**NOTE:** The ignition method may alter the appearance of the extracted aggregate and make it difficult to determine its source.

3. Determine the effective specific gravity of the aggregate recovered from the RAP material using the following equation:

$$G_{se} = \frac{P_s}{\frac{100}{G_{mm}} - \frac{P_b}{1.030}}$$

where:

- $G_{se}$  = Effective specific gravity
- $P_s$  = Percentage of extracted aggregate
- $G_{mm}$  = Maximum specific gravity
- $P_b$  = Percentage of binder in the RAP material

example:

$$G_{se} = \frac{94.5}{\frac{100}{2.481} - \frac{5.5}{1.030}} = 2.703$$

4. Determine the bulk specific gravity of the RAP material using the following equation:

$$G_{sb} = \frac{G_{se} \times G_b}{\left[ \left( \frac{P_{ba} \times G_{se}}{100} \right) + G_b \right]}$$

where:

- $G_{sb}$  = bulk specific gravity
- $G_{se}$  = effective specific gravity
- $P_{ba}$  = percentage of absorbed asphalt
- $G_b$  = specific gravity of asphalt cement ( $G_b = 1.030$ )

example:

$$G_{sb} = \frac{2.703 \times 1.030}{\left[ \left( \frac{2.1 \times 2.703}{100} \right) + 1.030 \right]} = 2.562$$

**Table 1 – Florida Approved Aggregate Sources**

Formation	Pit Number	Asphalt Absorption
Gravel	50-120	0.30
Granite Seams Schist	GA-383	0.33
Newalas Limestone	AL-149	0.36
Limestone	AL-485	0.36
Granite Gneiss	GA-177 GA-178 GA-181	0.43

	GA-182 GA-183	
Limestone	KY-309	0.43
Granite	GA-185	0.47
Limestone	IL-353	0.56
Limestone	KY-329	0.66
Tuscumbia Limestone	AL-351	0.94
Oolitic	87-339	1.77
Ft. Thompson Formation & Caloosahatchee	93-406	1.84
Miami Oolite & Ft. Thompson Formation	86-139 87-089 87-145	2.21
Suwannee Limestone	08-004 08-005 08-012	2.58
Miami Oolite	87-049 87-090	2.54
Ft. Thompson Formation & Tamiami	03-017 03-340 12-008 12-260	2.54
Caloosahatchee	01-011	2.69
Avon Park	34-106	3.30
Ocala Formation	38-268 38-036 29-023 29-361	3.28
Ocala Formation & Marianna Limestone	53-311 53-390	4.62

**b.** Determine the bulk specific gravity of the extracted material.

- 1.** Determine the fine and coarse bulk specific gravity of the extracted aggregate in accordance with FM 1-T 84 and

FM 1-T 85 respectively.

- a. When using the ignition oven extraction method (FM 5-563) calculate the bulk specific gravity of the extracted material using the following equation:

$$G_{sb} = \frac{100}{\frac{P_{s(+8)}}{G_{sb(+8)}} + \frac{P_{s(-8)}}{G_{sb(-8)}}}$$

where:

- $P_{s(+8)}$  = Percentage of coarse material above No. 8 sieve  
 $G_{sb(+8)}$  = Specific gravity of coarse material above the No. 8 sieve  
 $P_{s(-8)}$  = Percentage of fine material passing the No. 8 sieve  
 $G_{sb(-8)}$  = Specific gravity of material passing the No. 8 sieve

example:

$$G_{sb} = \frac{100}{\frac{34}{2.479} + \frac{66}{2.607}} = 2.562$$

- b. When the vacuum extraction method (FM 5-544) is used, the minus 200 portion will be lost during testing. Use the following equation to calculate the bulk specific gravity of the extracted material to account for this loss.

$$G_{sb} = \frac{100}{\frac{P_{s(c)}}{G_{sb(c)}} + \frac{P_{s(f)}}{G_{s(f)}} + \frac{P_{s(-200)}}{G_{sb(-200)}}}$$

where:

- $P_{s(c)}$  = Percentage of coarse material above No. 8 sieve  
 $G_{sb(c)}$  = Specific gravity of coarse material above the No. 8 sieve  
 $P_{s(f)}$  = Percentage of fine material passing the No. 8 sieve and retained on the No. 200 sieve.  
 $G_{sb(f)}$  = Specific gravity of fine material passing the No. 8 sieve and retained on the No. 200 sieve.  
 $P_{s(-200)}$  = Percentage of minus 200 material  
 $G_{sb(-200)}$  = Specific gravity of minus 200 material (2.750 constant)

example:

$$G_{sb} = \frac{100}{\frac{34}{2.479} + \frac{58}{2.589} + \frac{8}{2.750}} = 2.562$$

## VI. TRIAL AGGREGATE GRADATION BLENDS

- A. Establish the trial aggregate blends by mathematically combining the individual aggregate gradations into a single gradation using the following equation (see Figure 6).

$$P_{(n)} = \frac{A \times a}{100} + \frac{B \times b}{100} + \frac{C \times c}{100} + \frac{D \times d}{100} + Z \quad (\text{etc}).$$

where:

- $P_{(n)}$  = the percentage of material passing a given sieve for the combined aggregates A, B, C etc. in the JMF.



- A = percentage of material passing a given sieve for a given aggregate A.
- a = proportion of aggregate A used in the JMF, where (a+b+c+...) = 100.
- Z = change expected during the production process.

PERCENTAGE BY WEIGHT TOTAL AGGREGATE PASSING SIEVES

Blend	15%	30%	40%	15%			JOB MIX
Number	1	2	3	4	5	6	FORMULA
3/4" 19.0mm	100	100	100	100			100
1/2" 12.5mm	97	70	100	100			91
3/8" 9.5mm	94	38	95	100			79
No. 4 4.75mm	83	5	38	92			43
No. 8 2.36mm	66	4	19	82			31
No. 16 1.18mm	58	3	5	69			22
No. 30 600µm	47	3	5	48			17
No. 50 300µm	28	2	3	28			10
No. 100 150µm	14	2	3	18			7
No. 200 75µm	8.0	1.0	2.0	7.0			5.0
Sp. Gr.							

No. 200 increased due to expected aggregate breakdown during production.

**Figure 6 - Job Mix Formula**

example:

$$P_{1/2} = \left(97 \times \frac{15}{100}\right) + \left(70 \times \frac{30}{100}\right) + \left(100 \times \frac{40}{100}\right) + \left(100 \times \frac{15}{100}\right) = 91$$

$$P_{200} = \left(8.0 \times \frac{15}{100}\right) + \left(1.0 \times \frac{30}{100}\right) + \left(2.0 \times \frac{40}{100}\right) + \left(7.0 \times \frac{15}{100}\right) + 1.6 = 5.0$$

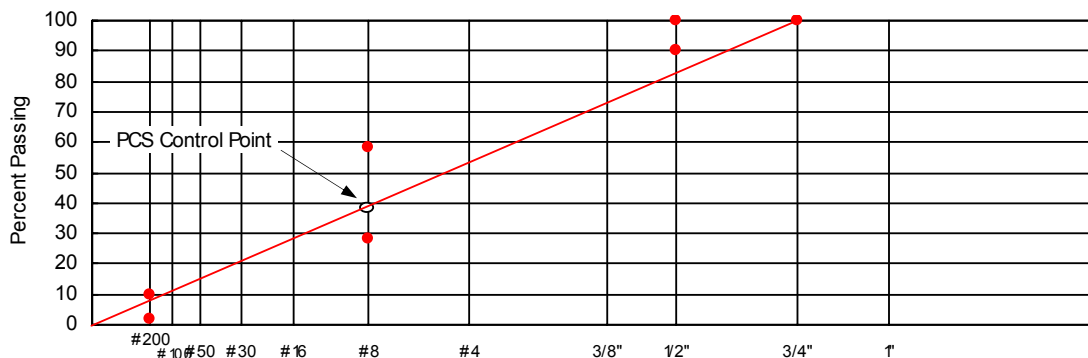
**NOTE:** It is the designer's responsibility to reflect and note any changes to the JMF anticipated during the production process.

**NOTE:** When using RAP material, use the gradation (percent passing) from

the extraction process in calculating the JMF.

- B.** Plot each trial blend on the corresponding Superpave 0.45 power chart (see Figure 7). Compare each gradation blend to appropriate mixture specifications. Gradation control is based on four control sieves: the maximum sieve, the nominal maximum sieve, the No. 8 mm sieve, and the No. 200 sieve. Select only the trial blends that meet the design gradation specification requirements.

**Note:** An aggregate blend will be designated FINE when it plots above the primary control sieve (PCS), and COARSE when it plots below the PCS (see AASHTO M 323-04, Table 4).



**Figure 7 - Superpave 0.45 Gradation Chart for a 12.5mm mix**

## VII. SAMPLE PREPARATION

**Note:** It is important to fabricate a gradation of the aggregate (particularly -200), which accounts for aggregate breakdown during the plant production process. This may be different for different aggregate types, blends, and plant type. Remember: FINAL ACCEPTANCE is based on the gradation of plant produced mix.

## A. SAMPLE BATCHING

**NOTE:** For the sample batching section it may be helpful to refer back to the Job Mix Formula in Figure 6 on page 17 to see where the percentages of different materials and individual sieve sizes come from.

1. Determine the sample mass based on the mix design type and specific test being performed.
2. If the designer expects excess fine material to be generated during the production process, determine the mass of the adjusted sample by the following equation:

$$M_{-200} = M_t \times \frac{P_{-200}}{100}$$

$$M_{\text{adj}} = M_t - M_{-200}$$

where:

- $M_{-200}$  = mass of the mineral filler.
- $M_t$  = mass based on test procedure.
- $P_{-200}$  = excess fines expected during the production process.
- $M_{\text{adj}}$  = adjusted sample mass.

example:

$$M_{-200} = 2500.0 \times \frac{1.6}{100} = 40.0$$

$$M_{\text{adj}} = 2500.0 - 40.0 = 2460.0$$

3. Calculate the mass of the individual aggregate components to be used.
  - a. Determine the mass of the coated RAP material using the

following equation (see Figure 8).

$$M_s = M_{adj} \times \frac{P_s}{P_{sr}}$$

$$P_{sr} = 100 - P_{br}$$

where:

$M_s$  = mass of the coated RAP material component.

$M_{adj}$  = total mass of the sample.

$P_s$  = percent of the RAP component.

$P_{sr}$  = percent aggregate in the RAP material.

$P_{br}$  = percent binder in the RAP material.

example:

$$P_{sr} = 100 - 5.5 = 94.5$$

$$M_s = 2460 \times \frac{15}{94.5} = 390$$

AGGREGATE WEIGH SHEET FOR SUPERPAVE MIX DESIGN					
Material Description	Milled Material	67 Stone	89 Stone	Screenings	Mineral Filler
Lab #	92000	92001	92003	92004	
Blend	15.0%	30.0%	40.0%	15.0%	1.6%
Blend Wt.	390	738	984	369	40

**Figure 8 - RAP Blend Weight**

**b.** Determine the mass of the virgin aggregate components using

the following equation (see Figure 9).

$$M_s = M_{adj} \times \frac{P_s}{100}$$

where:

$M_s$  = mass of the aggregate component.

$M_{adj}$  = total mass of the sample.

$P_s$  = percent of the aggregate component.

example:

$$M_s = 2460 \times \frac{30}{100} = 738$$

AGGREGATE WEIGH SHEET FOR SUPERPAVE MIX DESIGN					
Material Description	Milled Material	67 Stone	89 Stone	Screenings	Mineral Filler
Lab #	92000	92001	92003	92004	
Blend	15.0%	30.0%	40.0%	15.0%	1.6%
Blend Wt.	390	738	984	369	40

**Figure 9 - Virgin Aggregate Blend Weight**

4. Calculate the weight retained of each size fraction for each aggregate component using the following equation.

**Note:** Refer to Figure 5 on page 11 for the amount of RAP material retained on a particular size fraction ( $P_{r(n)}$ ).

- a. Determine the mass of the individual size fractions of the RAP material using the following equation and the gradation obtained

during the material preparation process. (see Figure 10).

$$M_{\text{rap}(n)} = M_{\text{rap}} \times \frac{P_{r(n)}}{100}$$

where:

$M_{\text{rap}(n)}$  = mass of the coated RAP material component of a particular size fraction.

$M_{\text{rap}}$  = mass of the coated RAP material component.

$P_{r(n)}$  = percent retained of the RAP material component on a particular size fraction.

$n$  = the particular size fraction.

example:

$$M_{\text{rap}(1/2)} = 390 \times \frac{3}{100} = 11.7\text{g}$$

$$M_{\text{rap}(3/8)} = 390 \times \frac{3}{100} = 11.7\text{g}$$

$$M_{\text{rap}(\#4)} = 390 \times \frac{11}{100} = 42.9\text{g}$$

$$M_{\text{rap}(\#8)} = 390 \times \frac{17}{100} = 66.3\text{g}$$

$$M_{\text{rap}(-8)} = 390 \times \frac{66}{100} = 257.4\text{g}$$

AGGREGATE WEIGH SHEET FOR SUPERPAVE MIX DESIGN					
Material Description	Milled Material	67 Stone	89 Stone	Screenings	Mineral Filler
Lab #	92000	92001	92003	92004	
Blend	15.0%	30.0%	40.0%	15.0%	1.6%
Blend Wt.	390	738	984	369	40
1 1/2					
1					
3/4					
1/2	11.7	221.4			
3/8	11.7	236.2	49.2		
4	42.9	243.5	560.9	29.5	
8	66.3	7.4	187.0	36.9	
-8	257.4	29.5	187.0	302.6	40.0

**Figure 10 - Weight of RAP Fractions**

- b. Determine the mass of the individual size fractions of the virgin aggregate using the following equation and the gradation obtained during the material preparation process. (see Figure 11).

$$M_{s(n)} = M_s \times \left( \frac{P_{s(n+1)} - P_{s(n)}}{100} \right)$$

where:

$M_{s(n)}$  = mass of the aggregate component of a particular

size fraction.

$M_s$  = mass of the aggregate component.

$P_{s(n)}$  = percent passing of the aggregate component on a particular size fraction.

$P_{s(n+1)}$  = percent passing of the aggregate component on the sieve one size larger than sieve size, n.

example:

$$M_{s(1/2)} = 738 \times \left( \frac{100 - 70}{100} \right) = 221.4\text{g}$$

$$M_{s(3/8)} = 738 \times \left( \frac{70 - 38}{100} \right) = 236.2\text{g}$$

$$M_{s(\#4)} = 738 \times \left( \frac{38 - 5}{100} \right) = 243.5\text{g}$$

$$M_{s(\#8)} = 738 \times \left( \frac{5 - 4}{100} \right) = 7.4\text{g}$$

$$M_{s(-8)} = 738 \left( \frac{4 - 0}{100} \right) = 29.5\text{g}$$



AGGREGATE WEIGH SHEET FOR SUPERPAVE MIX DESIGN					
Material Description	Milled Material	67 Stone	89 Stone	Screenings	Mineral Filler
Lab #	92000	92001	92003	92004	
Blend	15.0%	30.0%	40.0%	15.0%	1.6%
Blend Wt.	390	738	984	369	40
1 1/2					
1					
3/4					
1/2	12	221			
3/8	23	458	49		
4	66	701	610	30	
8	133	709	797	66	
-8	390	738	984	369	40.0

**Figure 11 - Weight of Virgin Aggregate Fractions**

- c. Determine the cumulative mass of the aggregate components rounding to the whole number (see Figure 12 ).

AGGREGATE WEIGH SHEET FOR SUPERPAVE MIX DESIGN					
Material Description	Milled Material	67 Stone	89 Stone	Screenings	Mineral Filler
Lab #	92000	92001	92003	92004	
Blend	15.0%	30.0%	40.0%	15.0%	1.6%
Blend Wt.	390	738	984	369	40
1 1/2					
1					
3/4					
1/2	11	221			
3/8	23	458	49		
4	66	701	610	30	
8	133	709	797	66	
-8	390	738	984	369	40.0
Total Aggregate Wt.		2500	2521		
Date	01 / 01 / 2000				
Design Number	Trial 1				
Type of Mix	SP-12.5 Recycle				
Technician	J. Doe				
Contractor	Superpavers Asphalt				
NOTES:	Weigh RAP Separately				
	Un-Coated RAP, Virgin Aggregate, and Mineral Filler = 2500g				
	Coated RAP, Virgin Aggregate, and Mineral Filler = 2521g				

**Figure 12 - Aggregate Weigh Sheet**

**NOTE:** The adjustment to the blend is eliminated by using the adjusted sample mass when calculating the aggregate component mass.

**NOTE:** It is essential that the batched samples represent the Job Mix Formula for accurate determination of the volumetric properties.

## **B. TRIAL ASPHALT BINDER**

1. Superpave requires the analysis of the volumetric properties at four asphalt contents, the optimum asphalt content, 0.5% and 1.0% above the optimum asphalt content, and 0.5% below the optimum asphalt content. Estimate the trial asphalt binder content for each aggregate blend selected in Section VI (Trial Aggregate Gradation Blends). This can be completed in accordance with AASHTO PP28 or, as an alternate method the designer may use his/her judgment when setting the trial asphalt binder content.

## **VIII. AGGREGATE CONSENSUS TESTING**

### **A. UNCOMPACTED VOID CONTENT OF FINE AGGREGATE**

1. Batch up an aggregate sample for each trial blend that will provide approximately 1,500 grams of minus 8 material.

**NOTE:** The minus 8 portion of the RAP material should be extracted prior to being incorporated with the virgin aggregate portion in order to minimize the effects of the extraction process on the fine aggregate angularity test.

2. Wash each sample over a No. 200 sieve in accordance with AASHTO T 11 and determine the dry bulk specific gravity of each sample in accordance with FM 1-T 84.
3. Dry each sample to constant mass at a temperature of  $230 \pm 9^{\circ}\text{F}$ .

4. Separate each of the samples into the individual size fractions and recombine in accordance with test method AASHTO T 304 Method A.
5. Determine the uncompacted void content of each sample in accordance with test method AASHTO T 304 Method A (see Figure 13). Refer to Section 334 of the Florida Department of Transportation Standard Specifications for Road and Bridge Construction for specification compliance.

Uncompacted Void Content				
		Sample #1	Sample #2	Sample #3
Mass of the empty measure		183.0	183.0	183.0
Volume of the cylindrical measure	(V)	<b>99.8</b>	<b>99.8</b>	<b>99.8</b>
Dry bulk specific gravity	(G)	<b>2.475</b>	<b>2.475</b>	<b>2.475</b>
Gross mass		318.0	318.2	317.9
Net mass of sample	(F)	<b>135.0</b>	<b>135.2</b>	<b>134.9</b>
Uncompacted void content	$((V - (F / G)) / V * 100)$	<b>45.3%</b>	<b>45.3%</b>	<b>45.4%</b>
Average uncompacted void content		<b>45.3%</b>		

**Figure 13 - Fine Aggregate Angularity Work Sheet**

6. Calculate the uncompacted void content using the following equation.

$$U = \frac{\left( V - \frac{F}{G} \right)}{V} \times 100$$

where:

U = uncompacted void content, percent, in the material.

V = volume of the cylindrical measure.  
F = net mass, g, of fine aggregate in the measure  
(gross mass minus the empty measure).  
G = dry bulk specific gravity of the fine aggregate.

example:

$$U = \frac{\left(99.8 - \frac{135.0}{2.475}\right)}{99.8} \times 100 = 45.3$$

## B. FLAT AND ELONGATED PARTICLES IN COARSE AGGREGATE

1. Obtain a sufficient quantity of each blended material, that when separated and reduced, produces approximately 100 particles of each size fraction larger than the 3/8" sieve and present in the amount of 10% or more of the original sample.
2. Separate each of the samples into individual size fractions.
3. Reduce each size fraction to sample size, approximately 100 particles, in accordance with AASHTO T 248.
4. Determine the amount of flat and elongated particles using a 5:1 ratio in accordance with ASTM D4791. Refer to Section 334 of the Florida Department of Transportation Standard Specifications for Road and Bridge Construction for specification compliance.
5. Calculate the amount of Flat and Elongated particles using the following equation.

$$P_{fe} = \frac{M_{fe}}{M_t} \times 100$$

where:

$P_{fe}$  = percent flat and elongated particles  
 $M_{fe}$  = mass of the flat and elongated particles

$M_t$  = mass of the sample

example:

$$P_{fe} = \frac{10.0}{200.0} \times 100 = 5.0$$

### C. SAND EQUIVALENT TEST

1. Reduce a sufficient quantity of the blended material, finer than the No. 4 sieve, required to fill four of the 3 oz tin measures in accordance with AASHTO T 248.
2. Determine the sand equivalent value in accordance with AASHTO T 176. Refer to Section 334 of the Florida Department of Transportation Standard Specifications for Road and Bridge Construction for specification compliance.
3. Calculate the sand equivalent value using the following equation:

$$P_{se} = \frac{S}{C} \times 100$$

where:

$P_{se}$  = percent sand equivalent  
 $S$  = sand measurement  
 $C$  = clay measurement

example:

$$P_{se} = \frac{3.3}{8.0} \times 100 = 41.3 = 42\%$$

**NOTE:** Always round the sand equivalent value up to the next whole number (i.e., if  $P_{se} = 42.2$ , then  $P_{se}$  is actually shown as 43%).

**SAND EQUIVALENT**

<i>Design #</i> _____	<i>Contractor</i> _____	<i>Superpavers Asphalt</i> _____	<i>Type of Mix</i> _____	<i>SP-12.5Recycle</i> _____
		Sample #1	Sample #2	Sample #3
<i>Sand Reading</i>		<u>3.3</u>	<u>3.4</u>	<u>3.2</u>
<i>Clay Reading</i>		<u>8.0</u>	<u>7.9</u>	<u>8.1</u>
<i>Sand Equivalent</i>		<u>42%</u>	<u>44%</u>	<u>40%</u>
<i>Average Sand Equivalent</i>			42%	

**Figure 14 - Sand Equivalent Work Sheet**

**D. PERCENTAGE OF FRACTURED PARTICLES IN COARSE AGGREGATE**

1. Obtain a sufficient quantity of each blended material as outlined in ASTM D5821.
2. Separate the material larger than the No. 4 sieve.
3. Determine the percentage of fractured particles in accordance with ASTM D5821. Refer to Section 334 of the Florida Department of Transportation Standard Specifications for Road and Bridge Construction for specification compliance.
4. Calculate the percentage of particles with one or more fractured faces and the percentage of particles with two or more fractured faces using the following equation:

$$P_{fp} = \frac{M_{fp}}{M_t} \times 100$$

where:

$P_{fp}$  = percent fractured particles

$M_t$  = mass of sample

$M_{fp}$  = mass fractured particles

## IX. VOLUMETRIC ANALYSIS

### A. COMPOSITE GRADATION

1. Determine the composite gradation of each trial blend by performing a washed gradation analysis as outlined in AASHTO T 11, or if RAP material is being used, an extraction analysis as outlined in FM 5-544 or FM 5-563.

**NOTE:** If the ignition extraction process is to be used, extract only the RAP material and recombine it with the virgin aggregate for complete analysis.

2. Batch out the appropriate mass as outlined in AASHTO T 11 and AASHTO T 27 of the dried and separated material for each trial blend.
3. Wash each sample over a No. 200 sieve in accordance with AASHTO T 11.
4. Dry each sample to constant mass at a temperature of  $230 \pm 9^\circ\text{F}$ .
5. Determine the composite gradation of each sample by shaking the sample on the appropriate apparatus designed to prevent the loss of material in accordance with AASHTO T 11 and AASHTO T 27.

**NOTE:** Any change in the blend, gradation of component materials, or minus 200 will result in the need to retest the composite gradation.

6. Calculate the percent passing on each sieve, (see Figures 15 & 16),



using the following equations:

$$M_{(-200)} = M_t - M_w + M_{(\text{pan})}$$

where:

$M_{(-200)}$  = mass of -200 material

$M_t$  = total mass of sample

$M_w$  = mass of the washed sample

$M_{(\text{pan})}$  = mass of -200 material retained in the pan

example:

$$M_{(-200)} = 2500.0 - 2385.0 + 10.0 = 125.0$$

**SUPERPAVE WASH GRAD. WORK SHEET**

SAMPLE #	Trial 1	LAB NO. _____
SUPPLIER		
MATERIAL		
ORIGINAL WEIGHT	2500.0	
WASHED WEIGHT	2385.0	
LOSS	115.0	
+	10.0	
TOTAL	125.0	

**Figure 15 – Mass of the -200 sieve**

$$P_{(n)} = \left( 1 - \frac{M_{(n)}}{M_t} \right) \times 100$$

where:

- $P_{(n)}$  = percent passing of a particular sieve
- $M_{(n)}$  = mass of material retained on a particular sieve
- $M_t$  = total mass of the sample

example:

$$P_{(n)} = \left( 1 - \frac{224.9}{2500.0} \right) \times 100 = 91.0 \%$$

**NOTE:** Percent passing values should be reported to the nearest whole number except the No. 200 sieve which should be reported to one decimal place.

**SUPERPAVE WASH GRAD. WORK SHEET**

SAMPLE #	Trial 1	LAB NO. _____
SUPPLIER		
MATERIAL		
ORIGINAL WEIGHT	2500.0	
WASHED WEIGHT	2385.0	
LOSS	115.0	
	+	2385.0
TOTAL	2500.0	

Weight Retained		Percent Passing	
1"		1"	
3/4"		3/4"	100
1/2"	224.9	1/2"	91
3/8"	525.9	3/8"	79
4	1423.9	4	43
8	1725.5	8	31
16	1949.3	16	22
30	2073.6	30	17
50	2250.5	50	10
100	2325.7	100	7
200	2375.0	200	5.0
Pan	2385.0		

Remarks: \_\_\_\_\_

Technician: \_\_\_\_\_

Date: 01/01/2000

**Figure 16 – Gradation sheet**

### C. MAXIMUM SPECIFIC GRAVITY

1. Batch out a minimum of two samples, for each asphalt content, of the appropriate mass as outlined in FM 1-T 209 of the dried and separated material for each trial blend.
2. Add the appropriate amount of asphalt binder.
3. Mix the sample of asphalt and aggregate until thoroughly coated.
4. Place the sample of asphalt mix in a pan at the appropriate thickness and condition for 2 hours stirring every hour as outlined in AASHTO R 30-02.
5. Determine the maximum specific gravity in accordance with FM 1-T 209.
6. Calculate the maximum specific gravity using the following equations:

$$G_{mm} = \frac{A}{B + D - E}$$

where:

- $G_{mm}$  = maximum specific gravity.  
A = mass of dry sample in air, g.  
B = final surface-dry mass of sample, g.  
D = mass of flask filled with water at 77°F, g.  
E = mass of flask filled with water and sample at 77°F, g.

example:

$$G_{mm} = \frac{1050.0}{1052.0 + 3310.2 - 3913.1} = 2.338$$

## D. BULK SPECIFIC GRAVITY

1. Batch out a minimum of two samples, for each asphalt content, of the appropriate mass of the dried and separated material for each trial blend. The mass can be calculated using the following equation or based on the past experience of the designer:

**NOTE:** It may be desirable to prepare a pilot specimen and make any necessary adjustment to the total mass of the sample to ensure the height value is within specifications

$$M_s = [G_{mm} - (V_a \times G_{mm})] \times 2032.2 \times P_s$$

where:

$M_s$  = Mass of the aggregate  
 $G_{mm}$  = Maximum Specific Gravity (Rice)  
 $V_a$  = Air Voids at  $N_{des}$  (0.04)  
 $P_s$  = Percent aggregate

example:

$$M_s = [2.338 - (0.04 \times 2.338)] \times 2032.2 \times 0.935 = 4353.6$$

2. Add the appropriate amount of asphalt binder.
3. Mix the sample of asphalt and aggregate until thoroughly coated.
4. Place the sample of asphalt mix in a pan at the appropriate thickness and condition for 2 hours stirring every hour as outlined in AASHTO R 30-02.
5. Place all necessary equipment for the compaction process in the oven 30 – 60 minutes prior to compaction.
6. Ensure that all calibration requirements have been met on the gyratory compactor as outlined in Section 334 of the Florida Department of

Transportation Specifications for Road and Bridge Construction.

7. Make all necessary adjustments to the compaction equipment for the type of mix to be used as outlined in Section 334 of the Florida Department of Transportation Specifications for Road and Bridge Construction.
8. Compact the specimens as outlined in AASHTO T 312. Use the number of gyrations as defined in AASHTO R35-04, Table 1 with the following exceptions: for Traffic Level C mixes, compact the mixture as specified for the Traffic Level of  $0.3 \times 10^6$  to  $< 3 \times 10^6$  ESAL's; for Traffic Level E mixes, compact the mixture as specified for the Traffic Level of  $10 \times 10^6$  to  $< 30 \times 10^6$  ESAL's.
9. Determine bulk specific gravity of the compacted specimens as outlined in FM 1-T 166 by measuring the weight in air, weight in water at 77°F, and weight at the saturated surface dry condition.
10. Calculate the bulk specific gravity at  $N_{\text{design}}$  as outlined in FM 1-T 166 using the following equation:

$$G_{\text{mb}} = \frac{M_{\text{air}}}{M_{\text{ssd}} - M_{\text{water}}}$$

where:

$G_{\text{mb}}$  = Bulk specific gravity at  $N_{\text{design}}$  (Compacted)  
 $M_{\text{air}}$  = Mass in air  
 $M_{\text{ssd}}$  = Mass at saturated surface dry condition  
 $M_{\text{water}}$  = Mass submerged in water at 77°F

example:

$$G_{\text{mb}} = \frac{4606.6}{4608.0 - 2576.4} = 2.267$$

The bulk specific gravity at  $N_{max}$  should also be checked on two specimens compacted at optimum asphalt content at  $N_{max}$ .

11. Calculate the bulk specific gravity at  $N_{ini}$  using the following equation:

$$G_{mb} @ N_{ini} = G_{mb} @ N_{design} \times \frac{H_{design}}{H_{ini}}$$

where:

$$\begin{aligned} G_{mb} @ N_{ini} &= \text{Bulk specific gravity at } N_{ini} \text{ (Calculated)} \\ G_{mb} @ N_{design} &= \text{Bulk specific gravity at } N_{design} \text{ (Compacted)} \\ H_{design} &= \text{Height at } N_{design} \\ H_{ini} &= \text{Height at } N_{ini} \end{aligned}$$

example:

$$G_{mb} @ N_{ini} = 2.267 \times \frac{115.1}{126.9} = 2.056$$

## 1. VOLUMETRIC CALCULATIONS

1. Calculate the air voids ( $V_a$ ) using the following equation:

$$V_a = \frac{G_{mm} - G_{mb}}{G_{mm}} \times 100$$

where:

$$\begin{aligned} V_a &= \text{Percent air voids} \\ G_{mm} &= \text{Maximum specific gravity (Rice)} \\ G_{mb} &= \text{Bulk specific gravity at } N_{des} \text{ (Compacted)} \end{aligned}$$

example:

$$V_a = \frac{2.338 - 2.244}{2.338} \times 100 = 4.0\%$$

2. Calculate the Voids in the Mineral Aggregate (VMA) using the following equation:

$$VMA = 100 - \left( \frac{G_{mb} \times P_s}{G_{sb}} \right)$$

where:

VMA = Percent voids in mineral aggregate  
 $G_{mb}$  = Bulk specific gravity at  $N_{des}$  (Compacted)  
 $P_s$  = Percent aggregate  
 $G_{sb}$  = Bulk specific gravity of the aggregate (Target Value)

example:

$$VMA = 100 - \left( \frac{2.244 \times 93.5}{2.467} \right) = 15.0\%$$

3. Calculate the percentage of voids filled with asphalt (VFA) using the following equation:

$$VFA = \frac{(VMA - V_a)}{VMA} \times 100$$

where:

VFA = Percent voids filled with asphalt  
VMA = Percent voids in mineral aggregate  
 $V_a$  = Percent air voids



example:

$$VFA = \frac{(15.0 - 4.0)}{15.0} \times 100 = 73\%$$

4. Calculate the effective specific gravity ( $G_{se}$ ) using the following equation:

$$G_{se} = \frac{P_s}{\left(\frac{100}{G_{mm}}\right) - \left(\frac{P_b}{1.030}\right)}$$

where:

$G_{se}$  = Effective specific gravity  
 $P_s$  = Percent aggregate  
 $G_{mm}$  = Maximum specific gravity (Rice)  
 $P_b$  = Percent binder

example:

$$G_{se} = \frac{93.5}{\left(\frac{100}{2.338}\right) - \left(\frac{6.5}{1.030}\right)} = 2.564$$

5. Calculate the percentage of absorbed asphalt using the following equation:

$$P_{ba} = \left[ \frac{(G_{se} - G_{sb})}{(G_{se} \times G_{sb})} \right] \times 1.030 \times 100$$

where:

$P_{ba}$  = Percent binder absorbed  
 $G_{se}$  = Effective specific gravity

$G_{sb}$  = Bulk specific gravity of the aggregate (Target)

example:

$$P_{ba} = \left[ \frac{(2.564 - 2.467)}{(2.564 \times 2.467)} \right] \times 1.030 \times 100 = 1.58\%$$

6. Calculate the Effective Binder Content using the following equation:

$$P_{be} = P_b - \left( \frac{P_{ba} \times P_s}{100} \right)$$

where:

$P_{be}$  = Percent effective binder  
 $P_b$  = Percent binder  
 $P_{ba}$  = Percent binder absorbed  
 $P_s$  = Percent aggregate

example:

$$P_{be} = 6.5 - \left( \frac{1.58 \times 93.5}{100} \right) = 5.0\%$$

7. Calculate the Dust to Effective Binder ratio using the following equation:

$$\text{Dust to Effective Binder Ratio} = \frac{P_{(-200)}}{P_{be}}$$

where:

$P_{(-200)}$  = Percent passing the No. 200 sieve  
 $P_{be}$  = Percent effective binder

example:

$$\text{Dust to Effective AC Ratio} = \frac{5.0}{5.0} = 1.0$$

8. Calculate the %G<sub>mm</sub> @ N<sub>ini</sub> using the following equation:

$$\%G_{mm} @ N_{ini} = \frac{G_{mb} @ N_{ini}}{G_{mm}} \times 100$$

where:

$$\begin{aligned} G_{mm} &= \text{Maximum specific gravity (Rice)} \\ G_{mb} @ N_{ini} &= \text{Bulk specific gravity at } N_{ini} \text{ (Calculated)} \end{aligned}$$

example:

$$\%G_{mm} @ N_{ini} = \frac{2.057}{2.338} \times 100 = 88.0\%$$

9. Calculate the %G<sub>mm</sub> @ N<sub>max</sub> using the following equation:

$$\%G_{mm} @ N_{max} = \frac{G_{mb} @ N_{max}}{G_{mm}} \times 100$$

where:

$$\begin{aligned} G_{mm} &= \text{Maximum specific gravity (Rice)} \\ G_{mb} @ N_{max} &= \text{Bulk specific gravity at } N_{max} \text{ (Compacted)} \end{aligned}$$

example:

$$\%G_{mm} @ N_{max} = \frac{2.268}{2.338} \times 100 = 97.0\%$$

## 2. OPTIMUM ASPHALT VOLUMETRICS

1. Determine the optimum asphalt content at 4.0% air voids by plotting the asphalt content versus the air voids of the four samples for each trial blend (see Figure 17).

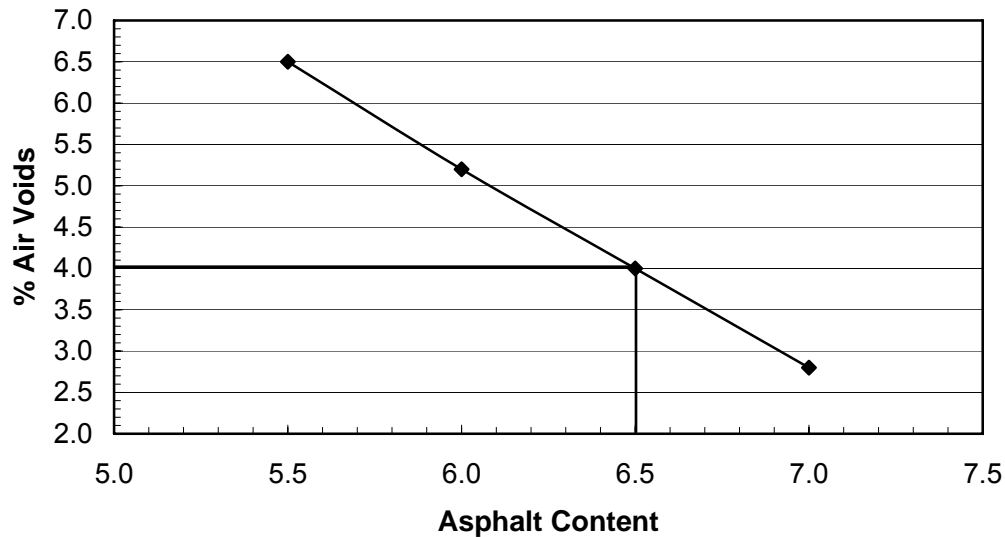
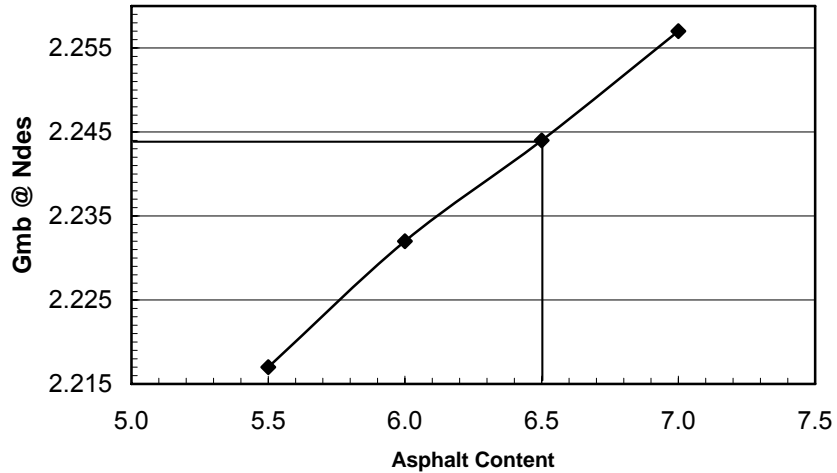


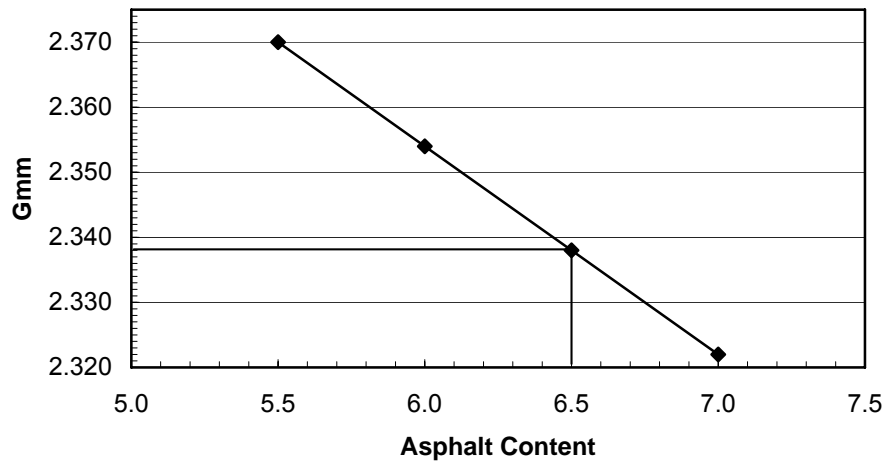
Figure 17 – Asphalt versus Air Voids

2. Determine the  $G_{mb} @ N_{des}$  of the optimum asphalt content by plotting the asphalt content versus the  $G_{mb} @ N_{des}$  values of the four samples for each trial blend (see Figure 18).



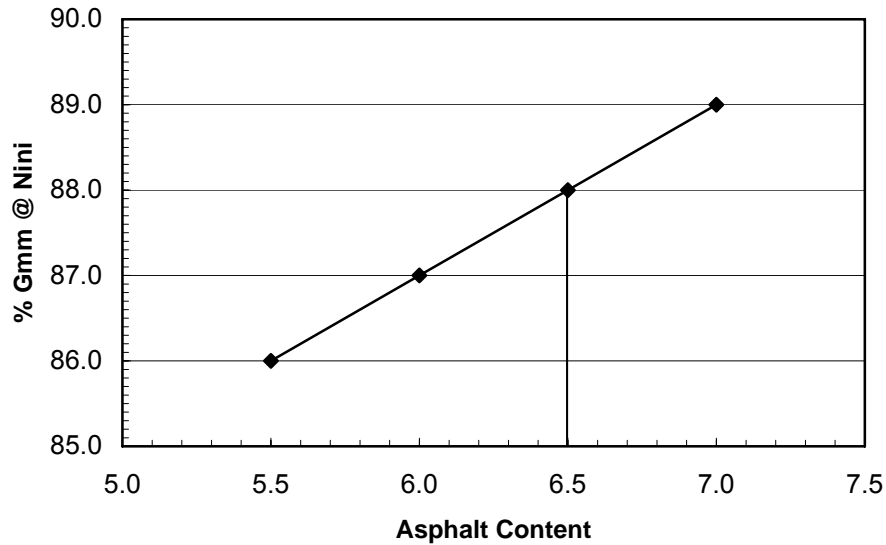
**Figure 18 – Asphalt versus  $G_{mb}$  @  $N_{des}$**

3. Determine the  $G_{mm}$  of the optimum asphalt content by plotting the asphalt content versus the  $G_{mm}$  values of the four samples for each trial blend (see Figure 19).



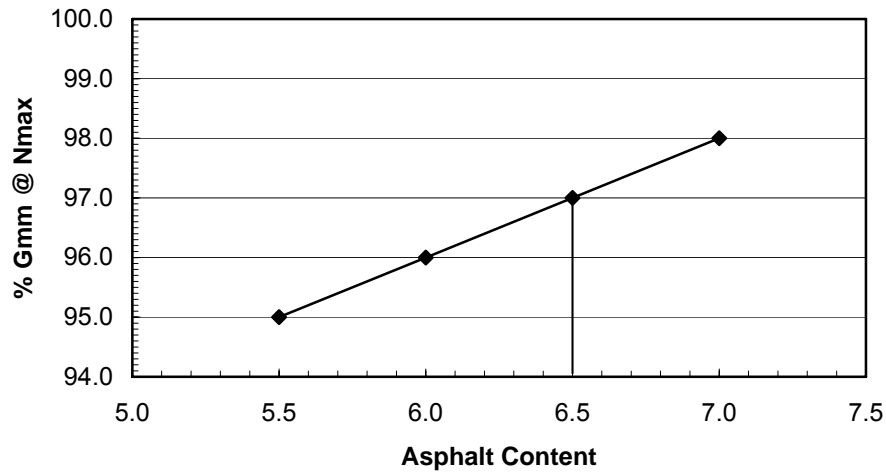
**Figure 19 – Asphalt versus  $G_{mm}$**

4. Determine the  $\%G_{mm} @ N_{ini}$  of the optimum asphalt content by plotting the asphalt content versus the  $\%G_{mm} @ N_{ini}$  values of the four samples for each trial blend (see Figure 20).



**Figure 20 – Asphalt versus  $\%G_{mm} @ N_{ini}$**

5. Determine the  $\%G_{mm} @ N_{max}$  of the optimum asphalt content by plotting the asphalt content and the  $\%G_{mm} @ N_{max}$  values of the four samples for each trial blend (see Figure 21).



**Figure 21 – Asphalt versus %G<sub>mm</sub> @ N<sub>max</sub>**

6. Calculate the VMA, VFA, P<sub>be</sub>, and the Dust to Effective AC Ratio of the optimum asphalt content using the equations from section IX.

### 3. MOISTURE SUSCEPTIBILITY

1. Batch out a minimum of six samples at the optimum asphalt content of the appropriate mass (approximately 1050g for 4" x 2.5" specimens) of the dried and separated material for each trial blend using the previous equations.

**NOTE:** It may be desirable to prepare a pilot specimen and make any necessary adjustment to height or sample mass to ensure the air void value and specimen size is within specifications as outlined in FM 1-T 283.

2. Add the appropriate amount of asphalt binder.
3. Mix the sample of asphalt and aggregate until thoroughly coated.

4. Place the sample of asphalt mix in a pan at the appropriate thickness and condition for 2 hours stirring every hour as outlined in AASHTO R 30-02.
5. Place all necessary equipment for the compaction process in the oven 30 – 60 minutes prior to compaction.
6. Ensure that all calibrations requirements have been met on the gyratory compactor as outlined in Section 334 of the Florida Department of Transportation Specifications for Road and Bridge Construction.
7. Make all necessary adjustments to the compaction equipment for the type of mix to be used as outlined in Section 334 of the Florida Department of Transportation Specifications for Road and Bridge Construction.
8. Compact the specimens as outlined in AASHTO T 312.
9. The number of gyrations should be set so that air voids of  $7.0\% \pm 1.0\%$  are achieved.
10. Determine bulk specific gravity of the compacted specimens as outlined in FM 1-T 166 by measuring the weight in air, weight in water at  $77\text{ }^{\circ}\text{F}$ , and weight at the saturated surface dry condition.
11. Discard any compacted specimen that results in air voids other than  $7.0\% \pm 1.0\%$ .
12. Arrange the compacted specimens into two groups of three specimens so that the average air voids of the two groups are approximately equal. One set of specimens will be designated as the control group while the other set will be designated as the conditioned group.
13. Determine the volume of air voids using the following equation.



$$V_{va} = \frac{V_a \times V_{mb}}{100}$$

where:

$V_{va}$  = Volume of air voids  
 $V_a$  = Percent air voids  
 $V_{mb}$  = Volume of the compacted specimen

example:

$$V_{va} = \frac{7.27 \times 498.3}{100} = 36.23$$

14. Store the control group at room temperature until time for testing.
15. Saturate the conditioned group in a vacuum container with distilled water at room temperature so that the specimens have at least one inch of water above their surface. Apply sufficient vacuum for a short period of time.
16. Determine bulk specific gravity of the conditioned specimens as outlined in FM 1-T 166. Compare the saturated surface dry mass of the conditioned specimens with the dry mass of the conditioned specimens determined in step 12 using the following equation.

$$V_{wa} = M_{ssd2} - M_{air}$$

where:

$V_{wa}$  = Volume of absorbed water  
 $M_{ssd2}$  = Saturated surface dry mass of the wet (conditioned) specimens after conditioning.  
 $M_{air}$  = Dry mass of the wet (conditioned) specimens before conditioning.

example:

$$V_{wa} = 1152.3 - 1119.6 = 32.7$$

- 17.** Determine the degree of saturation using the following equation. Repeat steps 16 through 18 until the required saturation level is reached (70 – 80%), as outlined in Section 334 of the Florida Department of Transportation Specifications for Road and Bridge Construction.

$$P_{st} = \frac{V_{wa}}{V_{va}} \times 100$$

where:

$P_{st}$  = Percent saturation  
 $V_{wa}$  = Volume of absorbed water  
 $V_{va}$  = Volume of air voids

example:

$$P_{st} = \frac{32.7}{36.2} \times 100 = 90.3$$

- 18.** Cover the conditioned specimens tightly with plastic film. Place each specimen in a plastic bag containing 10 ml of water and seal the bag. Place the specimens in a freezer at  $0^{\circ}\text{F} \pm 5^{\circ}\text{F}$  for a minimum of 16 hours.
- 19.** Remove the plastic bags and film from the conditioned specimens and submerge them in a water bath at  $140^{\circ}\text{F} \pm 1.8^{\circ}\text{F}$  for  $24 \pm 1$  hours.
- 20.** Place the control group in leak proof plastic bags. Submerge the control and the conditioned specimens in a  $77^{\circ}\text{F}$  water bath for a minimum of 2 hours.
- 21.** Determine the indirect tensile strengths of the control and the conditioned specimens using the Lottman apparatus as outlined in FM 1- T 283 using the following equation.

$$S_t = \frac{(2 \times P)}{(\pi \times T \times D)}$$

where:

$S_t$  = Tensile strength (psi)  
 $P$  = Maximum load (lbs)  
 $T$  = Specimen thickness (inches)  
 $D$  = Specimen diameter (inches)

example:

$$S_t = \frac{(2 \times 2650)}{(3.14 \times 2.489 \times 3.937)} = 172.2$$

22. Determine the average tensile strength of the control specimens and the average tensile strength of the conditioned specimens.
23. Determine the resistance of the asphalt mixture to the detrimental effect of water as the ratio of the original strength that is retained after the conditioning process using the following equation. Refer to Section 334 of the Florida Department of Transportation Standard Specifications for Road and Bridge Construction for specification compliance.

$$TSR = \frac{S_{cond}}{S_{cont}} \times 100$$

where:

TSR = Tensile strength ratio  
 $S_{cond}$  = Average tensile strength of the conditioned group  
 $S_{cont}$  = Average tensile strength of the control group

example:

$$\text{TSR} = \frac{157.0}{175.9} \times 100 = 89\%$$

#### 4. ASPHALT CALIBRATION FACTOR

1. Weigh the sample basket assembly with guards in place.
2. Batch out a minimum of two samples at the optimum asphalt content of the appropriate mass as outlined in FM 5-563 of the dried and separated material using the previous equations.
3. Add the appropriate amount of asphalt binder.
4. Mix the sample of asphalt and aggregate until thoroughly coated and immediately transfer the calibration sample to the sample baskets.
5. Place the catch pan under the sample baskets and evenly distribute the calibration sample in the sample baskets keeping the material approximately 1 inch away from the edges of the basket.

**NOTE:** Care should be taken to ensure that the entire sample is transferred to the sample baskets.

6. Allow the calibration sample to cool to room temperature.
7. Weigh the calibration sample and sample basket assembly with guards in place. Subtract this weight from the sample basket assembly to determine the sample weight.
8. Preheat the ignition furnace to 1000°F.
9. Enter a calibration factor of 0.00 and the sample weight into the ignition furnace.

10. Using the proper safety equipment place the sample basket assembly into the furnace. Care should be taken to ensure that the basket assembly does not touch the sides of the furnace.
11. Allow the test to continue until furnace indicates that the test is completed.
12. Using the proper safety equipment remove the sample basket assembly from the ignition furnace and retrieve the printout.
13. Repeat steps 1 through 12 for the second sample. The difference between the two samples must be within the single operator precision or two additional samples will need to be tested.
14. Determine the asphalt calibration factor using the following equation:

$$C = P_{b(\text{actual})} - P_{b(\text{measured})}$$

where:

- C = Asphalt calibration factor  
 $P_{b(\text{Actual})}$  = Percent binder (optimum asphalt)  
 $P_{b(\text{Measured})}$  = Average Percent binder (from printouts)

example:

$$C = 6.50 - 6.55 = -0.05\%$$

## Appendix A

### Mix Design Verification Process

1. A CTQP Qualified Mix Designer sends all applicable paperwork, the appropriate sized pre-batched samples, and the selected asphalt binder to the State Materials Office (SMO).
2. The submitted volumetric data is reviewed to ensure that all necessary information is included and that all specification requirements are met.
3. The Department's Aggregate Database is consulted to determine if the mines and/or terminals used are approved sources and that the target bulk specific gravities are used for all components. If any of the aggregate sources used are unapproved, work continues on the mix design and the mix designer is made aware that the mix design will not be issued until all of the sources are approved. If any of the aggregate bulk specific gravities do not match the targets, work is suspended until the information is corrected.
4. The mix design is given a conditional number, entered into our Records Database and sent out to the laboratory for testing.
5. The pre-batched samples are weighed and using the provided optimum asphalt content, the correct amount of asphalt cement to add to each sample is calculated and testing begins.
6. One of the large samples is randomly chosen for gradation and Fine Aggregate Angularity tests.
7. Two of the remaining large samples are chosen for gyratory compaction and two of the small samples are chosen for Maximum Specific Gravity testing. These samples are conditioned for two hours at the respective mixing temperature.
8. The ignition oven calibration factor is determined using samples provided at the appropriate mass for the type mix being verified.

9. Gradation, volumetric, and ignition oven data is compiled and summarized.

10. A fax will be sent to the mix designer and/or contractor if the data obtained at the SMO is outside allowable tolerances for the following tests:

- Gradation
  - $\geq 5\%$  deviation from the Job Mix Formula on any one sieve except for the No. 200 sieve
  - $\geq 15\%$  combined deviation for all sieves
  - $> 1.5\%$  deviation on the  $0.075\mu\text{m}$  sieve
- Bulk Specific Gravity
  - $> 0.022$  within laboratory
  - $> 0.040$  between laboratories
- Maximum Specific Gravity
  - $> 0.013$  within laboratory
  - $> 0.016$  between laboratories
- Air voids
  - 3.0 – 5.0%
- Ignition Oven Calibration Factor
  - $> 0.11$  within laboratory
  - $> 0.35$  between laboratory
- Fine Aggregate Angularity
  - $> 1\%$  lower than the minimum for the mix type

11. If discrepancies do exist, we may test any remaining samples at the SMO, request new samples from the mix designer, or request that the mix designer perform additional testing at their laboratory.

12. The mix designer may elect to adjust the optimum AC content. If this adjustment is 0.5% or less, we will re-calculate the volumetrics using our original data.

13. Once all of the results compare favorably, seven of the small samples are mixed, conditioned, and compacted into four-inch specimens for moisture susceptibility testing. The minimum requirements for this test are 100 p.s.i. average Dry Tensile Strength (DTS) for the control set of specimens, and 80% Tensile Strength Ratio (TSR) for the conditioned set of specimens.
14. If, on Trial #1, TSR is < 80%, a fax will be sent to the mix designer and/or contractor.
15. If the TSR was  $\geq 75\%$ , and the amount of anti-stripping agent in the AC was 0.5%, the mix designer has the option of increasing the anti-stripping agent to 0.75%. If he/she agrees to do this, the mix design will be approved with no additional testing necessary.
16. If the TSR was < 75%, an adjustment (percentage or type), is made to the anti-stripping agent, and the mix designer is required to submit additional samples for further testing.
17. If, after three attempts are made, the mix design still does not meet the requirements of the test, the mix design will be rejected.
18. Once all the requirements have been met, the mix design is conditionally approved, and is available in the Laboratory Information Management System (LIMS).