Hot-Mix Asphalt Level III Technician Course

LAKE LAND COLLEGE

2022-2023

Illinois Department of Transportation
Central Bureau of Materials

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HOT MIX ASPHALT LEVEL III TECHNICIAN COURSE

- **Students must attend all course sessions.**
- **Students are required to present photo identification on first day of class and prior to taking the written and physical exams.**

Prerequisite Course(s):

Students must complete the Mixture Aggregate Technician Course (3-day) or the Aggregate Technician Course (5-day), the Hot-Mix Asphalt Level I Technician Course, and the Hot-Mix Asphalt Level II Technician Course in order to enroll in the Hot-Mix Asphalt Level III Technician Course.

Written Test:

Written exam will be online and will have a time limit is 4 hours (Open Book)
Minimum grade of 70 is required.

Retest:

If the student fails the written exam, a retest **will not** be performed. The student shall retake the class and the exam. The student will be required to pay the appropriate fee for the additional class.

Lake Land College Instructor and Course Evaluation

Course: HMA Level III Technician **Section No#: ________________** **Date ____________________**

Instructors: **Tim Murphy** **Pat Koester**

Purpose: The main emphasis at Lake Land College is teaching. In this regard, each instructor must be continuously informed of the quality of his/her teaching skills and the respects in which his/her teaching skills can be improved. As a student, you are in a position to judge the quality of teaching from direct experience, and in order to help maintain the quality of instruction at Lake Land, you are asked to complete this evaluation.

Please do not sign your name: Your anonymity will be protected so that you can be fair, forthright and honest with your evaluation of this class and the instructor(s). Your participation is greatly appreciated.

Directions: For following subject areas, rate the **course** and/or **instructor** with this scale:

1 – Ineffective 2 – Weak 3 – Average 4 – Good 5 – Strong N/A - Doesn't apply

Please enter the appropriate scale which seems most appropriate to you for the course and instructors. On the back of this form you are strongly encouraged to record any comments that will clarify a particular rating, please refer to each item you are discussing by its assigned letter.

Course:			**Rating**
A)	**Objectives**	The objectives of this course were clearly and adequately covered.	_______
B)	**Content**	The content covered was relevant and met the requirements of the course.	_______
C)	**Organization**	Classroom activities were organized and clearly related to the subject.	_______
D)	**Materials**	Instructional material and resources were specific, current and clearly related to the course.	_______
E)	**Presentation**	Content of lessons was presented so that it was understandable to the students.	_______
F)	**Points of View**	When appropriate, different points of view and/or methods were used.	_______

Instructor(s):			**Tim**	**Pat**
G)	**Preparation**	Was organized and prepared for each session.	_______	_______
H)	**Knowledge**	Was knowledgeable of the information presented.	_______	_______
I)	**Vocabulary**	Used appropriate and understandable terminology and vocabulary.	_______	_______
J)	**Participation**	Encouraged students to participate and solicited student responses.	_______	_______
K)	**Interest**	Indicated an interest and enthusiasm for teaching of the subject matter.	_______	_______
L)	**Familiarity**	Were familiar and up to date with current industry practices.	_______	_______
M)	**Mannerisms**	Mannerisms of the instructors were professional.	_______	_______
N)	**Helpfulness**	Indicated a willingness to help the students as time permitted.	_______	_______
O)	**Impartiality**	Were fair and impartial in dealings with students in accordance to classroom policies.	_______	_______

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Lake Land College Instructor and Course Evaluation

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1 – Ineffective 2 – Weak 3 – Average 4 – Good 5 – Strong N/A - Doesn't apply

	Rating	
SUMMARY:	**Tim**	**Pat**
Considering everything, how would you rate the instructors?	_______	_______
Considering everything, how would you rate this course?	_______	

Please record any general impressions and/or comments for the following:

Instructor(s) Comments ____

____

____

____

____

Please record any general impressions and/or comments for the following:

Course Comments: ____

____

____

____

____

Please do not hand this evaluation to the instructor(s) in order to protect your anonymity. Please place the evaluation in the provided receptacle as you leave.

Once again, thank you for your interest and participation in this class.

Welcome

The Illinois DOT Hot-Mix Asphalt Certification Training Manual, Level 3, has been developed and maintained through the guidance and efforts of the following Quality Organizations.

- ❖ Illinois Department of Transportation
- ❖ Illinois Asphalt Paving Association
- ❖ Federal Highway Administration
- ❖ Lake Land College
- ❖ Asphalt Institute
- ❖ Murphy Pavement Technology

This manual has updated on an annual basis by Lake Land College with the help of Timothy R. Murphy, P.E. and under the guidance of the Illinois Department of Transportation.

Each student will have the opportunity to aid in improving the manual, as well as the overall course, through the course evaluation at the end of the course and/or by providing suggestions directly to the instructor.

The specifications and procedures referred to in this manual were accurate at the production time of the manual. They are in no way to be relied upon exclusively in the future for the design of Hot-Mix Asphalt Mixes.

It is recommended that the mix designer should obtain the latest criteria and procedures, as well as actual contract documents before attempting any mix designs.

COURSE SCHEDULE AND OUTLINE
For Hot-Mix Asphalt, Level III Training Course

MONDAY

1) Welcome and Overview of HMA Design Course (Chapter 1)
   - Overview of Week's Activities
   - Class Participation & Homework Discussion
2) IDOT Specifications Superpave Design Guidelines (Chapter 2)
3) PG Binder Specification and Discussion (Chapter 3)
4) Aggregate Specific Gravity (Chapter 4.1)
5) Introduction to Volumetric Concepts (Chapter 4.2)
6) Aggregate Properties (Chapter 5.1)
7) Aggregate Blending (Chapter 5.2)
8) Homework Assignment: Students Mix Design (Chapter 6)

TUESDAY

1) Review of Monday's work and Homework: Students Mix Design (Chapter 6)
2) Aggregate Blending, cont'd (Chapter 5.2)
3) Aggregate Batching (Chapter 5.3)
4) HMA Mix Design Overview and Tests (Chapter 7)
   - Batching discussion of aggregates and asphalt
   - Video: Mix Design Overview – mix, split, etc.
5) Volumetric Analysis and Graphing (Chapter 8)
6) Students Mix Design (Chapter 6)
7) Asphalt Design Concepts (Chapter 9)
8) Homework Assignment

WEDNESDAY

1) Review of Tuesday's work and Homework
2) Sustainable Asphalt in Illinois (Chapter 10.1)
3) Slag in HMA (Chapter 10.2)
4) Mixture Analysis and Adjustments (Chapter 11)
5) Specialty Mixtures (Chapter 12)
   - Stone Matrix Asphalt
   - IL-4.75 mm
   - HMA Surface Mixture, IL-9.5 mm (Fine-Graded) (Experimental Feature)
6) Homework Assignment

THURSDAY

1) Stripping of HMA with Visual Strip Rating Exercise (Chapter 13)
2) Mixture Design Verification (Chapter 14)
3) Mixture Troubleshooting (Chapter 15)
4) Additional Exercises Requested by Students

FRIDAY

1) 4-Hour Written Examination

BACKGROUND

Mix design of Hot-Mix asphalt (HMA) involves laboratory procedures aimed at determining an economical blend and gradation of mineral aggregates and asphalt cement that fulfills performance expectations for a given pavement. Well-designed asphalt mixtures can be expected to serve successfully for many years under a variety of load and environmental conditions. The mix design is just the starting point to assure that an asphalt concrete pavement layer will perform as required. Together with proper construction practice, mix design is the most important step in achieving well performing asphalt pavements. In many cases, the cause of poorly performing asphalt pavements have been attributed to poor or inappropriate mix design or producing a mixture different from what was designed in the laboratory.

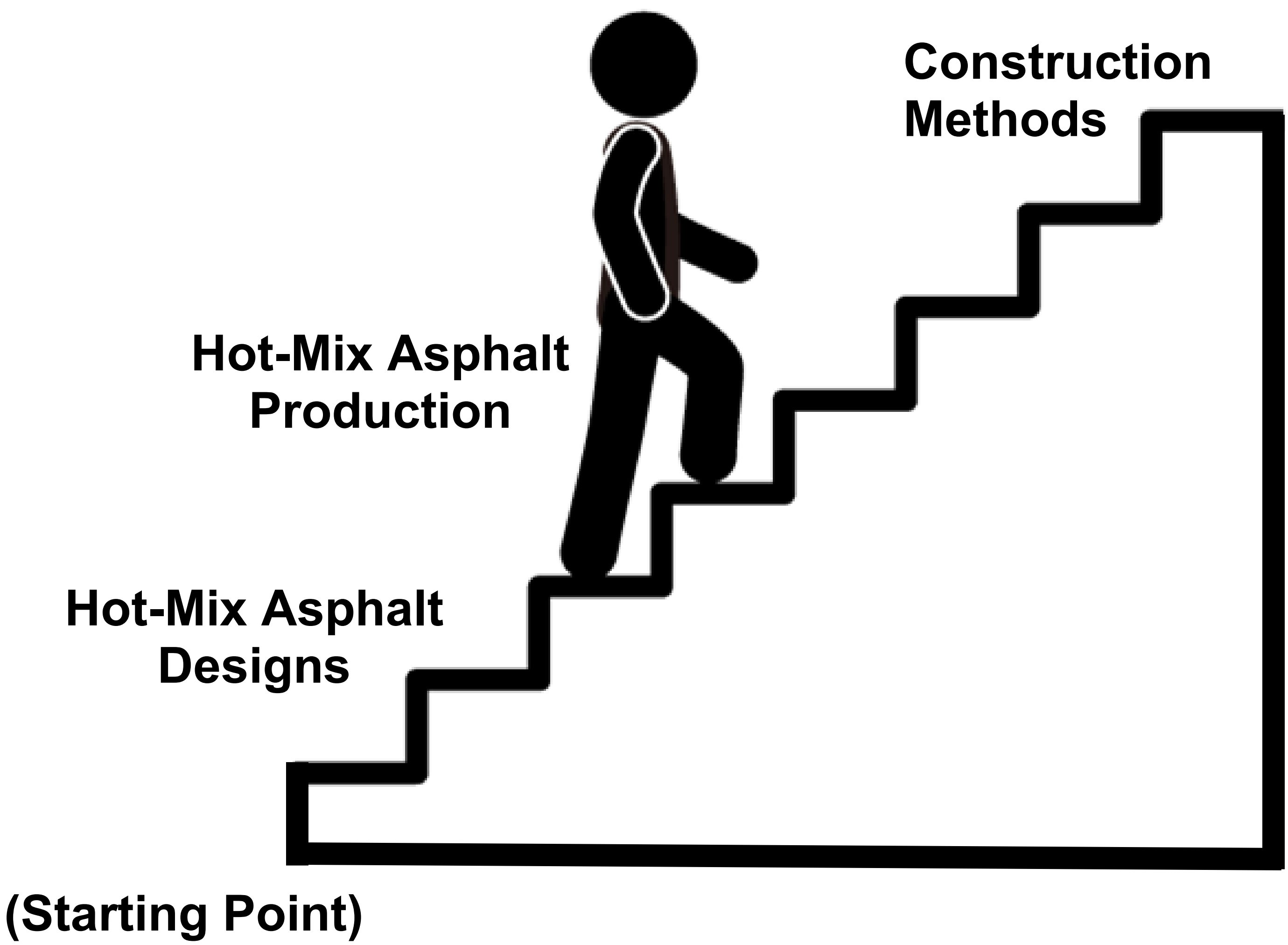
Correct mix design involves adhering to an established set of laboratory techniques and design criteria. These techniques and criteria serve as the design philosophy of the governing agency. They are based on scientific research and equally important on many years of experience in observing the performance of asphalt pavements. It is crucial that these laboratory procedures be followed exactly as written.

Successful mix design requires understanding the basis for and following written instructions. It also involves having proper training in laboratory techniques and interpreting the results of laboratory tests. Thus, it is philosophy of mix design, component material and mix characterization and proper laboratory techniques by hands-on laboratory practice.

Upon completion of this course the student will have a greater understanding of asphalt cement, mineral aggregate, the laboratory, all of the tests and other laboratory operations necessary to develop a successful mix design as defined by the Illinois Department of Transportation.

The development and content of this training course has been guided by a special task force consisting of industry representatives, FHWA and IDOT personnel. Any recommendations concerning modification to the program should be directed toward the task force or one of its members. It is the responsibility of the student to recognize that asphalt mix design procedures and specifications can change, so the student should always obtain the latest information before completing any mix design. This information can be obtained from the Illinois Department of Transportation office or from the Central Bureau of Materials.

WELL-DESIGNED ASPHALT MIXTURES



DATE:

SEQ NO:

Bituminous Mixture Design

Design Number: →	81BIT0002	
Lab Preparing the design?(PP,PL,IL,etc.)	IL	
Producer Name & Number->		
Material Code Number->	19525	Hot Mix Asphalt, E Surface N70

Agg. No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	033CMM13	032CMM16	038FAM20	037FAM02	004FAM01		10129M
Source (PROD#)	52103-11	50312-78	50312-78	50890-08	547-01		1757-05
(NAME)	Levy	Vulcan	Vulcan	ChicagoS&G	Dukane		Seneca
(LOC)	BH	McCook	McCook	Elgin	Addison		Lemont
Aggregate Blend	30.7	34.3	14.0	19.0	2.0		100.0

Agg. No. Sieve Size	#1	#2	#3	#4	#5	#6	Blend	Mixture Specifications Min	Mixture Specifications Max	FORMULA	FORMULA RANGE Min	FORMULA RANGE Max
25.4 (1)	100.0	100.0	100.0	100.0	100.0	100.0	100.0		100	100	100	100
19.0 (3/4)	100.0	100.0	100.0	100.0	100.0	100.0	100.0		100	100	100	100
12.5 (1/2)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	90	100	100	100	100
9.5 (3/8)	79.0	98.0	100.0	100.0	100.0	100.0	92.9	66	100	93	93	93
4.75 (#4)	14.0	27.0	100.0	99.0	100.0	100.0	48.4	24	65	48	43	53
2.36 (#8)	8.0	8.0	88.0	82.0	100.0	100.0	35.1	16	48	35	30	40
1.18 (#16)	5.0	6.0	54.0	62.0	100.0	100.0	24.9	10	32	25	25	25
600μm (#30)	4.0	5.0	31.0	42.0	100.0	100.0	17.3	--	--	17	13	21
300μm (#50)	3.0	5.0	12.0	17.0	100.0	100.0	9.5	4	15	10	10	10
150μm (#100)	3.0	4.0	7.0	5.0	95.0	100.0	6.1	3	10	6	6	6
75μm (#200)	2.2	4.1	4.3	2.0	90.0	100.0	4.9	2	6	4.9	3.4	6.4

	#1	#2	#3	#4	#5	#6	Blended SpGr	Dust AC Ratio
Bulk Sp Gr	2.382	2.663	2.648	2.629	2.82	1	2.565	
Apparent Sp Gr	2.591	2.782	2.788	2.752	2.82	1		
Absorption, %	3.4	1.6	1.9	1.7	1	0.01		
					SP GR AC		1.038	0.75

SUMMARY OF TEST DATA

	AC % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (P_a)	VMA	VOIDS FILLED	EFFECTIVE AC, VOL	EFFECTIVE AC, % WT	ABSORPTION G_{se}	ABSORPTION AC, % WT
MIX 1	5.5	2.274	2.462	7.65	16.2	52.8	8.56	3.91	2.676	1.68
MIX 2	6.0	2.309	2.449	5.70	15.4	62.9	9.67	4.35	2.681	1.76
MIX 3	6.5	2.329	2.426	4.01	15.1	73.4	11.08	4.94	2.675	1.67
MIX 4	7.0	2.341	2.412	2.94	15.1	80.6	12.17	5.40	2.679	1.72

	% AC	d (G_{mb})	D (G_{mm})	% VOIDS (P_a)	VMA	VFA	G_{se}	G_{sb}	TSR
Asphalt determined at 4.0% voids: -	6.51			Target					
OPTIMUM DESIGN DATA:---	6.5	2.329	2.426	4.0	15.1	73.4	2.675	2.565	0.82

REMARKS:

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Hot-Mix Asphalt Mix Design Pre-Test

1. List three ways to increase the Voids in the Mineral Aggregate (VMA).

2. Determine the combined gradation:

	Aggregate A 60%	Aggregate B 40%	Combined Gradation Blend
¾ inch	100		
#8	20	100	
#30	5	50	
#200	1.0	8.0	

3. What does the following nomenclature represent?

G_{mm} G_{mb} G_{sb} P_{be}

4. Given:
- Maximum specific gravity of a mixture = 2.641, and
- Average Superpave Gyratory Compactor (SGC) mixture bulk specific gravity measured in the field = 2.551.

   a) What is the mixture void level?

   b) Is this an acceptable value?

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Illinois DOT Specifications

- Standard Specifications for Road & Bridge Construction, current edition
  - –Fine Aggregate – 1003
  - –Coarse Aggregate – 1004
  - –Hot Mix Asphalt (HMA) – 1030
  - –Mixture Design – 1030.05
  - –Quality Management Program – 1030.06
  - –QC / QA – 1030.09
  - –RAP - 1031

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Illinois DOT Specifications

- Special Provisions
  - –Hot-Mix Asphalt – Start of Production
  - –https://webapps.dot.illinois.gov/WCTB/Lbhome

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Hierarchy

- Special Provisions
- Project Plans
- Recurring Special Provisions and Supplemental Specifications
- Standard Specifications

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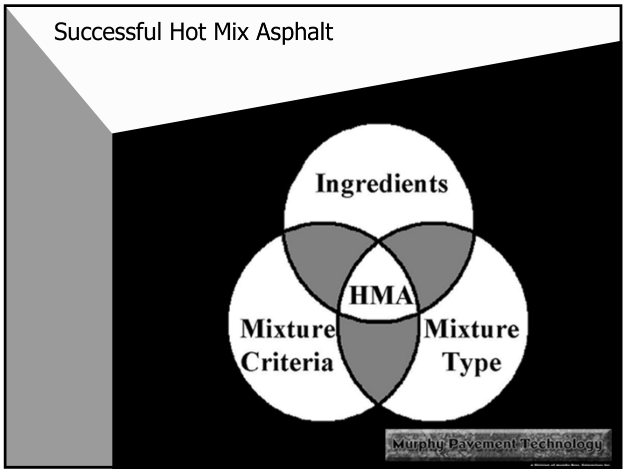
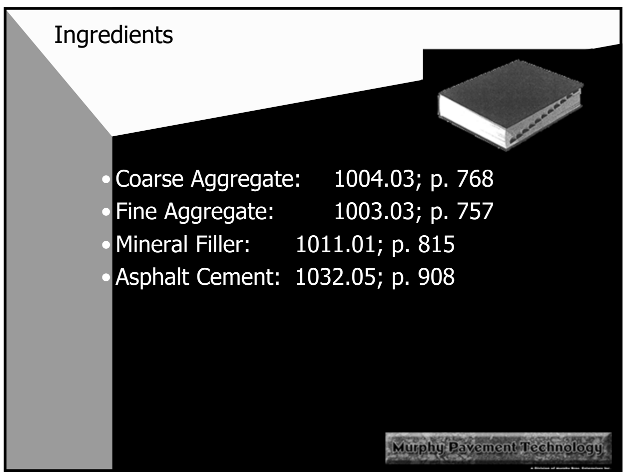
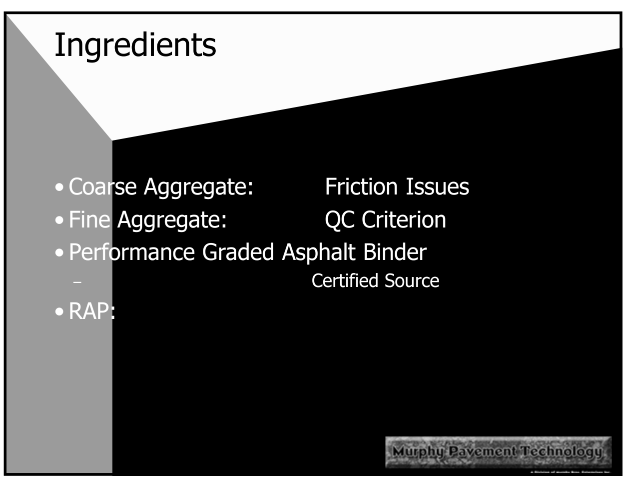

Successful Hot Mix Asphalt
Ingredients
HMA
Mixture Criteria
Mixture Type
Murphy Pavement Technology


Ingredients
• Coarse Aggregate: 1004.03; p. 768
• Fine Aggregate: 1003.03; p. 757
• Mineral Filler: 1011.01; p. 815
• Asphalt Cement: 1032.05; p. 908
Murphy Pavement Technology


Ingredients
• Coarse Aggregate: Friction Issues
• Fine Aggregate: QC Criterion
• Performance Graded Asphalt Binder
– Certified Source
• RAP:
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Mixture Types

- Standard Specifications for Road and Bridge Construction: current edition
- HMA – Article 1030
  - High & Low ESAL, SMA, & 4.75
    - Art. 1030.05(a)(1) – page 873

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Mixture Types

- Special Provisions
  - Start of Production

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Mixture Criteria

- Aggregate Composition (CA and FA requirements)
  - Top size & gradation
  - Quality
  - Friction
- Volumetric Criterion
  - Void contents, VMA, & VFA
  - Low ESAL vs. High ESAL

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Specification Review

- See Manual; Chapter 2, DOT Specification Overview and Review
  - N90 = FM20 @ 50% / 67%
  - JMF Gradations
  - Notes
- Changes occur

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Chapter 2: QC/QA Level III Mix Design

Illinois Department of Transportation

Hot-Mix Asphalt Specifications

Section	*Title*
1003.	Fine Aggregates
1004.	Coarse Aggregates
1011.	Mineral Filler
1030.	Hot-Mix Asphalt (HMA)
1032.05	Asphalt Binder
HMA	Specification Guidelines for Designers

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Illinois Department of Transportation

Hot-Mix Asphalt Specifications

1002.03 Water Intake. Water from shallow, muddy, or marshy surfaces shall not be used. The intake of the pipeline shall be enclosed to exclude silt, mud, grass, and other solid materials; and there shall be a minimum depth of 2 ft (600 mm) of water below the intake at all times.

SECTION 1003. FINE AGGREGATES

1003.01 Materials. Fine aggregate materials shall be according to the following.

(a) Description. The natural and manufactured materials used as fine aggregate are defined as follows.

(1) Sand. Sand shall be the fine granular material resulting from the natural disintegration of rock. Sand produced from deposits simultaneously with, and by the same operations as, gravel coarse aggregate may contain crushed particles in the quantity resulting normally from the crushing and screening of oversize particles.

(2) Silica Sand. Silica sand shall be composed of not less than 99.5 percent silica ($Si0_2$).

(3) Stone Sand. Stone sand shall be produced by washing, or processing by air separation, the fine material resulting from crushing rock quarried from undisturbed, consolidated deposits, or crushing gravel. The acceptance and use of crushed gravel stone sand shall be according to the Bureau of Materials Policy Memorandum, "Crushed Gravel Producer Self-Testing Program".

(4) Chats. Chats shall be the tailings resulting from the separation of metals from rocks in which they occur.

(5) Wet Bottom Boiler Slag. Wet bottom boiler slag shall be the hard, angular by-product of the combustion of coal in wet bottom boilers.

(6) Slag Sand. Slag sand shall be the graded product resulting from the screening of air-cooled blast furnace slag. Air-cooled blast furnace slag shall be the nonmetallic product, consisting essentially of silicates and alumino-silicates of lime and other bases, which is developed in a molten condition simultaneously with iron in a blast furnace.

The acceptance and use of air-cooled blast furnace slag sand shall be according to the Bureau of Materials Policy Memorandum, "Crushed Slag Producer Certification and Self-Testing Program".

(7) Granulated Slag Sand. Granulated slag sand shall be the graded product resulting from the screening of granulated slag. Granulated slag shall be the nonmetallic product, consisting essentially of silicates and alumino-silicates of lime and other bases, which is developed in a molten condition simultaneously with iron in a blast furnace. Granulated

slag sand is formed by introducing a large volume of water under high pressure into the molten slag.

(8) Steel Slag Sand. Steel slag sand shall be the graded product resulting from the screening of crushed steel slag. Crushed steel slag shall be the nonmetallic product which is developed in a molten condition simultaneously with steel in an open hearth, basic oxygen, or electric arc furnace. The acceptance and use of steel slag sand shall be according to the Bureau of Materials Policy Memorandum, "Slag Producer Self-Testing Program".

(9) Crushed Concrete Sand. Crushed concrete sand shall be the angular fragments resulting from crushing portland cement concrete by mechanical means. The acceptance and use of crushed concrete sand shall be according to the Bureau of Materials Policy Memorandum, "Recycling Portland Cement Concrete Into Aggregate".

(10) Construction and Demolition Debris Sand. Construction and demolition debris sand shall be the angular fragments resulting from mechanical crushing/screening of unpainted exterior brick, mortar, and/or concrete with small amounts of other materials. Construction and demolition debris sand shall be according to the Bureau of Materials Policy Memorandum, "Construction and Demolition Debris Sand as a Fine Aggregate for Trench Backfill".

(b) Quality. The fine aggregate shall meet the quality standards listed in the following table. Except for the minus No. 200 (75 µm) sieve material, all fine aggregate shall meet specified quality requirements before being proportioned for mix or combined to adjust gradation. The blended materials shall meet the minus No. 200 (75 µm) sieve requirements.

FINE AGGREGATE QUALITY			
QUALITY TEST	CLASS		
	A	B	C
Na_2SO_4 Soundness 5 Cycle, Illinois Modified AASHTO T 104, % Loss max.	10	15	20
Minus No. 200 (75 µm) Sieve Material, Illinois Modified AASHTO T 11, % max. 4/	3	6 1/	10 1/
Organic Impurities Check, Illinois Modified AASHTO T 21	Yes 2/	---	---
Deleterious Materials: 3/ 5/			
Shale, % max.	3.0	3.0	---
Clay Lumps, % max.	1.0	3.0	---
Coal, Lignite, & Shells, % max.	1.0	3.0	---
Conglomerate, % max.	3.0	3.0	---
Other Deleterious, % max.	3.0	3.0	---
Total Deleterious, % max.	3.0	5.0	---

1/ Does not apply to Gradations FA 20 or FA 21.

2/ Applies only to sand. Sand exceeding the colorimetric test standard of 11 (Illinois Modified AASHTO T 21) will be checked for mortar making properties according to Illinois Modified ASTM C 87, and shall develop a compressive strength at the age of 14 days when using Type I or II Cement of not less than 95 percent of the comparable standard.

3/ Applies only to sand.

4/ Fine aggregate used for hot-mix asphalt (HMA) shall not contain more than three percent clay (2 micron or smaller) particles as determined by Illinois Modified AASHTO T 88.

5/ Tests shall be run according to ITP 204.

(c) Gradation. All aggregates shall be produced according to the Bureau of Materials Policy Memorandum, “Aggregate Gradation Control System”.

The gradations prescribed may be manufactured by any suitable commercial process and by the use of any sizes or shapes of plant screen openings necessary to produce the sizes within the limits of the sieve analysis specified.

The gradation of the material from any one source shall be reasonably uniform and shall not be subject to the extreme percentages of gradation represented by the tolerance limits of the various sieve sizes.

The gradation numbers and corresponding gradation limits are listed in the following tables.

FINE AGGREGATE GRADATIONS

Grad No.	Sieve Size and Percent Passing										
	3/8	No. 4	No. 8 [4/]	No. 10	No. 16	No. 30 [5/]	No. 40	No. 50	No. 80	No. 100	No. 200 [1/]
FA 1	100	97±3			65±20			16±13		5±5	
FA 2	100	97±3			65±20			20±10		5±5	
FA 3	100	97±3		80±15			50±20		25±15		3±3
FA 4 [7/]	100				5±5						
FA 5	100	92±8								20±20	15±15
FA 6		92±8 [2/]								20±20	6±6
FA 7		100		97±3			75±15		35±10		3±3
FA 8			100				60±20			3±3	2±2
FA 9			100					30±15		5±5	
FA 10				100			90±10		60±30		7±7
FA 20	100	97±3	80±20		50±15			19±11		10±7	4±4
FA 21 [3/]	100	97±3	80±20		57±18			30±10		20±10	9±9
FA 22	100	[6/]	[6/]		8±8						2±2
FA 23	100	80±10	57±13		39±11	26±8		18±7		12±6	10±5
FA 24	100	95±5	77±13		57±13	35±10		19±6		15±6	10±5

Art. 1003.01 Fine Aggregates

FINE AGGREGATE GRADATIONS (Metric)											
Grad No.	Sieve Size and Percent Passing										
	9.5 mm	4.75 mm	2.36 mm [4/]	2.00 mm	1.18 mm	600 µm [5/]	425 µm	300 µm	180 µm	150 µm	75 µm [1/]
FA 1	100	97±3			65±20			16±13		5±5	
FA 2	100	97±3			65±20			20±10		5±5	
FA 3	100	97±3		80±15			50±20		25±15		3±3
FA 4 [7/]	100				5±5						
FA 5	100	92±8								20±20	15±15
FA 6		92±8 [2/]								20±20	6±6
FA 7		100		97±3			75±15		35±10		3±3
FA 8			100				60±20			3±3	2±2
FA 9			100					30±15		5±5	
FA 10				100			90±10		60±30		7±7
FA 20	100	97±3	80±20		50±15			19±11		10±7	4±4
FA 21 [3/]	100	97±3	80±20		57±18			30±10		20±10	9±9
FA 22	100	[6/]	[6/]		8±8						2±2
FA 23	100	80±10	57±13		39±11	26±8		18±7		12±6	10±5
FA 24	100	95±5	77±13		57±13	35±10		19±6		15±6	10±5

1/ Subject to maximum percent allowed in Fine Aggregate Quality Table.

2/ 100 percent shall pass the 1 in. (25 mm) sieve, except that for bedding material 100 percent shall pass the 3/8 in. (9.5 mm) sieve. If 100 percent passes the 1/2 in. (12.5 mm) sieve, the No. 4 (4.75 mm) sieve may be 75 ± 25.

3/ For all HMA mixtures. When used, either singly or in combination with other sands, the amount of material passing the No. 200 (75 µm) sieve (washed basis) in the total sand fraction for mix design shall not exceed ten percent.

4/ For each gradation used in HMA, the aggregate producer shall set the midpoint percent passing, and the Department will apply a range of ±15 percent. The midpoint shall not be changed without Department approval.

5/ For each gradation used in HMA, the aggregate producer shall set the midpoint percent passing, and the Department will apply a range of ±13 percent. The midpoint shall not be changed without Department approval.

6/ For fine aggregate gradation FA 22, the aggregate producer shall set the midpoint percent passing, and the Department will apply a range of ±10 percent. The midpoint shall not be changed without Department approval.

7/ When used as backfill for pipe underdrains, Type 3, the fine aggregate shall meet one of the modified FA 4 gradations shown in the following table.

FA 4 Modified		
Sieve Size	Percent Passing	
	Option 1	Option 2
3/8 in. (9.5 mm)	100	100
No. 4 (4.75 mm)		97 ± 3
No. 8 (2.36 mm)		5 ± 5
No. 10 (2 mm)	10 ± 10	
No. 16 (1.18 mm)	5 ± 5	2 ± 2
No. 200 (75 µm)	1 ± 1	1 ± 1

(d) Incompatibility. Incompatibility of any of the gradations or combinations of gradations permitted resulting in unworkable mixtures, nonadherence to the final mix gradation limits, or any other indication of incompatibility shall be just cause for rejection of one or both of the sizes.

(e) Storage of Fine Aggregate. Sites for storage of all fine aggregates shall be grubbed and cleaned prior to storing the material.

Stockpiles shall be built according to the Bureau of Materials Policy Memorandum, "Aggregate Gradation Control System (AGCS)" and the following.

(1) Fine aggregate of various gradations and from different sources shall be stockpiled separately.

(2) Stockpiles shall be separated to prevent intermingling at the base. If partitions are used, they shall be of sufficient heights to prevent intermingling.

(3) Fine aggregates for portland cement concrete and HMA shall be handled in and out of the stockpiles in such a manner that will prevent contamination, segregation, and degradation.

At the time of use, the fine aggregate shall be free from frozen material, material used to caulk rail cars, and all foreign materials which may have become mixed during transportation and handling.

(f) Shipping Tickets. Shipping tickets for the material shall be according to the Bureau of Materials Policy Memorandum, "Designation of Aggregate Information on Shipping Tickets".

1003.02 Fine Aggregate for Portland Cement Concrete and Mortar. The aggregate shall be according to Article 1003.01 and the following.

(a) Description. The fine aggregate shall consist of washed sand, washed stone sand, or a blend of washed sand and washed stone sand approved by the Engineer. Stone sand produced through an air separation system approved by the Engineer may be used in place of washed stone sand.

Art. 1003.02 Fine Aggregates

(b) Quality. The fine aggregate for portland cement concrete shall meet Class A Quality, except the minus No. 200 (75 µm) sieve Illinois Modified AASHTO T 11 requirement in the Fine Aggregate Quality Table shall not apply to washed stone sand or any blend of washed stone sand and washed sand approved by the Engineer. The fine aggregate for masonry mortar shall meet Class A Quality.

(c) Gradation. The washed sand for portland cement concrete shall be Gradation FA 1 or FA 2. Washed stone sand for portland cement concrete, which includes any blend with washed sand, shall be Gradation FA 1, FA 2, or FA 20. Fine aggregate for masonry mortar shall be Gradation FA 9.

(d) Use of Fine Aggregates. The blending, alternate use, and/or substitution of fine aggregates from different sources for use in portland cement concrete will not be permitted without the approval of the Engineer. Any blending shall be by interlocked mechanical feeders at the aggregate source or concrete plant. The blending shall be uniform, and the equipment shall be approved by the Engineer.

(e) Alkali Reaction.

(1) ASTM C 1260. Each fine aggregate will be tested by the Department for alkali reaction according to ASTM C 1260. The test will be performed with Type I or II portland cement having a total equivalent alkali content (Na_2O + $0.658K_2O$) of 0.90 percent or greater. The Engineer will determine the assigned expansion value for each aggregate, and these values will be made available on the Department's Alkali-Silica Potential Reactivity Rating List. The Engineer may differentiate aggregate based on ledge, production method, gradation number, or other factors. An expansion value of 0.03 percent will be assigned to limestone or dolomite fine aggregates (manufactured stone sand). However, the Department reserves the right to perform the ASTM C 1260 test.

(2) ASTM C 1293 by Department. In some instances, such as chert natural sand or other fine aggregates, testing according to ASTM C 1260 may not provide accurate test results. In this case, the Department may only test according to ASTM C 1293.

(3) ASTM C 1293 by Contractor. If an individual aggregate has an ASTM C 1260 expansion value that is unacceptable to the Contractor, an ASTM C 1293 test may be performed by the Contractor to evaluate the Department's ASTM C 1260 test result. The laboratory performing the ASTM C 1293 test shall be approved by the Department according to the Bureau of Materials Policy Memorandum "Minimum Laboratory Requirements for Alkali-Silica Reactivity (ASR) Testing".

The ASTM C 1293 test shall be performed with Type I or II portland cement having a total equivalent alkali content (Na_2O + $0.658K_2O$) of 0.80 percent or greater. The interior vertical wall of the ASTM C 1293 recommended container (pail) shall be half covered with a wick of absorbent material consisting of blotting paper. If the testing laboratory desires to use an alternate container, wick of absorbent material, or amount of coverage inside the container with blotting paper, ASTM C 1293 test results with an alkali-reactive aggregate of known expansion characteristics shall be provided to the Engineer for review and approval. If the expansion is less than 0.040 percent after one year, the aggregate will be assigned an ASTM C 1260 expansion value of 0.08 percent that will be valid for two years, unless the Engineer determines the aggregate has changed significantly. If the aggregate is manufactured into multiple gradation numbers, and the other gradation numbers have the same or lower ASTM C 1260 value, the ASTM C 1293 test result may apply to multiple gradation numbers.

The Engineer reserves the right to verify a Contractor's ASTM C 1293 test result. When the Contractor performs the test, a split sample shall be provided to the Engineer. The Engineer may also independently obtain a sample at any time. The aggregate will be considered reactive if the Contractor or Engineer obtains an expansion value of 0.040 percent or greater.

1003.03 Fine Aggregate for Hot-Mix Asphalt (HMA). The aggregate shall be according to Article 1003.01 and the following.

(a) Description. Fine aggregate for HMA shall consist of sand, stone sand, chats, slag sand, or steel slag sand. For gradation FA 22, uncrushed material will not be permitted. Fine aggregate for SMA shall consist of stone sand, slag sand, or steel slag sand.

(b) Quality. The fine aggregate for all HMA shall be Class B Quality or better.

(c) Gradation. The fine aggregate gradation for all HMA shall be FA 1, FA 2, FA 20, FA 21, or FA 22. The fine aggregate gradation for SMA shall be FA/FM 20 or FA/FM 22.

For mixture IL-4.75 and surface mixtures with an Ndesign = 90, at least 50 percent of the required fine aggregate fraction shall consist of either stone sand, slag sand, or steel slag meeting the FA 20 gradation.

For mixture IL-9.5FG, at least 67 percent of the required fine aggregate fraction shall consist of either stone sand, slag sand, steel slag sand, or combinations thereof meeting FA 20 gradation.

For mixture IL-19.0, Ndesign = 90 the fine aggregate fraction shall consist of at least 67 percent manufactured sand meeting FA 20 or FA 22 gradation. For mixture IL-19.0, Ndesign = 50 or 70 the fine aggregate fraction shall consist of at least 50 percent manufactured sand meeting FA 20 or FA 22 gradation. The manufactured sand shall be stone sand, slag sand, steel slag sand, or combinations thereof.

Gradation FA 1, FA 2, or FA 3 shall be used when required for prime coat aggregate application for HMA.

1003.04 Fine Aggregate for Bedding, Backfill, Trench Backfill, Embankment, Porous Granular Backfill, and French Drains. The aggregate shall be according to Article 1003.01 and the following.

(a) Description. The fine aggregate shall consist of sand, stone sand, chats, wet bottom boiler slag, slag sand, or granulated slag sand. Crushed concrete sand, construction and demolition debris sand, and steel slag sand produced from an electric arc furnace may be used in lieu of the above for trench backfill.

(b) Quality. The fine aggregate shall be reasonably free from an excess of soft and unsound particles and other objectionable matter.

(c) Gradation. The fine aggregate gradations shall be as follows.

Application	Gradation
Granular Embankment, Granular Backfill, Trench Backfill, and Bedding and Backfill for Pipe Culverts and Storm Sewers	FA 1, FA 2, or FA 6 through FA 21
Porous Granular Embankment, Porous Granular Backfill, French Drains, and Bedding and Backfill for Pipe Underdrains, Type 1	FA 1, FA 2, or FA 20, except the percent passing the No. 200 (75 µm) sieve shall be 2±2
Backfill for Pipe Underdrains, Type 3	FA 4 Modified (see Article 1003.01(c))

1003.05 Fine Aggregate for Membrane Waterproofing. The aggregate shall be according to Article 1003.01 and the following.

(a) Description. The fine aggregate shall consist of sand, stone sand, wet bottom boiler slag, slag sand, or chats.

(b) Quality. The fine aggregate shall meet the Class B Quality Deleterious Count, and when subjected to Illinois Modified AASHTO T 104, the weighted average loss shall not be more than ten percent.

(c) Gradation. The fine aggregate shall be Gradation FA 8.

1003.06 Fine Aggregate for Controlled Low-Strength Material (CLSM). The aggregate shall be according to Article 1003.01 and the following.

(a) Description. The fine aggregate shall consist of sand.

(b) Quality. The fine aggregate shall be reasonably free from an excess of soft and unsound particles and other objectionable matter.

(c) Gradation. The fine aggregate gradation shall be FA 1 or FA 2. Blending of fine aggregate will not be permitted.

1003.07 Fine Aggregate for Select Fill Used for Retaining Wall Applications Utilizing Soil Reinforcement. The aggregate shall be according to Article 1003.01 and the following.

(a) Description. The fine aggregate shall consist of sand or stone sand.

(b) Quality. The fine aggregate shall have a maximum sodium sulfate (Na_2SO_4) loss of 15 percent according to Illinois Modified AASHTO T 104.

(c) Gradation. The fine aggregate shall be FA 1, FA 2, or FA 20.

(d) Internal Friction Angle. The effective internal friction angle for the fine aggregate shall be a minimum 34 degrees according to AASHTO T 236 on samples compacted to 95 percent density according to Illinois Modified AASHTO T 99. The AASHTO T 296 test with pore pressure measurement may be used in lieu of AASHTO T 236. If the Contractor's design uses a friction angle greater than 34 degrees this greater value shall be taken as the minimum required.

(e) pH. The pH shall be determined according to Illinois Modified AASHTO T 289.

(1) When geosynthetic soil reinforcement is used, the fine aggregate pH shall be 4.5 to 9.0 for permanent applications, and 3.0 to 10.0 for temporary applications.

(2) When steel reinforcement is used, the fine aggregate pH shall be 5.0 to 10.0.

(f) Corrosion Mitigation. The fine aggregates shall also meet the following when used in conjunction with steel soil reinforcement in non-temporary wall applications.

(1) Resistivity. The resistivity according to Illinois Modified AASHTO T 288 shall be greater than 3000 ohm centimeters for galvanized reinforcement, and 1500 ohm centimeters for aluminized Type 2 reinforcement.

(2) The chlorides shall be less than 100 parts per million according to Illinois Modified AASHTO T 291 or ASTM D 4327. For either test, the sample shall be prepared according to Illinois Modified AASHTO T 291.

(3) The sulfates shall be less than 200 parts per million according to Illinois Modified AASHTO T 290 or ASTM D 4327. For either test, the sample shall be prepared according to Illinois Modified AASHTO T 290.

(4) The organic content shall be a maximum of 1.0 percent according to Illinois Modified AASHTO T 267.

(g) Test Frequency. Prior to the start of construction, the Contractor shall provide internal friction angle and pH test results to demonstrate the select fill material meets the specification requirements. Resistivity, chlorides, sulfates, and organic content test results shall also be provided if steel reinforcement is used. The laboratory performing the Illinois Modified AASHTO T 288 test shall be approved by the Department according to the Bureau of Materials Policy Memorandum "Minimum Laboratory Requirements for Resistivity Testing". These test results shall be no more than 12 months old. In addition, a sample of select fill material will be obtained by the Engineer for testing and approval before construction begins. Thereafter, the minimum frequency of subsequent sampling and testing at the jobsite will be one per 40,000 tons (36,300 metric tons) of select fill.

1003.08 Fine Aggregate for Micro-Surfacing and Slurry Sealing. The aggregate shall be according to Article 1003.01 and the following.

(a) Description. The fine aggregate shall consist of stone sand, wet bottom boiler slag, slag sand, granulated slag sand, steel slag sand, or crushed concrete sand.

(b) Quality. The fine aggregate shall be Class B Quality.

(c) Gradation. Rut filling mixes shall be FA 23. Surface mixes shall be FA 24.

(d) Use of Fine Aggregates. The blending, alternate use, and/or substitutions of aggregates from different sources for use in this work will not be permitted without the approval of the Engineer. Any blending shall be by interlocked mechanical feeders. The blending shall be uniform, compatible with the other components of the mix, and the equipment shall be approved by the Engineer.

If blending aggregates, the blend shall have a washed gradation preformed every other day or a minimum of three tests per week. Testing shall be completed before the aggregate receives final acceptance for use in the mix.

Aggregates shall be screened at the stockpile prior to delivery to the paving machine to remove oversized material or contaminants.

SECTION 1004. COARSE AGGREGATES

1004.01 Materials. Coarse aggregate materials shall be according to the following.

(a) Description. The natural and manufactured materials used as coarse aggregate are defined as follows.

(1) Gravel. Gravel shall be the coarse granular material resulting from the reduction of rock by the action of the elements and having subangular to rounded surfaces. It may be partially crushed.

(2) Chert Gravel. Chert gravel shall be the coarse granular material occurring in alluvial deposits resulting from reworking by weathering and

erosion of chert bearing geological formations and containing a minimum of 80 percent chert or similar siliceous material.

(3) Crushed Gravel. Crushed gravel shall be the product resulting from crushing, by mechanical means, and shall consist entirely of particles obtained by crushing gravel. The acceptance and use of crushed gravel shall be according to the Bureau of Materials Policy Memorandum, "Crushed Gravel Producer Self-Testing Program".

(4) Crushed Stone. Crushed stone shall be the angular fragments resulting from crushing undisturbed, consolidated deposits of rock by mechanical means. Crushed stone shall be divided into the following, when specified.

a. Carbonate Crushed Stone. Carbonate crushed stone shall be either dolomite or limestone. Dolomite shall contain 11.0 percent or more magnesium oxide (MgO). Limestone shall contain less than 11.0 percent magnesium oxide (MgO).

b. Crystalline Crushed Stone. Crystalline crushed stone shall be either metamorphic or igneous stone, including but is not limited to, quartzite, granite, rhyolite and diabase.

(5) Wet Bottom Boiler Slag. Wet bottom boiler slag shall be the hard, angular by-product of the combustion of coal in wet bottom boilers.

(6) Crushed Slag. Crushed slag shall be the graded product resulting from the processing of air-cooled blast furnace slag. Air-cooled blast furnace slag shall be the nonmetallic product, consisting essentially of silicates and alumino-silicates of lime and other bases, which is developed in a molten condition simultaneously with iron in a blast furnace. It shall be air-cooled and shall have a compact weight (Illinois Modified AASHTO T 19) of not less than 70 lb/cu ft (1100 kg/cu m). The acceptance and use of air-cooled blast furnace slag shall be according to the Bureau of Materials Policy Memorandum, "Crushed Slag Producer Certification and Self-Testing Program".

(7) Crushed Sandstone. Crushed sandstone shall be the angular fragments resulting from crushing, by mechanical means, a cemented sand composed predominantly of quartz grains. Sandstone shall have an Insoluble Residue of 50.0 percent or higher.

(8) Crushed Concrete. Crushed concrete shall be the angular fragments resulting from crushing portland cement concrete by mechanical means. The acceptance and use of crushed concrete shall be according to the Bureau of Materials Policy Memorandum, "Recycling Portland Cement Concrete Into Aggregate".

(9) Chats. Chats shall be the tailings resulting from the separation of metals from the rocks in which they occur.

(10) Crushed Steel Slag. Crushed steel slag shall be the graded product resulting from the processing of steel slag. Steel slag shall be the nonmetallic product which is developed in a molten condition simultaneously with steel in an open hearth, basic oxygen, or electric furnace. The acceptance and use of crushed steel slag shall be according to the Bureau of Materials Policy Memorandum, "Slag Producer Self-Testing Program".

(b) Quality. The coarse aggregate shall be according to the quality standards listed in the following table.

COARSE AGGREGATE QUALITY				
QUALITY TEST	CLASS			
	A	B	C	D
Na_2SO_4 Soundness 5 Cycle, Illinois Modified AASHTO T 104 1/, % Loss max.	15	15	20	25 2/
Los Angeles Abrasion, Illinois Modified AASHTO T 96 11/, % Loss max.	40 3/	40 4/	40 5/	45
Minus No. 200 (75 µm) Sieve Material, Illinois Modified AASHTO T 11	1.0 6/	---	2.5 7/	---
Deleterious Materials 10/				
Shale, % max.	1.0	2.0	4.0 8/	---
Clay Lumps, % max.	0.25	0.5	0.5 8/	---
Coal & Lignite, % max.	0.25	---	---	---
Soft & Unsound Fragments, % max.	4.0	6.0	8.0 8/	---
Other Deleterious, % max.	4.0 9/	2.0	2.0 8/	---
Total Deleterious, % max.	5.0	6.0	10.0 8/	---
Oil-Stained Aggregate 10/, % max.	5.0	---	---	

1/ Does not apply to crushed concrete.

2/ For aggregate surface course and aggregate shoulders, the maximum percent loss shall be 30.

3/ For portland cement concrete, the maximum percent loss shall be 45.

4/ Does not apply to crushed slag or crushed steel slag.

5/ For hot-mix asphalt (HMA) binder mixtures, except when used as surface course, the maximum percent loss shall be 45.

6/ For crushed aggregate, if the material finer than the No. 200 (75 µm) sieve consists of the dust from fracture, essentially free from clay or silt, this percentage may be increased to 2.5.

7/ Does not apply to aggregates for HMA binder mixtures.

8/ Does not apply to Class A seal and cover coats.

9/ Includes deleterious chert. In gravel and crushed gravel aggregate, deleterious chert shall be the lightweight fraction separated in a 2.35 heavy media separation. In crushed stone aggregate, deleterious chert shall be the lightweight fraction separated in a 2.55 heavy media separation. Tests shall be run according to Illinois Modified AASHTO T 113.

10/ Test shall be run according to ITP 203.

11/ Does not apply to crushed slag.

All varieties of chert contained in gravel coarse aggregate for portland cement concrete, whether crushed or uncrushed, pure or impure, and irrespective of color, will be classed as chert and shall not be present in the total aggregate in excess of 25 percent by weight (mass).

Aggregates used in Class BS concrete (except when poured on subgrade), Class PS concrete, and Class PC concrete (bridge superstructure products only, excluding the approach slab) shall contain no more than two percent by weight (mass) of deleterious materials. Deleterious materials shall include substances whose disintegration is accompanied by an increase in volume which may cause spalling of the concrete.

(c) Gradation. All aggregates shall be produced according to the Bureau of Materials Policy Memorandum, "Aggregate Gradation Control System (AGCS)".

The sizes prescribed may be manufactured by any suitable commercial process and by the use of any sizes or shapes of plant screen openings necessary to produce the sizes within the limits of the sieve analysis specified.

The gradation of the material from any one source shall be reasonably close to the gradation specified and shall not be subject to the extreme percentages of gradation represented by the tolerance limits for the various sieve sizes. The gradation numbers and corresponding gradation limits are listed in the following table.

Art. 1004.01 Coarse Aggregates

Grad No.	COARSE AGGREGATE GRADATIONS												
	Sieve Size and Percent Passing												
	3 in.	2 1/2 in.	2 in.	1 1/2 in.	1 in.	3/4 in.	1/2 in.	3/8 in.	No. 4	No. 8	No. 16	No. 50	No. 200 [1/]
CA 1	100	95±5	60±15	15±15	3±3								
CA 2		100	95±5		75±15		50±15		30±10		20±15		8±4
CA 3		100	93±7	55±20	8±8		3±3						
CA 4			100	95±5	85±10		60±15		40±10		20±15		8±4
CA 5				97±3 [2/]	40±25		5±5		3±3				
CA 6				100	95±5		75±15		43±13		25±15		8±4
CA 7				100	95±5		45±15 [7/]		5±5				
CA 8				100	97±3	85±10	55±10		10±5		3±3 [3/]		
CA 9				100	97±3		60±15		30±15		10±10		6±6
CA 10					100	95±5	80±15		50±10		30±15		9±4
CA 11					100	92±8	45±15 [4/ 7/]		6±6		3±3 [3/ 5/]		
CA 12						100	95±5	85±10	60±10		35±10		9±4
CA 13						100	97±3	80±10	30±15		3±3 [3/]		
CA 14							90±10 [6/]	45±20	3±3				
CA 15							100	75±15	7±7		2±2		
CA 16							100	97±3	30±15		2±2 [3/]		
CA 17	100								65±20		45±20	20±10	10±5
CA 18	100				95±5				75±25		55±25	10±10	2±2
CA 19	100				95±5				60±15		40±15	20±10	10±5
CA 20							100	92±8	20±10	5±5	3±3		

Grad No.	COARSE AGGREGATE GRADATIONS (metric)												
	Sieve Size and Percent Passing												
	75 mm	63 mm	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	300 µm	75 µm [1/]
CA 1	100	95±5	60±15	15±15	3±3								
CA 2		100	95±5		75±15		50±15		30±10		20±15		8±4
CA 3		100	93±7	55±20	8±8		3±3						
CA 4			100	95±5	85±10		60±15		40±10		20±15		8±4
CA 5				97±3 [2/]	40±25		5±5		3±3				
CA 6				100	95±5		75±15		43±13		25±15		8±4
CA 7				100	95±5		45±15 [7/]		5±5				
CA 8				100	97±3	85±10	55±10		10±5		3±3 [3/]		
CA 9				100	97±3		60±15		30±15		10±10		6±6
CA 10					100	95±5	80±15		50±10		30±15		9±4
CA 11					100	92±8	45±15 [4/ 7/]		6±6		3±3 [3/ 5/]		
CA 12						100	95±5	85±10	60±10		35±10		9±4
CA 13						100	97±3	80±10	30±15		3±3 [3/]		
CA 14							90±10 [6/]	45±20	3±3				
CA 15							100	75±15	7±7		2±2		
CA 16							100	97±3	30±15		2±2 [3/]		
CA 17	100								65±20		45±20	20±10	10±5
CA 18	100				95±5				75±25		55±25	10±10	2±2
CA 19	100				95±5				60±15		40±15	20±10	10±5
CA 20							100	92±8	20±10	5±5	3±3		

1/ Subject to maximum percent allowed in Coarse Aggregate Quality table.

2/ Shall be 100 percent passing the 1 3/4 in. (45 mm) sieve.

3/ When used in HMA (High and Low ESAL) mixtures, the percent passing the No. 16 (1.18 mm) sieve for gradations CA 11, CA 13, or CA 16 shall be 4±4 percent.

4/ When using gradation CA 11 for IL-19.0 and IL-19.0L binder, the percent passing the 1/2 in. (12.5 mm) sieve may also be 15±10 percent.

5/ The No. 16 (1.18 mm) requirement will be waived when CA 11 is used in the manufacture of portland cement concrete.

6/ Shall be 100 percent passing the 5/8 in. (16 mm) sieve.

7/ When Class BS concrete is to be pumped, the coarse aggregate gradation shall have a minimum of 45 percent passing the 1/2 in. (12.5 mm) sieve. The Contractor may combine two or more coarse aggregate sizes, consisting of CA 7, CA 11, CA 13, CA 14, and CA 16, provided a CA 7 or CA 11 is included in the blend.

Note: When CA 7, CA 8, CA 11, CA 13, CA 14, CA 15, or CA 16 are used under paved median, Notes 3, 4, 5, and 6 shall apply.

(d) Incompatibility. Incompatibility of any of the gradations or combinations of gradations permitted resulting in unworkable mixtures, nonadherence to the final mix gradation limits, or any other indication of incompatibility shall be just cause for rejection of one or both of the sizes.

(e) Storage. Sites for stockpiles shall be grubbed and cleaned prior to storing the aggregates.

The stockpiles shall be built according to the Bureau of Materials Policy Memorandum, "Aggregate Gradation Control System (AGCS)" and the following.

(1) Segregation or degradation due to improper stockpiling or loading out of stockpiles shall be just cause for rejecting the material.

(2) Separate stockpiles shall be provided for the various kinds of aggregates.

(3) Stockpiles shall be separated to prevent intermingling at the base. If partitions are used, they shall be of sufficient heights to prevent intermingling.

(4) Coarse aggregates shall be handled in and out of the stockpiles in such a manner that will prevent contamination and degradation.

(5) Crushed concrete, crushed slag, or lightweight aggregate for portland cement concrete shall be stockpiled in a moist condition (saturated surface dry or greater) and the moisture content shall be maintained uniformly throughout the stockpile by periodic sprinkling.

At the time of use, the coarse aggregate shall be free from frozen material, material used to caulk rail cars, and all foreign material which may have become mixed during transportation and handling.

(f) Shipping Tickets. Shipping tickets for the material shall be according to the Bureau of Materials Policy Memorandum, "Designation of Aggregate Information on Shipping Tickets".

1004.02 Coarse Aggregate for Portland Cement Concrete. The aggregate shall be according to Article 1004.01 and the following.

(a) Description. The coarse aggregate shall be gravel, crushed gravel, crushed stone, crushed concrete, crushed slag, or crushed sandstone.

(b) Quality. The coarse aggregate shall be Class A quality.

(c) Gradation. The gradations of coarse aggregate used in the production of portland cement concrete for pavements and structures shall be according to Table 1 of Article 1020.04. Washing equipment will be required where producing conditions warrant.

(d) Combining Sizes. Each size shall be stored separately and care shall be taken to prevent them from being mixed until they are ready to be proportioned. Separate compartments shall be provided to proportion each size.

(1) When Class BS concrete is to be pumped, the coarse aggregate gradation shall have a minimum of 45 percent passing the 1/2 in. (12.5 mm) sieve. The Contractor may combine two or more coarse aggregate sizes, consisting of CA 7, CA 11, CA 13, CA 14, or CA 16, provided a CA 7 or CA 11 is included in the blend.

(2) If the coarse aggregate is furnished in separate sizes, they shall be combined in proportions to provide a uniformly graded coarse aggregate grading within the following limits.

Class of Concrete 1/	Combined Sizes	Sieve Size, in. (mm), and Percent Passing						
		2 1/2 (63)	2 (50)	1 3/4 (45)	1 1/2 (37.5)	1 (25)	1/2 (12.5)	No. 4 (4.75)
PV 2/								
	CA 5 & CA 7	---	---	100	98±2	72±22	22±12	3±3
	CA 5 & CA 11	---	---	100	98±2	72±22	22±12	3±3
SI and SC 2/								
	CA 3 & CA 7	100	95±5	---	---	55±25	20±10	3±3
	CA 3 & CA 11	100	95±5	---	---	55±25	20±10	3±3
	CA 5 & CA 7	---	---	100	98±2	72±22	22±12	3±3
	CA 5 & CA 11	---	---	100	98±2	72±22	22±12	3±3

1/ See Table 1 of Article 1020.04.

2/ Any of the listed combination of sizes may be used.

(e) Mixing Gravel, Crushed Gravel, Crushed Stone, and Crushed Slag Coarse Aggregates. Two different specified sizes of crushed stone, gravel, and crushed gravel from one source or any two sources may be combined in any consistent ratio in a mix; but the use of alternate batches of crushed stone, gravel, or crushed gravel of any one size or combination of sizes will not be permitted. Coarse aggregates of any one size from different sources shall not be mixed without permission from the Engineer. Crushed slag shall not be combined or mixed with gravel, crushed gravel, or crushed stone aggregates.

(f) Freeze-Thaw Rating. When coarse aggregate is used to produce portland cement concrete for base course, base course widening, pavement (including precast), driveway pavement, sidewalk, shoulders, curb, gutter, combination curb and gutter, median, paved ditch, concrete superstructures on subgrade such as bridge approach slabs (excluding precast), concrete structures on subgrade such as bridge approach footings, or their repair using concrete, the gradation permitted will be determined from the results of the Department's Freeze-Thaw Test (Illinois Modified AASHTO T 161). A list of freeze-thaw ratings for all Class A quality coarse aggregate sources will be available. The gradations permitted for each rating shall be as follows.

Freeze-Thaw Rating (Top Size) in.	mm	Gradation Permitted
1 1/2 in.	(37.5 mm)	Combined CA 5 & CA 7, Combined CA 5 & CA 11, CA 7, or CA 11
1 in.	(25 mm)	CA 7 or CA 11
3/4 in.	(19 mm)	CA 11
1/2 in.	(12.5 mm)	CA 13, CA 14, or CA 16
NON-ACC		Not Acceptable

Additional requirements may be placed on coarse aggregates when used in continuously reinforced concrete pavement. Such requirements will be stipulated on the most recent Freeze-Thaw Rating List.

(g) Alkali Reaction.

(1) ASTM C 1260. Each coarse aggregate will be tested by the Department for alkali reaction according to ASTM C 1260. The test will be performed with Type I or II portland cement having a total equivalent alkali content (Na_2O + $0.658K_2O$) of 0.90 percent or greater. The Engineer will determine the assigned expansion value for each aggregate, and these values will be made available on the Department's Alkali-Silica Potential Reactivity Rating List. The Engineer may differentiate aggregate based on ledge, production method, gradation number, or other factors. An expansion value of 0.05 percent will be assigned to limestone or dolomite coarse aggregates. However, the Department reserves the right to perform the ASTM C 1260 test.

(2) ASTM C 1293 by Department. In some instances testing a coarse aggregate according to ASTM C 1260 may not provide accurate test

results. In this case, the Department may only test according to ASTM C 1293.

(3) ASTM C 1293 by Contractor. If an individual aggregate has an ASTM C 1260 expansion value that is unacceptable to the Contractor, an ASTM C 1293 test may be performed by the Contractor according to Article 1003.02(e)(3).

If lightweight aggregate is specified for structures, it shall be according to ASTM C 330, the second paragraph of Article 1004.01(c), and Articles 1004.01(d) and 1004.01(e). Lightweight aggregate of any one size from different sources shall not be mixed without permission of the Engineer. Lightweight aggregate may be combined or mixed with gravel, crushed gravel, or crushed stone.

1004.03 Coarse Aggregate for Hot-Mix Asphalt (HMA). The aggregate shall be according to Article 1004.01 and the following.

(a) Description. The coarse aggregate for HMA shall be according to the following table.

<table>
<tr><th>Use</th><th>Mixture</th><th colspan="2">Aggregates Allowed</th></tr>
<tr><td>Class A</td><td>Seal or Cover</td><td colspan="2"><u>Allowed Alone or in Combination</u> [5/]:

Gravel
Crushed Gravel
Carbonate Crushed Stone
Crystalline Crushed Stone
Crushed Sandstone
Crushed Slag (ACBF)
Crushed Steel Slag
Crushed Concrete</td></tr>
<tr><td>HMA
Low ESAL</td><td>Stabilized Subbase or Shoulders</td><td colspan="2"><u>Allowed Alone or in Combination</u> [5/]:

Gravel
Crushed Gravel
Carbonate Crushed Stone
Crystalline Crushed Stone
Crushed Sandstone
Crushed Slag (ACBF)
Crushed Steel Slag [1/]
Crushed Concrete</td></tr>
<tr><td>HMA
High ESAL
Low ESAL</td><td>Binder
IL-19.0
or IL-19.0L

SMA Binder</td><td colspan="2"><u>Allowed Alone or in Combination</u> [5/]:

Crushed Gravel
Carbonate Crushed Stone [2/]
Crystalline Crushed Stone
Crushed Sandstone
Crushed Slag (ACBF)
Crushed Concrete [3/]</td></tr>
<tr><td>HMA
High ESAL
Low ESAL</td><td>C Surface and Binder
IL-9.5
IL-9.5FG
or IL-9.5L

SMA
Ndesign 50 Surface</td><td colspan="2"><u>Allowed Alone or in Combination</u> [5/]:

Crushed Gravel
Carbonate Crushed Stone [2/]
Crystalline Crushed Stone
Crushed Sandstone
Crushed Slag (ACBF)
Crushed Steel Slag [4/]
Crushed Concrete [3/]</td></tr>
<tr><td rowspan="6">HMA
High ESAL</td><td rowspan="6">D Surface and Binder
IL-9.5
or IL-9.5FG

SMA
Ndesign 50
Surface</td><td colspan="2"><u>Allowed Alone or in Combination</u> [5/]:

Crushed Gravel
Carbonate Crushed Stone (other than Limestone) [2/]
Crystalline Crushed Stone
Crushed Sandstone
Crushed Slag (ACBF)
Crushed Steel Slag [4/]
Crushed Concrete [3/]</td></tr>
<tr><td colspan="2"><u>Other Combinations Allowed:</u></td></tr>
<tr><td>Up to...</td><td>With...</td></tr>
<tr><td>25% Limestone</td><td>Dolomite</td></tr>
<tr><td>50% Limestone</td><td>Any Mixture D aggregate other than Dolomite</td></tr>
<tr><td>75% Limestone</td><td>Crushed Slag (ACBF) or Crushed Sandstone</td></tr>
</table>

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Art. 1004.03 Coarse Aggregates

Use	Mixture	Aggregates Allowed	
HMA High ESAL	E Surface IL-9.5 or IL-9.5FG SMA Ndesign 80 Surface	<u>Allowed Alone or in Combination</u> [5/]: Crushed Gravel Crystalline Crushed Stone Crushed Sandstone Crushed Slag (ACBF) Crushed Steel Slag Crushed Concrete[3/] No Limestone.	
		<u>Other Combinations Allowed:</u>	
		Up to...	*With...*
		50% Dolomite[2/]	Any Mixture E aggregate
		75% Dolomite[2/]	Crushed Sandstone, Crushed Slag (ACBF), Crushed Steel Slag, or Crystalline Crushed Stone
		75% Crushed Gravel or Crushed Concrete[3/]	Crushed Sandstone, Crystalline Crushed Stone, Crushed Slag (ACBF), or Crushed Steel Slag
HMA High ESAL	F Surface IL-9.5 or IL-9.5FG SMA Ndesign 80 Surface	<u>Allowed Alone or in Combination</u> [5/]: Crystalline Crushed Stone Crushed Sandstone Crushed Slag (ACBF) Crushed Steel Slag No Limestone.	
		<u>Other Combinations Allowed:</u>	
		Up to...	*With...*
		50% Crushed Gravel, Crushed Concrete[3/], or Dolomite[2/]	Crushed Sandstone, Crushed Slag (ACBF), Crushed Steel Slag, or Crystalline Crushed Stone

1/ Crushed steel slag allowed in shoulder surface only.

2/ Carbonate crushed stone shall not be used in SMA Ndesign 80. In SMA Ndesign 50, carbonate crushed stone shall not be blended with any of the other aggregates allowed alone in Ndesign 50 SMA binder or Ndesign 50 SMA surface.

3/ Crushed concrete will not be permitted in SMA mixes.

4/ Crushed steel slag shall not be used as binder.

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5/ When combinations of aggregates are used, the blend percent measurements shall be by volume.

(b) Quality. For surface courses, the coarse aggregate shall be Class B quality or better. For SMA surface and binder courses the coarse aggregate shall be Class B Quality or better. For Class A (seal or cover coat), and other binder courses, the coarse aggregate shall be Class C quality or better.

(c) Gradation. The coarse aggregate gradations shall be as listed in the following table.

Use	Size/Application	Gradation No.
Class A-1, A-2, & A-3	3/8 in. (10 mm) Seal	CA 16 or CA 20
Class A-1	1/2 in. (13 mm) Seal	CA 15
Class A-2 & A-3	Cover Coat	CA 14
HMA High ESAL	IL-19.0	CA 11 [1/]
	SMA 12.5 [2/]	CA 13, CA 14, or CA 16 [3/]
	SMA 9.5 [2/]	CA 13, CA 14, or CA 16 [3/]
	IL-9.5	CA 16
	IL-9.5FG	CA 16
HMA Low ESAL	IL-19.0L	CA 11 [1/]
	IL-9.5L	CA 16

1/ CA 16 or CA 13 may be blended with CA 11.

2/ The coarse aggregates shall be capable of being combined with the fine aggregates and mineral filler to meet the approved mix design and the mix requirements noted herein.

3/ The specified coarse aggregate gradations may be blended.

(d) Flat and Elongated Particles. For SMA the coarse aggregate shall meet the criteria for Flat and Elongated Particles listed in Illinois Modified AASHTO M 325.

(e) Absorption. For SMA the coarse aggregate shall also have water absorption $\leq$ 2.5 percent.

1004.04 Coarse Aggregate for Granular Embankment Special; Granular Subbase; and Aggregate Base, Surface, and Shoulder Courses. The aggregate shall be according to Article 1004.01 and the following.

(a) Description. The coarse aggregate shall be gravel, crushed gravel, crushed stone, crushed concrete, crushed slag, or crushed sandstone, except gravel shall not be used for subbase granular material, Type C.

The coarse aggregate for aggregate base course and aggregate shoulders, if approved by the Engineer, may be produced by blending aggregates from more than one source, provided the method of blending results in a uniform product. The components of a blend need not be of the same kind of material. The source of material or blending proportions shall not be changed during the progress of the work without written permission from the Engineer. Where a natural aggregate is deficient in fines, the material added to make up deficiencies shall be a fine aggregate of Class C quality or higher according to Section 1003 and/or mineral filler meeting the requirements of Article 1011.01.

(b) Quality. The coarse aggregate shall be Class D Quality or better.

(c) Gradation. The coarse aggregate gradation shall be used as follows.

Use	Gradation
Granular Embankment, Special	CA 6 or CA 10 1/
Granular Subbase:	
Subbase Granular Material, Ty. A	CA 6 or CA 10 2/
Subbase Granular Material, Ty. B	CA 6, CA 10, CA 12, or CA 19 2/
Subbase Granular Material, Ty. C	CA 7, CA 11, or CA 5 & CA 7 3/
Aggregate Base Course	CA 6 or CA 10 2/
Aggregate Surface Course:	
Type A	CA 6 or CA 10 1/
Type B	CA 6, CA 9, or CA 10 4/
Aggregate Shoulders	CA 6 or CA 10 2/

1/ Gradation CA 2, CA 4, CA 9, or CA 12 may be used if approved by the Engineer.

2/ Gradation CA 2 or CA 4 may be used if approved by the Engineer.

3/ If the CA 5 and CA 7 blend is furnished, proper mixing will be required either at the source or at the jobsite according to Article 1004.02(d).

4/ Gradation CA 4 or CA 12 may be used if approved by the Engineer.

(d) Plasticity. All material shall comply with the plasticity index requirements listed below. The plasticity index requirement for crushed gravel, crushed stone, and crushed slag may be waived if the ratio of the percent passing the No. 200 (75 µm) sieve to that passing the No. 40 (425 µm) sieve is 0.60 or less.

Use	Plasticity Index - Percent 1/	
	Gravel	Crushed Gravel, Stone, & Slag
Granular Embankment, Special	0 to 6	0 to 4
Granular Subbase:		
Subbase Granular Material, Type A	0 to 9	---
Subbase Granular Material, Type B	0 to 9	---
Aggregate Base Course	0 to 6	0 to 4
Aggregate Surface Course:		
Type A	2 to 9	---
Type B 2/	2 to 9	---
Aggregate Shoulders	2 to 9	---

1/ Plasticity Index shall be determined by the method given in AASHTO T 90. Where shale in any form exists in the producing ledges, crushed stone samples shall be soaked a minimum of 18 hours before processing for plasticity index or minus No. 40 (425 µm) material. When clay material is added to adjust the plasticity index, the clay material shall be in a minus No. 4 (4.75 mm) sieve size.

2/ When Gradation CA 9 is used, the plasticity index requirement will not apply.

1004.05 Coarse Aggregate for Blotter, Embankment, Backfill, Trench Backfill, Bedding, and French Drains. The aggregate shall be according to Article 1004.01 and the following.

(a) Description. The coarse aggregate shall be gravel, crushed gravel, crushed stone, crushed concrete, crushed slag, chats, crushed sandstone, or wet bottom boiler slag.

For pipe underdrains, Type 2, the crushed stone shall be a crystalline crushed stone.

(b) Quality. The coarse aggregate shall consist of sound durable particles reasonably free of objectionable deleterious material.

(c) Gradation. The coarse aggregate gradations shall be as follows.

SECTION 1030. HOT-MIX ASPHALT

1030.01 Description. This section describes the materials, mix designs, proportioning, mixing, and transportation requirements to produce and place hot-mix asphalt (HMA) following the Quality Management Program (QMP) designated in the plans.

Warm mix asphalt (WMA) is an asphalt mixture which can be produced at temperatures lower than allowed for HMA by utilizing qualified WMA technologies. WMA is produced with the use of additives, a water foaming process, or a combination of both. WMA shall conform to all HMA specifications unless specificly noted.

For simplicity of text, the following HMA nomenclature applies to this Section.

Mixture Type	Application	Mixture-Nominal Maximum Aggregate Size
High ESAL	Binder Course	IL-19.0, IL-9.5, IL-9.5FG, IL-4.75, SMA-12.5, SMA-9.5
	Surface Course	IL-9.5, IL-9.5FG, SMA-12.5, SMA-9.5
Low ESAL 1/	Binder Course	IL-19.0L, IL-9.5L
	Surface Course	IL-9.5L

1/ High ESAL mixtures may be used in similar Low ESAL mixture applications.

1030.02 Materials. Materials shall be according to the following.

	Item	Article/Section
(a)	Coarse Aggregate	1004.03
(b)	Fine Aggregate	1003.03
(c)	Reclaimed Asphalt Pavement	1031
(d)	Mineral Filler	1011
(e)	Hydrated Lime	1012.01
(f)	Slaked Quicklime (Note 1)	
(g)	Performance Graded Asphalt Binder	1032
(h)	Fibers (Note 2)	
(i)	WMA Technologies (Note 3)	
(j)	Reclaimed Asphalt Shingles	1031
(k)	Collected Dust	1102.01(a)(4)
(l)	Truck Bed Release Agents for HMA (Note 4)	1030.12
(m)	Liquid Anti-Strip (Note 5)	
(n)	Packaged, Dry, Rapid Hardening Mortar or Concrete	1018

Note 1. Slaked quicklime shall be according to ASTM C 5.

Note 2. A stabilizing additive such as cellulose or mineral fiber shall be added to stone matrix asphalt (SMA) mixtures and shall meet the requirements listed in Illinois Modified AASHTO M 325. Prior to approval and use of fibers, the Contractor shall submit a notarized certification by the producer of these materials stating they meet these requirements.

Note 3. WMA additives or foaming processes shall be selected from the Department's qualified producer list "Technologies for the Production of Warm Mix Asphalt (WMA)".

Note 4. Truck Bed Release Agents for HMA shall be selected from the Department's Qualified Product List "Asphalt Release Agents for Vehicles Transporting Hot-Mix Asphalt".

Note 5. Liquid additives to control stripping shall be shown effective by the Contractor by completing tensile strength and tensile strength ratio (TSR) testing according to AASHTO T 283 for the mix design and submitting the results to the Engineer.

1030.03 Equipment. Equipment shall be according to the following.

	Item	Article/Section
(a)	Hot-Mix Asphalt Plant	1102.01
(b)	Storage Tanks for Asphalt Binders (Note 1)	1102.01(a)(6)
(c)	Heating Equipment (Note 2)	1102.07

Note 1. Tanks for the storage of asphalt binder shall be clearly and uniquely identified. Different grades of asphalt binder shall not be blended.

Note 2. The asphalt binder shall be transferred to the asphalt tanks and brought to a temperature of 250 to 350 °F (120 to 180 °C). If, at anytime, the asphalt binder temperature exceeds 350 °F (180 °C), the asphalt binder shall not be used. Polymer modified asphalt binder, when specified, shall be shipped, maintained, and stored at the mix plant according to the manufacturer's requirements.

1030.04 Reference Documents. The HMA mixtures shall be designed, sampled, tested, and accepted according to the following.

(a) Appendices listed in the Manual of Test Procedures for Materials.

(1) Development of Gradation Bands on Incoming Aggregate at Hot-Mix Asphalt and Portland Cement Concrete Plants
(2) Model Annual Quality Control Plan for Hot-Mix Asphalt Production
(3) Model Quality Control Addendum for Hot-Mix Asphalt Production
(4) Procedure for Correlating Nuclear Gauge Densities with Core Densities for Hot-Mix Asphalt
(5) Hot-Mix Asphalt Test Strip Procedures
(6) Hot-Mix Asphalt QC/QA QC Personnel Responsibilities and Duties Checklist
(7) Hot-Mix Asphalt QC/QA Initial Daily Plant and Random Samples
(8) Hot-Mix Asphalt QC/QA Procedure for Determining Random Density Locations
(9) Hot-Mix Asphalt QC/QA Control Charts
(10) Hot-Mix Asphalt Mix Design Verification Procedure
(11) Calibration of Equipment for Asphalt Binder Content Determination (Nuclear Asphalt Binder Content Gauge and Ignition Oven)
(12) Hot-Mix Asphalt Mix Design Procedure for Dust Correction Factor Determination
(13) Calibration of the Ignition Oven for the Purpose of Characterizing Reclaimed Asphalt Pavements (RAP)
(14) Hot-Mix Asphalt Composite Sample Blending and Splitting Diagram

(15) Hot-Mix Asphalt (HMA) Production Gradation Windage Procedure for Minus #200 (minus 75 µm) Material
(16) Stripping of Hot-Mix Asphalt Mixtures Visual Identification and Classification
(17) Procedure for Introducing Additives to Hot-Mix Asphalt Mixtures and Testing in the Lab
(18) Ignition Oven Aggregate Mass Loss Procedure
(19) Procedure for Internal Angle Calibration of Superpave Gyratory Compactors (SGCs) Using the Dynamic Angle Validator (DAV-2)
(20) Segregation Control of Hot-Mix Asphalt
(21) Determination of Aggregate Bulk (Dry) Specific Gravity (Gsb) of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)
(22) Use of Corrections Factors for Adjusting the Gradation of Cores to Estimate the Gradation of the In-Place Pavement
(23) Off-Site Preliminary Test Strip Procedures for Hot-Mix Asphalt
(24) Hot-Mix Asphalt Production Inspection Checklist
(25) Hot-Mix Asphalt Rounding Test Values
(26) Hot-Mix Asphalt Laboratory Equipment
(27) Illinois Specification 101 Minimum Requirements for Electronic Balances
(28) Hot-Mix Asphalt PFP Pay Adjustments
(29) Hot-Mix Asphalt PFP and QCP Procedure for Determining Random Density Locations
(30) Hot-Mix Asphalt PFP and QCP Random Jobsite Sampling
(31) Hot-Mix Asphalt PFP Dispute Resolution
(32) Hot-Mix Asphalt QCP Pay Adjustments
(33) Best Practices for Hot-Mix Asphalt PFP and QCP
(34) Hot-Mix Asphalt PFP and QCP Calculations of Monetary Deductions

(b) Illinois Modified AASHTO procedures listed in the Manual of Test Procedures for Materials.

AASHTO M 323	Standard Specification for Superpave Volumetric Mix Design
AASHTO M 325	Standard Specification for Stone Matrix Asphalt (SMA)
AASHTO R 30	Standard Practice for Mixture Conditioning of Hot Mix Asphalt (HMA)
AASHTO R 35	Standard Practice for Superpave Volumetric Design for Asphalt Mixtures
AASHTO R 46	Standard Practice for Designing Stone Matrix Asphalt (SMA)
AASHTO T 30	Standard Method of Test for Mechanical Analysis of Extracted Aggregate
AASHTO T 164	Standard Method of Test for Quantitative Extraction of Asphalt Binder from Hot Mix Asphalt (HMA)
AASHTO T 166	Standard Method of Test for Bulk Specific Gravity (G_{mb}) of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens
AASHTO T 209	Standard Method of Test for Theoretical Maximum Specific Gravity (Gmm) and Density of Asphalt Mixtures

AASHTO T 283	Standard Method of Test for Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage
AASHTO T 287	Standard Method of Test for Asphalt Binder Content of Asphalt Mixtures by the Nuclear Method
AASHTO T 305	Standard Method of Test for Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures
AASHTO T 308	Standard Method of Test for Determining the Asphalt Binder Content of Asphalt Mixtures by the Ignition Method
AASHTO T 312	Standard Method of Test for Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
AASHTO T 324	Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Asphalt Mixtures
AASHTO T 393	Standard Test Method for Determining the Fracture Potential of Asphalt Mixtures Using the Illinois Flexibility Index Test (I-FIT)

(c) Illinois Modified ASTM procedures listed in the Manual of Test Procedures for Materials.

ASTM D 2950	Standard Test Method for Density of Bituminous Concrete in Place by Nuclear Methods
ASTM D 8159	Standard Test Method for Automated Extraction of Asphalt Binder from Asphalt Mixtures

(d) Bureau of Materials Policy Memorandums.

(1) 1-08 Performance Graded Asphalt Binder Qualification Procedure

(2) 4-08 Approval of Hot-Mix Asphalt Plants and Equipment

(3) 6-08 Minimum Private Laboratory Requirements for Construction Materials Testing or Mix Design

(4) 21-08 Minimum Department and Local Agency Laboratory Requirements for Construction Materials Testing or Mix Design

1030.05 Mixture Design. The Contractor shall submit designs for each required mixture. The mixture design shall be performed at a HMA mix design laboratory according to the Bureau of Materials Policy Memorandum, “Minimum Private Laboratory Requirements for Construction Materials Testing or Mix Design”. Each design shall be verified and approved by the Department as detailed in the document "Hot-Mix Asphalt Mixture Design Verification Procedure”.

(a) Mixture Composition. The Job Mix Formula (JMF) represents the mix design comprised of aggregate gradation and asphalt binder content that produce the desired mix criteria in the laboratory. The ingredients of the mix design shall be combined in such proportions as to produce a mixture conforming to the composition limits by weight unless by volume is specified. The JMF shall fall within the following limits.

MIXTURE COMPOSITION (% PASSING) [1/]

Sieve Size	IL-19.0		IL-19.0L [2/]		SMA-12.5 [3/]		SMA-9.5 [3/]		IL-9.5		IL-9.5L [2/]		IL-9.5FG		IL-4.75	
	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
1 1/2 in. (37.5 mm)																
1 in. (25 mm)		100		100												
3/4 in. (19 mm)	90	100	95	100		100		100								
1/2 in. (12.5 mm)	75	89			90	99	95	100		100		100		100		100
3/8 in. (9.5 mm)					50	85	70	95	90	100	95	100	90	100		100
#4 (4.75 mm)	40	60	38	65	20	40	30	50	32	69	52	80	60	75 [7/]	90	100
#8 (2.36 mm)	26	42			16	24 [4/]	20	30	32	52 [5/]	38	65	45	60 [7/]	70	90
#16 (1.18 mm)	15	30						21	10	32			25	40	50	65
#30 (600 µm)								18					15	30		
#50 (300 µm)	6	15						15	4	15			8	15	15	30
#100 (150 µm)	4	9							3	10			6	10	10	18
#200 (75 µm)	3.0	6.0	3.0	7.0	8.0	11.0 [6/]	8.0	11.0 [6/]	4.0	6.0	4.0	8.0	4.0	6.5	7.0	9.0 [6/]
#635 (20 µm)						≤ 3		≤ 3								
Dust/Asphalt Binder Ratio		1.0		1.0						1.0		1.0		1.0		1.0

Notes:
1/ Based on percent of total aggregate weight.
2/ Percent passing the #30 (600 µm) sieve shall be less than 50 percent of the percentage passing the #4 (4.75 mm) sieve for IL-19.0L and #8 (2.36 mm) for the IL-9.5L.
3/ When the bulk specific gravity (Gsb) of the component aggregates vary by more than 0.20, the blend gradations shall be based on percent by volume.
4/ When establishing the Adjusted Job Mix Formula (AJMF) the percent passing the #8 (2.36 mm) sieve shall not be adjusted above 24 percent.
5/ The mixture composition shall not exceed 44 percent passing the #8 (2.36 mm) sieve for surface courses with Ndesign = 90.
6/ Additional minus #200 (75 µm) material required by the mix design shall be mineral filler, unless otherwise approved by the Engineer.
7/ When the mixture is used as a binder, the maximum shall be increased by 5 percent passing.

(b) Volumetric Requirements. The target value for the air voids of the HMA shall be 4.0 percent at the design number of gyrations. The voids in the mineral aggregate (VMA) of the HMA design shall be based on the nominal maximum size of the aggregate in the mix, and shall conform to the following requirements.

	Voids in the Mineral Aggregate (VMA), % Minimum for Ndesign				
Mix Design	30	50	70	80	90
IL-19.0		13.5	13.5		13.5
IL-9.5		15.0	15.0		15.0
IL-9.5FG		15.0	15.0		15.0
IL-4.75 1/		18.5			
SMA-12.5 1/		16.0		17.0	
SMA-9.5 1/		16.0		17.0	
IL-19.0L	13.5				
IL-9.5L	15.0				

1/ Maximum draindown shall be 0.3 percent according to Illinois Modified AASHTO T 305.

(c) Contractor Determination of Tensile Strength and Tensile Strength Ratio (TSR). The mixture designer shall determine if the proposed mix design meets minimum tensile strength requirements and is resistant to stripping. These determinations shall be made based on tests performed according to Illinois Modified AASHTO T 283.

The proposed mix design shall have a minimum conditioned tensile strength of 60 psi (415 kPa) for non-polymer modified performance graded (PG) asphalt binders and 80 psi (550 kPa) for polymer modified PG asphalt binders except modified PG 64-28 or lower asphalt binders which shall have a minimum tensile strength of 70 psi (485 kPa).

The conditioned to unconditioned TSR shall be equal to or greater than 0.85 for 6 in. (150 mm) specimens. Mixtures, either with or without an additive, with TSRs less than 0.85 for 6 in. (150 mm) specimens will be considered unacceptable. Also, the conditioned tensile strength for mixtures containing an anti-strip additive shall not be lower than the conditioned tensile strength of the same mixture without the anti-strip additive.

If it is determined that an additive is required, the additive may be hydrated lime, slaked quicklime, or a liquid additive. Dry hydrated lime shall be added at a minimum rate of 1.0 percent by weight of total dry aggregate. Slurry shall be added in such quantity as to provide the required amount of hydrated lime solids by weight of total dry aggregate. The method of application shall be according to Article 1102.01(a)(8).

(d) Mix Design Verification Testing. Mix designs shall be submitted for verification according to the document "Hot-Mix Asphalt Mixture Design Verification Procedure".

High ESAL mixture designs shall meet the following requirements for tensile strength, TSR, Hamburg wheel, and I-FIT criteria. Low ESAL mixture designs shall meet TSR and I-FIT criteria.

If a mix fails the Department's verification testing, the Contractor shall make necessary changes to the mix and provide passing volumetric, tensile strength, TSR, Hamburg wheel, and I-FIT procedure results before resubmittal. The Department will verify the passing results.

(1) Tensile Strength. The minimum allowable conditioned tensile strength shall be according to Article 1030.05(c).

(2) TSR. The minimum TSR shall be according to Article 1030.05(c).

(3) Hamburg Wheel Test. The maximum allowable rut depth shall be 0.5 in. (12.5 mm). The minimum number of wheel passes at the 0.5 in. (12.5 mm) rut depth is based on the high temperature binder grade of the mix as specified in the mix requirements table on the plans and shall be according to the following.

Illinois Modified AASHTO T 324 Requirements 1/	
PG Grade	Minimum Number of Wheel Passes
PG 58-xx (or lower)	5,000
PG 64-xx	7,500
PG 70-xx	15,000 2/
PG 76-xx (or higher)	20,000 2/

1/ When WMA is produced at temperatures of 275 ± 5 °F (135 ± 3 °C) or less, loose mix shall be oven aged at 270 ± 5 °F (132 ± 3 °C) for two hours prior to gyratory compaction of Hamburg wheel specimens.

2/ For IL-4.75 binder course, the minimum number of wheel passes shall be reduced by 5,000.

(4) I-FIT. The minimum flexibility index (FI) shall be as follows.

Illinois Modified AASHTO T 393		
Mixture	Short Term Aging, Minimum FI	Long Term Aging, Minimum FI 2/
HMA 1/	8.0	5.0 3/
SMA	16.0	10.0
IL-4.75	12.0	-

1/ All mix designs, except for SMA and IL-4.75 mixtures.

2/ Required for surface courses only.

3/ Production long term aging FI for HMA shall be a minimum of 4.0.

1030.06 Quality Management Program. The Quality Management Program (QMP) will be shown on the plans as Pay for Performance (PFP), Quality Control for Performance (QCP), or Quality Control / Quality Assurance (QC/QA) for each HMA mixture or full-depth pavement according to the following.

PFP shall be used on interstate, freeway, and expressway resurfacing and full-depth projects having a minimum quantity of 8,000 tons (7,260 metric tons) per mix.

QCP shall be used on mainline mixture quantities between 1,200 and 8,000 tons (1,016 and 7,620 metric tons) as well as shoulder applications greater than 8 ft (2.4 m) wide and at least 1,200 tons (1,016 metric tons).

QC/QA shall be used for mixtures less than 1,200 tons (1,016 metric tons), shoulder applications 8 ft (2.4 m) wide or less, hand method, variable width shoulders, incidental surfacing, intermittent resurfacing, driveways, entrances, minor sideroads, sideroad returns, patching, turn lanes less than 500 ft (152 m) in length, temporary pavement, and shared-use paths or bike lanes unless paved with the mainline pavement.

The following shall apply to PFP, QCP, and QC/QA.

(a) Laboratory. The Contractor shall provide a laboratory, at the plant, according to the Bureau of Materials Policy Memorandum, “Minimum Private Laboratory Requirements for Construction Materials Testing or Mix Design”. The requirements for the laboratory and equipment for production and mix design are listed in the document "Hot-Mix Asphalt Laboratory Equipment".

The Engineer may inspect measuring and testing devices at any time to confirm both calibration and condition. If laboratory equipment becomes inoperable, the Contractor shall cease mix production. If the Engineer determines the equipment is not within the limits of dimensions or calibration described in the appropriate test method, the Engineer may stop production until corrective action is taken.

(b) Annual QC Plan and QC Addenda. The Contractor shall submit, in writing to the Engineer, a proposed Annual QC Plan following the format of the document “Model Annual Quality Control Plan for Hot-Mix Asphalt Production" for each HMA plant for approval before each construction season. This shall include documentation that each HMA plant has been calibrated and approved by the Department. Job-specific QC Addenda to the Annual QC Plan must be submitted in writing to the Engineer following the format of the document "Model Quality Control Addendum for Hot-Mix Asphalt Production" for approval before the pre-construction conference. The Annual QC Plan and the QC Addenda shall address all elements involved in the production and quality control of the HMA incorporated in the project.

Production of HMA shall not begin without written approval of the Annual QC Plan and QC Addenda by the Engineer.

The approved Annual QC Plan and QC Addenda shall become part of the contract between the Department and the Contractor but shall not be construed, in itself, as acceptance of any HMA produced. Failure to execute the contract according to the approved Annual QC Plan and QC Addenda shall result in suspension of HMA production or other appropriate actions as directed by the Engineer.

The Annual QC Plan and QC Addenda may be amended during the progress of the work, by either party, subject to mutual agreement. Revisions shall require proper justification and be provided to the Department by the Contractor to ensure product quality. Any revision in the Annual QC Plan or QC Addenda must be approved in writing by the Engineer.

(c) General Quality Control (QC) by the Contractor. The Contractor's quality control activities shall ensure mixtures meet contract requirements.

(1) Inspection and Testing. The Contractor shall perform or have performed the inspection and testing required to conform with contract requirements. QC includes the recognition of obvious defects and their immediate correction. QC may require increased testing, communication of test results to the plant or the job site, modification of operations, suspension of HMA production, rejection of material, or other actions as appropriate.

The Engineer shall be immediately notified of any failing tests and subsequent remedial action. Passing tests shall be reported to the Engineer prior to the start of the next day's production.

(2) Personnel. The Contractor shall provide a QC Manager who shall have overall responsibility and authority for quality control. This individual shall have successfully completed the Department's "Hot-Mix Asphalt Level II" course.

In addition to the QC Manager, the Contractor shall provide sufficient personnel to perform the required visual inspections, sampling, testing, and documentation in a timely manner. Mix designs shall be developed by personnel who have successfully completed the Department's "Hot-Mix Asphalt Level III" course. Technicians performing mix design testing and plant sampling/testing shall have successfully completed the Department's "Hot-Mix Asphalt Level I" course. The Contractor may also provide a Gradation Technician who has successfully completed the Department's "Gradation Technician Course" to run gradation tests only under the supervision of a Hot-Mix Asphalt Level II Technician. The Contractor shall provide a Hot-Mix Asphalt Density Tester who has successfully completed the Department's "Nuclear Density Testing" course to run all nuclear density tests on the job site.

Only quality control personnel shall perform the required QC duties. The Contractor is referred to the document "Hot-Mix Asphalt QC Personnel Responsibilities and Duties Checklist" for a description of personnel qualifications and duties.

(d) Additional Contractor and Department Duties.

(1) The Engineer will initiate and witness asphalt binder sampling by the Contractor at a minimum frequency of one injection line-sample per week, per HMA plant. Sample containers will be furnished by the Department. The Engineer will take possession of and submit the properly identified samples, according to Policy Memorandum 1-08, to the Central Bureau of Materials for testing.

(2) Immediately upon completion of coring for density samples or thickness checks, the Contractor shall remove water from the core holes and fill the holes with packaged, dry, rapid hardening mortar or concrete. The cementitious material shall be mixed in a separate container, placed in the hole, consolidated by rodding, and struck-off flush with the adjacent pavement. Depressions in the surface of filled core holes greater than 1/4 in. (6 mm) at the time of final inspection shall require removal and replacement of the fill materials.

1030.07 Pay for Performance (PFP). PFP is a program that evaluates pay parameters using percent within limits to determine a pay adjustment. Monetary deductions for dust/AB ratios and unconfined edge densities may also apply.

(a) Definitions.

(1) Quality Control (QC). QC includes all production and construction activities by the Contractor necessary to achieve a level of quality.

(2) Quality Assurance (QA). QA includes all monitoring and testing activities by the Engineer necessary to assess product quality, to identify acceptability of the product, and to determine payment.

(3) Percent Within Limits (PWL). PWL is the percentage of material within the quality limits for a given quality characteristic.

(4) Quality Characteristic. The characteristics that are evaluated by the Department to determine payment using PWL. The quality characteristics (i.e. pay parameters) for this program are air voids, field VMA, and density. Field VMA will be calculated using the combined aggregates bulk specific gravity (G_{sb}) from the mix design.

(5) Quality Level Analysis (QLA). QLA is a statistical procedure for determining the amount of in-place mixture within specification limits.

(6) Mixture Lot. A mixture lot will begin once an acceptable test strip has been completed and the adjusted job mix fomula (AJMF) has been determined. If the test strip is waived, the mixture lot will begin with the start of production. A mixture lot consists of ten mixture sublots. If

seven or fewer mixture sublots remain at the end of production of a mixture, the test results for these sublots will be combined with the previous lot for evaluation of PWL and pay factors.

(7) Mixture Sublot. A mixture sublot for air voids and field VMA will be a maximum of 1,000 tons (910 metric tons). If the project quantity is less than 8,000 tons (7,260 metric tons), the sublot size will be adjusted to achieve a minimum of 8 tests.

a. If the remaining quantity is greater than 200 tons (180 metric tons) but less than 1,000 tons (910 metric tons), the last mixture sublot will be that quantity.

b. If the remaining quantity is 200 tons (180 metric tons) or less, the quantity shall be combined with the previous mixture sublot.

(8) Density Lot. A density lot consists of 30 density intervals. If 19 or fewer density intervals remain at the end of production of a mixture, the test results for these sublots will be combined with the previous lot for evaluation of percent within limits and pay factors.

(9) Density Interval. A density interval will be every 0.2 miles (320 m) for lift thicknesses of 3 in. (75 mm) or less and 0.1 miles (160 m) for lift thicknesses greater than 3 in. (75 mm). In cases where paving is completed over multiple lanes in a single pass of one or more pavers to eliminate unconfined edges or cold joints between lanes, the paving lane is defined as the total combined width of the lanes paved in that single pass. If the paving lane width is greater than 20 ft (6 m), the density intervals will be every 0.1 mi. (160 m) for lift thicknesses of 3 in. (75 mm) or less and 0.05 mi. (80 m) for lift thicknesses greater than 3 in. (75 mm). If the last density interval for a lift is less than 200 ft (60 m), it will be combined with the previous density interval.

(10) Density Specimen. A density specimen shall consist of a 4 in. (100 mm) core taken at a random test location within each density interval.

(11) Density Test. A density test shall consist of testing a density specimen according to Illinois Modified AASHTO T 166.

When establishing the target density, the HMA maximum theoretical specific gravity (G_{mm}) will be based on the running average of four Department test results including the current day of production. Initial G_{mm} will be based on the average of the first four test results.

(12) Unconfined Edge Density. The location of the unconfined edge density test sample will be randomly selected within each 0.5 mile (800 m) sublot for each mixture with an unconfined edge according to the document "Hot-Mix Asphalt PFP and QCP Calculations of Monetary Deductions". The last sublot may be less than 0.5 mile (800 m) but at least 200 ft (60 m). If longitudinal joint sealant (LJS) is used at a joint, the joint will not be included in the unconfined edge density testing.

(13) Pay Adjustment. The pay adjustment is calculated using the test results of the pay parameters (air voids, field VMA and density).

(14) Combined Full-Depth Pay Adjustment. For full-depth pavements, the composite pay factors for all incorporated mixtures are combined to determine the combined full-depth pay adjustment.

(15) Monetary Deduction. In addition to the pay adjustment for the pay parameters air voids, field VMA, and density for each mix or full-depth pavement, it will be determined if there is a monetary deduction for dust/AB ratio and/or unconfined edge density.

(b) Quality Control (QC) by the Contractor. The Contractor's QC plan shall include the schedule of testing for both quality characteristics used to determine pay and other quality characteristics required to control the product. The schedule shall include sample time and location. The minimum test frequency shall be according to the following.

Minimum Quality Control Sampling and Testing Requirements		
Quality Characteristic	Minimum Test Frequency	Sampling Location
Mixture Gradation	1/day	per QC Plan
Asphalt Binder Content		
G_{mm}		
G_{mb}		
Density	per QC plan	per QC Plan

The Contractor shall submit QC test results to the Engineer within 48 hours of sampling.

(c) Initial Production Testing. The Contractor shall split and test the first two samples with the Department for comparison purposes. The Contractor shall complete all tests and report all results to the Engineer within two working days of sampling. The Engineer will make Department test results of the initial production testing available to the Contractor within two working days from the receipt of the samples.

(d) Additional Contractor Duties. The Contractor shall obtain the random mixture samples identified by the Engineer according to the document "Hot-Mix Asphalt PFP and QCP Random Jobsite Sampling". One composite sample per sublot shall be collected in the presence of the Engineer. The composite sample shall be split into four equal mix samples. The Contractor shall transport the Department's mix sample to the location designated by the Engineer.

The Contractor shall provide personnel and equipment to collect density specimens for the Engineer. Core locations will be determined by the Engineer following the document "Hot-Mix Asphalt PFP and QCP Procedure for Determining Random Density Locations". The Contractor shall cut the cores within the same day and prior to opening to traffic unless otherwise approved by the Engineer. The Contractor shall transport the Department's secured density specimens to the location designated by the Engineer.

(e) Quality Assurance (QA) by the Engineer. The Department's laboratories which conduct PFP testing will participate in the AASHTO re:source's (formerly AMRL) Proficiency Sample Program. The Engineer will test each mixture sublot for air voids, field VMA, and dust/AB ratio; and each density interval for density to determine payment according to the document "Hot-Mix Asphalt PFP Pay Adjustments". A sublot shall begin once an acceptable test-strip has been completed and the AJMF has been determined.

(1) Air Voids, Field VMA, and Dust/AB Ratio. For each sublot, the Engineer will determine the random tonnage for the sample and the Contractor shall be responsible for obtaining the sample according to the document "Hot-Mix Asphalt PFP and QCP Random Jobsite Sampling". The Engineer will not disclose the random location of the sample until after the truck containing the random tonnage has been loaded and en-route to the project.

(2) Density. For each density interval, the Engineer will determine the random location for the density test according to the document "Hot-Mix Asphalt PFP and QCP Procedure for Determining Random Density Locations". The Engineer will not disclose the random location of the sample until after the final rolling.

The Engineer will witness and secure all mixture and density samples.

(f) Test Results. The Department's test results for the first mixture sublot and density interval, of every lot will be available to the Contractor within three working days from the receipt of secured samples. Test results for remaining sublots will be available to the Contractor within ten working days from receipt of the secured sample that was delivered to the Department's testing facility or a location designated by the Engineer.

The Engineer will maintain a complete record of Department test results. Copies will be furnished upon request. The records will contain, at a minimum, all the Department test results, raw data, random numbers used and resulting calculations for sampling locations, and QLA calculations.

(g) Dispute Resolution. Dispute resolution testing will only be permitted when the Contractor submits their split sample test results prior to receiving Department split sample test results and meets the requirements listed in the document "Hot-Mix Asphalt PFP Dispute Resolution". If dispute resolution is chosen, the Contractor shall submit a request in writing within four working days of receipt of the Department results of the QLA for the lot in question. The Engineer will document receipt of the request. The request shall specify Method 1 (pay parameter dispute) or Method 2 (individual parameter dispute) as defined in the document "Hot-Mix Asphalt PFP Dispute Resolution". The Central Bureau of Materials laboratory will be used for dispute resolution testing.

(h) Acceptance by the Engineer. To be considered acceptable, all the Department's test results shall be within the acceptable limits listed below.

Acceptable Limits		
Parameter		Acceptable Range
Air Voids		2.0 – 6.0 %
Field VMA		-1.0 – +3.0 % 1/
Density	IL-19.0, IL-9.5, IL-9.5FG, IL-4.75	90.0 – 98.0 %
	SMA 12.5, SMA 9.5	92.0 – 98.0 %
Dust / AB Ratio		0.4 – 1.6 2/

1/ Based on minimum required field VMA as stated in the mix design volumetric requirements in Article 1030.05(b).

2/ Does not apply to SMA.

In addition, the PWL for any quality characteristic shall be 50 percent or above for any lot. No visible pavement distress shall be present such as, but not limited to, segregation, excessive coarse aggregate fracturing or flushing.

1030.08 Quality Control for Performance (QCP). QCP is a program that uses step-based pay without an incentive to determine pay adjustment. A monetary deduction for dust/AB ratios also applies.

(a) Definitions.

(1) Quality Control (QC). QC includes all production and construction activities by the Contractor necessary to achieve a level of quality.

(2) Quality Assurance (QA). QA includes all monitoring and testing activities by the Engineer necessary to assess product quality, to identify acceptability of the product, and to determine payment.

(3) Pay Parameters. Pay parameters are air voids, field VMA and density. Field VMA will be calculated using the combined aggregates bulk specific gravity (G_{sb}) from the mix design.

(4) Mixture Lot. A mixture lot will begin once an acceptable test strip has been completed and the AJMF has been determined. If the test strip is waived, a mixture lot will begin with the start of production. A mixture lot will consist of four sublots unless it is the last or only lot, in which case it may consist of as few as one sublot.

(5) Mixture Sublot. A mixture sublot for air voids, field VMA, and dust/AB ratio will be a maximum of 1,000 tons (910 metric tons).

a. If the remaining quantity is greater than 200 tons (180 metric tons) but less than 1,000 tons (910 metric tons), the last mixture sublot will be that quantity.

b. If the remaining quantity is 200 tons (180 metric tons) or less, the quantity will be combined with the previous mixture sublot.

(6) Density Interval. Density intervals will be every 0.2 miles (320 m) for lift thicknesses of 3 in. (75 mm) or less and 0.1 miles (160 m) for lift thicknesses greater than 3 in. (75 mm). In cases where paving is completed over multiple lanes in a single pass of one or more pavers to eliminate unconfined edges or cold joints between lanes, the paving lane is defined as the total combined width of the lanes paved in that single pass. If the paving lane width is greater than 20 ft (6 m), the density intervals will be every 0.1 mi. (160 m) for lift thicknesses of 3 in. (75 mm) or less and 0.05 mi. (80 m) for lift thicknesses greater than 3 in. (75 mm). If the last density interval for a lift is less than 200 ft (60 m), it will be combined with the previous density interval.

(7) Density Sublot. A density sublot will be the average of five consecutive density intervals.

a. If fewer than three density intervals remain outside a density sublot, they will be included in the previous density sublot.

b. If three to five density intervals remain, they will be considered a density sublot.

(8) Density Specimen. A density specimen shall consist of a 4 in. (100 mm) core taken at a random location within each density interval.

(9) Density Test. A density test shall consist of testing a density specimen according to Illinois Modified AASHTO T 166.

When establishing the target density, the HMA maximum theoretical specific gravity (G_{mm}) will be based on the running average of four Department test results. Initial G_{mm} will be based on the average of the first four test results. If less than four G_{mm} results are available, an average of all available Department G_{mm} test results will be used.

(10) Pay Adjustment. The pay adjustment is calculated using the test results of the pay parameters (air voids, field VMA and density).

(11) Combined Full-Depth Pay Adjustment. For full-depth pavements, the composite pay factors for all incorporated mixtures are combined to determine the combined full-depth pay adjustment.

(12) Monetary Deduction. In addition to the pay adjustment for the pay parameters air voids, field VMA, and density for each mix or full-depth pavement, it will be determined if there is a monetary deduction for dust/AB ratio.

(b) Quality Control (QC) Testing by the Contractor. The Contractor's QC plan shall include the schedule of testing for both pay parameters and non-pay parameters necessary to control the product. The minimum test frequency shall be according to the following table.

Minimum Quality Control Mixture Sampling and Testing Requirements		
Quality Characteristic		Minimum Test Frequency
Air Voids	G_{mb}	1 per sublot
	G_{mm}	
Washed Mixture Gradation		
Asphalt Binder Content		
Dust/AB Ratio 1/		
Field VMA		

1/ Dust/AB ratio is not used in the calculation of the pay adjustment but is used to verify the mix is within acceptable limits and determine if there are monetary deductions for this parameter.

The Contractor's results from mix sample testing of split samples, in conjunction with additional quality control tests, shall be used to control production.

The Contractor shall submit their mix sample test results from the split sample to the Engineer within 48 hours of the time of sampling.

(c) Additional Contractor Duties. The Contractor shall obtain the random mixture samples at locations identified by the Engineer according to the document, "Hot-Mix Asphalt PFP and QCP Random Jobsite Sampling". One composite sample per sublot shall be collected in the presence of the Engineer. The composite sample shall be split into four equal mix samples. The Contractor shall transport the Department's mix sample to the location designated by the Engineer.

The Contractor shall provide personnel and equipment to collect density specimens for the Engineer. Core locations will be determined by the Engineer following the document "Hot-Mix Asphalt PFP and QCP Procedure for Determining Random Density Locations". The Contractor shall cut the cores within the same day and prior to opening to traffic unless otherwise approved by the Engineer. The Contractor shall transport the Department's secured density specimens to the location designated by the Engineer.

(d) Quality Assurance (QA) by the Engineer. The Department's laboratories which conduct QCP testing will participate in the AASHTO re:source's (formerly AMRL) Proficiency Sample Program. Quality Assurance by the Engineer will be as follows.

(1) Air Voids, Field VMA, and Dust/AB Ratio. The Engineer will determine the random tonnage for the sample and the Contractor shall be responsible for obtaining the sample according to the document "Hot-Mix Asphalt PFP and QCP Random Jobsite Sampling Procedure". The Engineer will not disclose the random location of the sample until after

the truck containing the random tonnage has been loaded and en-route to the project.

(2) Density. For each density interval, the Engineer will determine the random location for the density test according to the document "Hot-Mix Asphalt PFP and QCP Procedure for Determining Random Density Locations". The Engineer will not disclose the random location of the sample until after the final rolling.

The Engineer will witness and secure all mixture samples to be tested by the Department.

The Engineer will select at random one sublot mixture sample from each lot for testing of air voids, field VMA and dust/AB ratio. The Engineer will test a minimum of one mixture sample per project. The Engineer will test all pavement cores for density. QA test results will be available to the Contractor within ten working days from receipt of split mixture samples and cores from the last sublot from each lot.

The Engineer will maintain a complete record of all Department test results and copies will be provided to the Contractor with each set of sublot results. The records will contain, at a minimum, the originals of all Department test results and raw data, random numbers used and resulting calculations for sampling locations, and pay calculations.

When the QA mixture test results are compared to QC results for a sublot and they are within the precision limits listed in the following table, the QA sublot results will be defined as the final mixture results for that sublot. When QA results are compared to QC results for a sublot and they do not meet the precision limits listed in the following table, the Department will verify the results by testing the retained split sample. The retest results will replace all of the original results and will be defined as the final mixture results for that sublot.

If the final mixture QA results for the random sublot do not meet the 100 percent sublot pay factor limits listed in the document "Hot-Mix Asphalt QCP Pay Adjustments" or do not compare to QC results within the precision limits in the following table, the Engineer will test all sublot split mixture samples for the lot.

Test Parameter	Limits of Precision
G_{mb}	0.030
G_{mm}	0.026
Field VMA	1.0 %

If the dust/AB ratio results for the random sublot do not fall within 0.6 and 1.2, the Department will test the remaining sublots for that lot to determine the dust/AB ratio monetary deductions.

(e) Acceptance by the Engineer. To be acceptable, all of the Department's test results will be within the acceptable limits listed in the following table.

Test Parameter		Acceptable Limits
Air Voids		2.0 – 6.0 %
Field VMA		-1.0 – +3.0 % 1/
Density	IL-19.0, IL-9.5, IL-9.5FG, IL-4.75	90.0 – 98.0 %
	SMA 12.5, SMA 9.5	92.0 – 98.0 %
Dust / AB Ratio		0.4 – 1.6 2/

1/ Based on minimum required VMA as stated in the mix design volumetric requirements in Article 1030.05(b).

2/ Does not apply to SMA.

In addition, no visible pavement distresses shall be present such as, but not limited to, segregation, excessive coarse aggregate fracturing or flushing.

1030.09 Quality Control / Quality Assurance (QC/QA). QC/QA is a method specification acceptance program with no pay adjustments or deductions.

(a) Required Mixture Tests. The Contractor shall complete testing of all required mixture samples within 3 1/2 hours of sampling.

(1) Mixture Sampling. The Contractor shall obtain required mixture samples according to the document, "Hot-Mix Asphalt QC/QA Initial Daily Plant and Random Samples".

(2) Frequency. The Contractor shall use the test methods identified to perform the following mixture tests at a frequency not less than that indicated.

Frequency of Mixture Tests [3/, 4/]				
Parameter	Production Tons (Metric Tons) Per Day	Initial Daily Plant Tests	Daily Random Tests	Test Method
Aggregate Gradation of Washed Ignition Oven or Solvent Extraction	All	1	1	Illinois Modified AASHTO T 30
Asphalt Binder Content	All	1	1	Illinois Modified AASHTO T 164, T 287, T 308 [1/]
Field VMA [2/]	< 1200 (1090)	1	1 for first 2 days	Illinois Modified AASHTO R 35
	≥ 1200 (1090)	1	1	
Air Voids Bulk Specific Gravity of Gyratory Sample	< 1200 (1090)	1	1 for first 2 days	Illinois Modified AASHTO T 312
	≥ 1200 (1090)	1	1	
Maximum Specific Gravity of Mixture	< 1200 (1090)	1	1 for first 2 days	Illinois Modified AASHTO T 209
	≥ 1200 (1090)	1	1	
Draindown IL-4.75, SMA-12.5 and SMA-9.5	All		1	Illinois Modified AASHTO T 305

1/ The ignition oven shall not be used if the calibration factor exceeds 1.5 percent.

2/ The combined G_{sb} used in the VMA calculation shall be listed in the approved mix design.

3/ If the day's production is less than 250 tons (225 metric tons) per mix, gradation analysis, air voids, field VMA and asphalt binder content tests will not be required on a specific mixture. A minimum of one set of mixture tests for each mix shall be performed for each five consecutive production-day period when the accumulated tonnage produced in that period exceeds 500 tons (450 metric tons). A Hot-Mix Asphalt Level II Technician shall oversee all QC operations.

4/ If the required tonnage of any mixture for a single pay item is less than 250 tons (225 metric tons) in total, the Contractor may propose intentions of waiving the "Required Mixture Tests" in the QC Addenda. The mixture shall be produced using a mix design that has been verified as specified and validated by the Department's recent acceptable field test data. A Hot-Mix Asphalt Level II Technician shall oversee all quality control operations for the mixture.

(3) Dust/AB Ratio and Moisture Content. During production, the dust/AB ratio and the moisture content of the mixture at discharge from the mixer shall meet the following.

Parameter	All Mixtures
Dust/AB Ratio 1/	0.6 to 1.2
Moisture, max.	0.3 %

1/ Does not apply to SMA.

If at any time the dust/AB ratio or moisture content of the mixture falls outside the stated limits, production of the HMA shall cease. The cause shall be determined and corrective action satisfactory to the Engineer shall be initiated prior to resuming production.

(4) Additional HMA Samples. The Contractor shall, when necessary, take and test additional samples (designated "check" samples) at the plant during HMA production. These samples in no way replace the required plant samples described above. Check samples shall be tested only for the parameters deemed necessary by the Contractor. Check sample test results shall be noted in the Plant Diary but shall not be plotted on the control charts. The Contractor shall detail the situations in which check samples will be taken in the Annual QC Plan.

(b) Required Density Tests. The Contractor shall control the compaction process by testing the mix density at random locations as determined according to the document "Hot-Mix Asphalt QC/QA Procedure for Determining Random Density Locations", and recording the results on forms approved by the Engineer. The Contractor shall follow the density testing procedures detailed in the document "Illinois Modified ASTM D 2950, Standard Test Method for Density of Bituminous Concrete In-Place by Nuclear Method". When required, the Contractor shall be responsible for establishing the correlation to convert nuclear density results to core densities according to the document "Procedure for Correlating Nuclear Gauge Densities with Core Densities for Hot-Mix Asphalt". The Engineer may require a new nuclear/core correlation if the Contractor's gauge is recalibrated during the project.

(1) Paving. For paving, density tests shall be performed at randomly selected locations within 0.5 mile (800 m) intervals for each lift of 3 in. (75 mm) or less in thickness. For lifts in excess of 3 in. (75 mm) in thickness, a test shall be performed within 0.25 mile (400 m) intervals. In no case shall more than one-half day's production be completed without performing QC density testing.

Longitudinal joint density testing shall also be performed at each random density test location. Longitudinal joint testing shall be located at a distance equal to 4 in. (100 mm) from each pavement edge.

(a) Confined Edge. Each confined edge density shall be represented by a one-minute nuclear density reading or a core density and shall be included in the average of density readings or core densities taken across the mat which represent the Individual Test.

(b) Unconfined Edge. Each unconfined edge joint density shall be represented by an average of three one-minute nuclear density readings or a single core density at the given density test location and shall meet the density requirements specified in the Density Control Limits table below. The three one-minute nuclear density readings shall be spaced 10 ft (3 m) apart longitudinally along the unconfined pavement edge and centered at the random density test location.

Density testing will not be required on longitudinal joints treated with longitudinal joint sealant (LJS).

(2) Patching. For patching, density tests shall be performed each day on randomly identified patches following the document "Hot-Mix Asphalt QC/QA Procedure for Determining Random Density Locations". Density testing frequency shall be a minimum of one test per half day of production per mix.

(c) Control Limits. The AJMF values shall be plotted on the control charts within the following control limits.

CONTROL LIMITS						
Parameter	IL-19.0, IL-9.5, IL-9.5FG, IL-19.0L, IL-9.5L		SMA-12.5, SMA-9.5		IL-4.75	
	Individual Test	Moving Avg. of 4	Individual Test	Moving Avg. of 4	Individual Test	Moving Avg. of 4
% Passing: 1/						
1/2 in. (12.5 mm)	± 6 %	± 4 %	± 6 %	± 4 %		
3/8 in. (9.5mm)			± 4 %	± 3 %		
# 4 (4.75 mm)	± 5 %	± 4 %	± 5 %	± 4 %		
# 8 (2.36 mm)	± 5 %	± 3 %	± 4 %	± 2 %		
# 16 (1.18 mm)			± 4 %	± 2 %	± 4 %	± 3 %
# 30 (600 μm)	± 4 %	± 2.5 %	± 4 %	± 2.5 %		
Total Dust Content # 200 (75 μm)	± 1.5 %	± 1.0 %			± 1.5 %	± 1.0 %
Asphalt Binder Content	± 0.3 %	± 0.2 %	± 0.2 %	± 0.1 %	± 0.3 %	± 0.2 %
Air Voids	± 1.2 %	± 1.0 %	± 1.2 %	± 1.0 %	± 1.2 %	± 1.0 %
Field VMA 2/	-0.7 %	-0.5 %	-0.7 %	-0.5 %	-0.7 %	-0.5 %

1/ Based on washed ignition oven or solvent extraction gradation.

2/ Allowable limit below minimum design VMA requirement

DENSITY CONTROL LIMITS			
Mixture Composition	Ndesign	Individual Test (includes confined edges)	Unconfined Edge Joint Density, minimum
IL-4.75	50	93.0 – 97.4 %	91.0 %
IL-9.5FG	50 – 90	93.0 – 97.4 %	91.0 %
IL-9.5	90	92.0 – 96.0 %	90.0 %
IL-9.5, IL-9.5L,	< 90	92.5 – 97.4 %	90.0 %
IL-19.0	90	93.0 – 96.0 %	90.0 %
IL-19.0, IL-19.0L	< 90	93.0 [1/] – 97.4 %	90.0 %
SMA-9.5, SMA-12.5	50 or 80	93.5 – 97.4 %	91.0 %

1/ 92.0 percent when placed as first lift on an unimproved subgrade.

(d) Control Charts. Standardized control charts shall be maintained by the Contractor at the laboratory and shall be accessible at all times for review by the Engineer.

Control limits for each required parameter, both individual tests and the average of four tests, shall be plotted on control charts as described in the document "Hot-Mix Asphalt QC/QA Control Charts".

The results of individual required tests listed in Article 1030.09(c) obtained by the Contractor shall be recorded on the control chart immediately upon completion of a test, but no later than 24 hours after sampling. Only the required tests and resamples shall be recorded on the control chart.

Control Chart Requirements	All Mixtures
Gradation [1/ 3/]	% Passing Sieves: 1/2 in. (12.5 mm) [2/] # 4 (4.75 mm) # 8 (2.36 mm) # 30 (600 µm)
Total Dust Content [1]	# 200 (75 µm)
Volumetric	Asphalt Binder Content
	Bulk Specific Gravity
	Maximum Specific Gravity of Mixture
	Air Voids
	Density
	Field VMA

1/ Based on washed ignition oven or solvent extraction.

2/ Does not apply to IL-4.75.

3/ SMA also requires the 3/8 in. (9.5mm) sieve.

(e) Corrective Action for Required Mixture Tests.

(1) Individual Test Results. When an individual test result exceeds its control limit, the Contractor shall immediately resample and retest. If at the end of the day no material remains from which to resample, the first sample taken the following day shall serve as the resample as well as the first sample of the day. This result shall be recorded as a retest. If the retest passes, the Contractor may contine the required test frequency. Additional check samples should be taken to verify mix compliance.

a. If the retest for air voids, field VMA, or asphalt binder content exceeds control limits, HMA production shall cease and immediate corrective action shall be instituted by the Contractor. After corrective action, HMA production shall be restarted, the HMA production shall be stabilized, and the Contractor shall immediately resample and retest. The corrective action shall be documented.

b. Gradation. For gradation retest failures, immediate corrective action shall be instituted by the Contractor. After corrective action, the Contractor shall immediately resample and retest. The corrective action shall be documented.

(2) Moving Average. When the moving average values trend toward the moving average control limits, the Contractor shall take corrective action and increase the sampling and testing frequency. The corrective action shall be documented.

The Contractor shall notify the Engineer whenever the moving average values exceed the moving average control limits. If two consecutive moving average values fall outside the moving average control limits, the Contractor shall cease mixture production. Corrective action shall be immediately instituted by the Contractor. Mixture production shall not be reinstated without the approval of the Engineer.

(3) Dust Control. If the washed ignition oven or solvent extraction gradation test results indicate fluctuating dust, corrective action to control the dust shall be taken. If the Engineer determines that positive dust control equipment is necessary, the equipment as specified in Article 1102.01(c)(7) shall be installed prior to the next construction season.

(f) Corrective Action for Required Nuclear Density Tests. When an individual nuclear density test exceeds the control limits, the Contractor shall immediately retest in a location that is halfway between the failed test site and the finish roller. If the retest passes, the Contractor shall continue the normal density test frequency. An additional density check test should be performed to verify the mix compaction.

If the retest fails, the Contractor shall immediately conduct one of the following procedures.

(1) Low Density. If the failing density retest indicates low densities, the Contractor shall immediately increase the compaction effort, review all mixture test results representing the HMA being produced, and make corrective action as needed. The Contractor shall immediately perform a second density retest within the area representing the increased compaction effort and mixture adjustments.

(2) High Density. If the failing density retest indicates high densities, the Contractor shall cease production and placement until all mixture test results are reviewed and corrective action is taken. If the high density failure is a result of a change in the mixture, existing material in the surge bin may be subject to rejection by the Engineer. After restart of HMA production, a second density retest shall then be performed in the area representing the mixture adjustments.

If the second retest from either procedure passes, production and placement of the HMA may continue. The increased compaction effort for low density failures shall not be reduced to that originally being used unless it is determined by investigation that the cause of the low density was unrelated to compaction effort, the cause was corrected, and tests show the corrective action has increased the density within the required limits.

If the second retest fails, production and placement of the HMA shall cease until the Contractor has completed an investigation and the problem(s) causing the failing densities has/have been determined. If the Contractor's corrective action is approved by the Engineer, production and placement of the HMA may then be resumed. The Contractor shall increase the frequency of density testing to show, to the satisfaction of the Engineer, that the corrective action taken has corrected the density problem.

(g) Additional Contractor Duties.

"(1) The Contractor shall sample approximately 150 lb (70 kg) of mix as required for the Department's random mixture verification tests according to Article 1030.09(h)(1)."

(2) The Contractor shall complete split verification sample tests listed in the Limits of Precision table in Article 1030.09(h)(2).

(3) The Contractor shall provide personnel and equipment to collect density verification cores for the Engineer. Core locations will be determined by the Engineer following the document "Hot-Mix Asphalt QC/QA Procedure for Determining Random Density Locations" at density verification intervals defined in Article 1030.09(b). After the Engineer identifies a density verification location and prior to opening to traffic,

the Contractor shall cut a 4 in. (100 mm) diameter core. With the approval of the Engineer, the cores may be cut at a later time.

(h) Verification by the Engineer. The Engineer will observe the Contractor's quality control processes and complete testing of the test strip samples, identify random verification mixture sample locations, conduct mixture verification testing, identify random density verification locations, conduct density verification testing, and identify asphalt binder samples for testing.

(1) The Engineer will determine the random verification mixture sample locations according to the document "Hot-Mix Asphalt QC/QA Initial Daily Plant and Random Samples".

"The Engineer will randomly identify one sample for each 3,000 tons (2,720 metric tons) of mix, with a minimum of one sample per mix. If the remaining mix quantity is 600 tons (544 metric tons) or less, the quantity will be combined with the previous 3,000 tons (2,720 metric tons) in the Engineer's random sample identification. If the required tonnage of a mixture for a single pay item is less than 250 tons (225 metric tons) in total, the Engineer will waive mixture verification tests."

The Engineer will witness, secure and take possession of the verification mixture sample. Department mixture testing will be completed on asphalt binder content, bulk specific gravity, maximum specific gravity and field VMA. If an anti-strip additive was used in the mixture, the Department will also test for stripping according to Illinois Modified AASHTO T 283. If the mixture fails to meet the minimum tensile strength and TSR criteria as specified in Article 1030.05(d), no further mixture will be accepted until the Contractor takes such action as is necessary to furnish a mixture meeting the criteria.

Differences between the Contractor's and the Department's split verification sample test results will be considered acceptable if within the following limits.

Test Parameter	Limits of Precision
Asphalt Binder Content	0.3 %
Maximum Specific Gravity of Mixture	0.026
Bulk Specific Gravity	0.030
Field VMA	1.0 %

If comparison of the mixture verification test results are outside the above limits of precision, the Engineer will complete an investigation. The investigation may include review and observation of the Contractor's and the Department's technician performance, testing procedure, and equipment.

(2) After final rolling and prior to paving subsequent lifts, the Engineer will identify the random density verification test locations. Cores will be used for density verification for all paving greater than or equal to 3 ft (1 m) in width when the paving length exceeds 300 ft (90 m). The Engineer may utilize nuclear gauges for paving less than 3 ft (1 m) in width, for any paving 300 ft (90 m) or less in length, and for patches. Additional items or locations where nuclear gauges will be used will be shown in the plans.

Density verification test locations will be determined according to the document "Hot-Mix Asphalt QC/QA Procedure for Determining Random Density Locations". The density testing interval for paving wider than or equal to 3 ft (1 m) will be 0.5 miles (800 m) for lift thicknesses of 3 in. (75 mm) or less and 0.2 miles (320 m) for lift thicknesses greater than 3 in. (75 mm). The density testing interval for paving less than 3 ft (1 m) wide will be 1 mile (1,600 m). If a day's paving will be less than the prescribed density testing interval, the length of the day's paving will be the interval for that day. The density testing interval for mixtures used for patching will be 50 patches with a minimum of one test per mixture per project.

The Engineer will witness the Contractor coring, and secure and take possession of all density samples at the density verification locations. The Engineer will test the cores collected by the Contractor for density according to Illinois Modified AASHTO T 166 or AASHTO T 275.

"The HMA maximum theoretical specific gravity (G_{mm}) will be based on the Department mixture verification test. If there is more than one Department mixture verification G_{mm} test, the G_{mm} will be based on the average of the Department test results."

A density verification test will be the result of a single core or the average of the nuclear density tests at one location. The results of each density test must be within acceptable limits. The Engineer will promptly notify the Contractor of observed deficiencies.

(i) Acceptance by the Engineer. Final acceptance will be based on the following.

(1) Acceptable limits. To be considered acceptable, the Department's verification test results shall be within the following acceptable limits.

Parameter		Acceptable Limits
Field VMA		-1.0 – +3.0 % 1/
Air Voids		2.0 – 6.0 %
Density	IL-9.5, IL-19.0, IL-4.75, IL-9.5FG	90.0 – 98.0 %
	SMA 12.5, SMA 9.5	92.0 – 98.0 %
Dust / AB Ratio		0.4 – 1.6 2/

1/ Based on minimum required VMA as stated in the mix design volumetric requirements in Article 1030.05(b).

2/ Does not apply to SMA.

(2) The Contractor's process control charts and actions.

In addition, no visible pavement distress such as, but not limited to, segregation, excessive coarse aggegate fracturing, or flushing shall be present.

If any of the above is not met, the work will be considered in non-conformance with the contract.

(j) Documentation. The Contractor shall be responsible for maintaining the Annual QC Plan and QC Addendum.

The Contractor shall be responsible for documenting all observations, records of inspection, adjustments to the mixture, test results, retest results, and corrective actions in a bound hardback field book or bound hardback diary which will become the property of the Department.

The Contractor shall be responsible for the maintenance of all permanent records whether obtained by the Contractor, the Contractor's consultants, or the producer of the HMA.

The Contractor shall provide the Engineer full access to all documentation throughout the progress of the work.

Adjustments to mixture production and test results shall be recorded and sent to the Engineer on forms approved by the Engineer.

1030.10 Start of HMA Production and Job Mix Formula (JMF) Adjustments. The start of HMA production and JMF adjustments shall be as follows.

For each contract, a 300 ton (275 metric ton) test strip will be required at the beginning of HMA production for each mixture with a quantity of 3,000 tons (2,750 metric ton) or more according to the document "Hot-Mix Asphalt Test Strip Procedures".

An off-site preliminary test strip may be required for new mixture types according to the document "Off-Site Preliminary Test Strip Procedures for Hot-Mix Asphalt".

When a test strip is constructed, the Contractor shall collect and split the mixture according to the document "Hot-Mix Asphalt Test Strip Procedures". Within two working days after sampling the mixture placed in the test strip, the Contractor shall deliver prepared samples to the District laboratory for verification testing. The Contractor shall complete mixture tests stated in Article 1030.09(a). The Department will complete testing of loose mixture samples and gyratory cylinders provided by the Contractor. Mixture sampled shall include enough material for the Department to conduct mixture tests detailed in Article 1030.09(a) and in the document "Hot-Mix Asphalt Mixture Design Verification Procedure" Section 3.3. The mixture test results shall meet the requirements of Articles 1030.05(b) and 1030.05(d), except tensile strength and TSR testing will only be conducted on the first use of a mix design for the year and Hamburg wheel tests will only be conducted on High ESAL mixtures.

"When a test strip is not required, each HMA mixture with a quantity of 3,000 tons (2,750 metric tons) or more shall still be sampled on the first day of production: I-FIT and Hamburg wheel testing for High ESAL; I-FIT testing for Low ESAL. Within two working days after sampling the mixture, the Contractor shall deliver gyratory cylinders to the District laboratory for Department verification testing. The High ESAL mixture test results shall meet the requirements of Articles 1030.05(d)(3) and 1030.05(d)(4). The Low ESAL mixture test results shall meet the requirements of Article 1030.05(d)(4)."

If the test strip mixture fails to meet the requirements for tensile strength or TSR, a resample shall be provided by the Contractor to the Department. Failure of a resampled mixture test shall result in the Contractor stopping production. The Contractor shall take corrective action and re-submit for testing according to Article 1030.05(d), substitute an approved mix design, or submit a new mix design for mix verification testing according to Article 1030.05(d).

Based on the test results from the test strip, if any JMF adjustment or plant change is needed, the JMF shall become the Adjusted Job Mix Formula (AJMF). If an adjustment/plant change is made, the Engineer may require a new test strip to be constructed. Upon completion of the first acceptable test strip, the JMF shall become the AJMF regardless of whether or not the JMF has been adjusted.

If the HMA placed during the initial test strip is determined to be unacceptable to remain in place by the Engineer, it shall be removed and replaced. In no case shall the target for the amount passing be outside the mixture composition limits stated in Article 1030.05(a).

The limitations between the JMF and AJMF are as follows.

Parameter	High ESAL Adjustment	Low ESAL Adjustment
1/2 in. (12.5 mm)	± 5.0 %	± 6.0 %
# 4 (4.75 mm)	± 4.0 %	± 5.0 %
# 8 (2.36 mm)	± 3.0 %	
# 30 (600 µm)	1/	
# 200 (75 µm)	1/	± 2.5 %
Asphalt Binder Content	± 0.3 %	± 0.5 %

1/ In no case shall the target for the amount passing be greater than the JMF.

Adjustments outside the above limitations will require a new mix design.

Production is not required to stop after a growth curve has been constructed for PFP and QCP mixtures. For QC/QA mixtures, volumetric test results that are within Acceptable Limits shall be available to the Engineer before production may resume.

Upon notification by the Engineer of a failing Hamburg wheel or I-FIT test, the Contractor shall immediately resample and the Department will test. Paving may continue as long as all other mixture criteria is being met. If the second set of Hamburg wheel or I-FIT tests fail, no additional mixture shall be produced until the Engineer receives both passing Hamburg wheel and I-FIT tests.

During production, the Contractor and Engineer shall continue to evaluate test results and mixture laydown and compaction performance. Adjustments within the above requirements may be necessary to obtain the desired mixture properties. If an adjustment/plant change is made, the Engineer may request additional growth curves and supporting mixture tests.

1030.11 Preparation of Mixture for Cracks, Joints, and Flangeways. When the mixture is prepared in a batch-type mixing plant, the heated aggregate and the asphalt binder shall be measured separately and accurately by weight or by volume. The heated aggregate and asphalt binder shall be mixed in a pug mill mixer. When the aggregate is in the mixer, the asphalt binder shall be added and mixing continued until a homogeneous mixture is produced in which all particles of aggregate are coated uniformly. The mixing time will be determined by the Engineer.

When the mixture is prepared in a dryer drum plant, the heated aggregate and asphalt binder shall be accurately proportioned and mixed in the dryer drum plant.

For all types of plants, the ingredients shall be combined in such proportions as to produce a mixture according to the following composition limits by weight.

Mixture Composition	
Fine Aggregate (FA 1, FA 2 or FA 3)	93 - 96 %
Asphalt Binder (PG 58-28, PG 64-22)	6 - 9 %

With the permission of the Engineer, an approved cold-lay sand asphalt mixture may be used in lieu of the above mixture.

1030.12 Transportation. Vehicles used in transporting HMA shall have clean and tight beds. The beds shall be sprayed with asphalt release agents from the Department's qualified product list. In lieu of a release agent, the Contractor may use a light spray of water with a light scatter of manufactured sand (FA 20 or FA 21) evenly distributed over the bed of the vehicle. After spraying, the bed of the vehicle shall be in a completely raised position and it shall remain in this position until all excess asphalt release agent or water has been drained.

When the air temperature is below 60 °F (15 °C), the bed, including the end, endgate, sides and bottom shall be insulated with fiberboard, plywood, or other approved insulating material and shall have a thickness of not less than 3/4 in. (19 mm). When the insulation is placed inside the bed, the insulation shall be covered with sheet steel approved by the Engineer. Each vehicle shall be equipped with a cover of canvas or other suitable material meeting the approval of the Engineer which shall be used if any one of the following conditions is present.

(a) Ambient air temperature is below 60 °F (15 °C).

(b) The weather is inclement.

(c) The temperature of the HMA immediately behind the paver screed is below 250 °F (120 °C).

(d) The mixture being placed is SMA.

The cover shall extend down over the sides and ends of the bed for a distance of approximately 12 in. (300 mm) and shall be fastened securely. The covering shall be rolled back before the load is dumped.

SECTION 1031. RECLAIMED ASPHALT PAVEMENT AND RECLAIMED ASPHALT SHINGLES

1031.01 Description. Reclaimed asphalt pavement and reclaimed asphalt shingles shall be according to the following.

(a) Reclaimed Asphalt Pavement (RAP). RAP is the material produced by cold milling or crushing an existing hot-mix asphalt (HMA) pavement. The Contractor shall supply written documentation that the RAP originated from roadways or airfields under federal, state, or local agency jurisdiction.

(b) Reclaimed Asphalt Shingles (RAS). RAS is the material produced from the processing and grinding of preconsumer or post-consumer shingles. RAS shall be a clean and uniform material with a maximum of 0.5 percent unacceptable material by weight of RAS, as defined in Bureau of Materials Policy Memorandum, "Reclaimed Asphalt Shingle (RAS) Sources". RAS shall come from a facility source on the Department's "Qualified Producer List of Certified Sources for Reclaimed Asphalt Shingles" where it shall be ground and processed to 100 percent passing the 3/8 in. (9.5 mm) sieve and 93 percent passing the #4 (4.75 mm) sieve based on a dry shake gradation. RAS shall be uniform in gradation and asphalt binder content and shall meet the testing requirements specified herein. In addition, RAS shall meet the following Type 1 or Type 2 requirements.

(1) Type 1. Type 1 RAS shall be processed, preconsumer asphalt shingles salvaged from the manufacture of residential asphalt roofing shingles.

(2) Type 2. Type 2 RAS shall be processed post-consumer shingles only, salvaged from residential, or four unit or less dwellings not subject to the National Emission Standards for Hazardous Air Pollutants (NESHAP).

1031.02 Stockpiles. RAP and RAS stockpiles shall be according to the following.

(a) RAP Stockpiles. The Contractor shall construct individual RAP stockpiles meeting one of the following definitions. Stockpiles shall be sufficiently separated to prevent intermingling at the base. Stockpiles shall be identified by signs indicating the type as listed below (i.e. "Homogeneous Surface").

Prior to milling, the Contractor shall request the Department provide documentation on the quality of the RAP to clarify the appropriate stockpile.

(1) Fractionated RAP (FRAP). FRAP shall consist of RAP from Class I, HMA (High and Low ESAL) mixtures. The coarse aggregate in FRAP shall be crushed aggregate and may represent more than one aggregate type and/or quality, but shall be at least C quality. FRAP shall be fractionated prior to testing by screening into a minimum of two size fractions with the separation occurring on or between the No. 4 (4.75 mm) and 1/2 in. (12.5 mm) sieves. Agglomerations shall be minimized such that 100 percent of the RAP in the coarse fraction shall pass the maximum sieve size specified for the mixture composition of the mix design.

(2) Homogeneous. Homogeneous RAP stockpiles shall consist of RAP from Class I, HMA (High and Low ESAL) mixtures and represent: 1) the same aggregate quality, but shall be at least C quality; 2) the same type of crushed aggregate (either crushed natural aggregate, ACBF slag, or steel slag); 3) similar gradation; and 4) similar asphalt binder content. If approved by the Engineer, combined single pass surface/binder millings may be considered "homogeneous" with a quality rating dictated by the lowest coarse aggregate quality present in the mixture.

(3) Conglomerate. Conglomerate RAP stockpiles shall consist of RAP from Class I, HMA (High and Low ESAL) mixtures. The coarse aggregate in this RAP shall be crushed aggregate and may represent more than one

aggregate type and/or quality, but shall be at least C quality. This RAP may have an inconsistent gradation and/or asphalt binder content prior to processing. Conglomerate RAP shall be processed prior to testing by crushing to where all RAP shall pass the 5/8 in. (16 mm) or smaller screen. Conglomerate RAP stockpiles shall not contain steel slag.

(4) Conglomerate "D" Quality (Conglomerate DQ). Conglomerate DQ RAP stockpiles shall be according to Articles 1031.02(a)(1) through 1031.02(a)(3), except they may also consist of RAP from HMA shoulders, bituminous stabilized subbases, or HMA (High or Low ESAL) binder mixture. The coarse aggregate in this RAP may be crushed or round but shall be at least D quality. This RAP may have an inconsistent gradation and/or asphalt binder content.

(5) Non-Quality. RAP stockpiles that do not meet the requirements of the stockpile categories listed above shall be classified as "Non-Quality".

RAP/FRAP containing contaminants, such as earth, brick, sand, concrete, sheet asphalt, non-bituminous surface treatment (i.e. high friction surface treatments), pavement fabric, joint sealants, plant cleanout, etc., will be unacceptable unless the contaminants are removed to the satisfaction of the Engineer. Sheet asphalt shall be stockpiled separately.

(b) RAS Stockpiles. Type 1 and Type 2 RAS shall be stockpiled separately and shall not be intermingled. Each stockpile shall be signed indicating what type of RAS is present.

Unless otherwise specified by the Engineer, mechanically blending manufactured sand (FM 20 or FM 22) or fine FRAP up to an equal weight of RAS with the processed RAS will be permitted to improve workability. The sand shall be B quality or better from an approved Aggregate Gradation Control System source. The sand shall be accounted for in the mix design and during HMA production.

Records identifying the shingle processing facility supplying the RAS, RAS type, and lot number shall be maintained by project contract number and kept for a minimum of three years.

Additional processed RAP/FRAP/RAS shall be stockpiled in a separate working pile, as designated in the QC Plan, and only added to the original stockpile after the test results for the working pile are found to meet the requirements specified in Articles 1031.03 and 1031.04.

1031.03 Testing. RAP/FRAP and RAS testing shall be according to the following.

(a) RAP/FRAP Testing. When used in HMA, the RAP/FRAP shall be sampled and tested either during or after stockpiling.

(1) During Stockpiling. For testing during stockpiling, washed extraction samples shall be run at the minimum frequency of one sample per 500 tons (450 metric tons) for the first 2,000 tons (1,800 metric tons)

and one sample per 2,000 tons (1,800 metric tons) thereafter. A minimum of five tests shall be required for stockpiles less than 4,000 tons (3,600 metric tons).

(2) After Stockpiling. For testing after stockpiling, the Contractor shall submit a plan for approval to the Department proposing a satisfactory method of sampling and testing the RAP/FRAP pile either in-situ or by restockpiling. The sampling plan shall meet the minimum frequency required above and detail the procedure used to obtain representative samples throughout the pile for testing.

Each sample shall be split to obtain two equal samples of test sample size. One of the two test samples from the final split shall be labeled and stored for Department use. The Contractor shall perform a washed extraction on the other test sample according to Illinois Modified AASHTO T 164. The Engineer reserves the right to test any sample (split or Department-taken) to verify Contractor test results.

(b) RAS Testing. RAS or RAS blended with manufactured sand shall be sampled and tested during stockpiling according to the Bureau of Materials Policy Memorandum, "Reclaimed Asphalt Shingle (RAS) Source".

Samples shall be collected during stockpiling at the minimum frequency of one sample per 200 tons (180 metric tons) for the first 1,000 tons (900 metric tons) and one sample per 500 tons (450 metric tons) or a minimum of once per week, whichever is more frequent, thereafter. A minimum of five samples are required for stockpiles less than 1,000 tons (900 metric tons).

Before testing, each sample shall be split to obtain two test samples. One of the two test samples from the final split shall be labeled and stored for Department use. The Contractor shall perform a washed extraction and test for unacceptable materials on the other test sample according to Illinois Modified AASHTO T 164. The Engineer reserves the right to test any sample (split or Department-taken) to verify Contractor test results.

The Contractor shall obtain and make available all of the test results from the start of the original stockpile.

1031.04 Evaluation of Tests. Evaluation of test results shall be according to the following.

(a) Limits of Precision. The limits of precision between the Contractor's and the Department's split sample test results shall be according to the following.

Test Parameter	Limits of Precision		
% Passing	RAP	FRAP	RAS
1/2 in. (12.5 mm)	6.0 %	5.0 %	
# 4 (4.75 mm)	6.0 %	5.0 %	
# 8 (2.36 mm)	4.0 %	3.0 %	4.0 %
# 30 (600 µm)	3.0 %	2.0 %	4.0 %
# 200 (75 µm)	2.5 %	2.2 %	4.0 %
Asphalt Binder	0.4 %	0.3 %	3.0 %
G_{mm}	0.035	0.030	

If the test results are outside the above limits of precision, the Engineer will immediately investigate.

(b) Evaluation of RAP/FRAP Test Results. All of the extraction results shall be compiled and averaged for asphalt binder content and gradation, and when applicable G_{mm}. Individual extraction test results, when compared to the averages, will be accepted if within the tolerances listed below.

Parameter	FRAP/Homogeneous/ Conglomerate
1 in. (25 mm)	
1/2 in. (12.5 mm)	± 8 %
# 4 (4.75 mm)	± 6 %
# 8 (2.36 mm)	± 5 %
# 16 (1.18 mm)	
# 30 (600 µm)	± 5 %
# 200 (75 µm)	± 2.0 %
Asphalt Binder	± 0.4 % 1/
G_{mm}	± 0.03 2/

1/ The tolerance for FRAP shall be ± 0.3 percent.

2/ For stockpile with slag or steel slag present as determined in the Manual of Test Procedures Appendix B 21, "Determination of Aggregate Bulk (Dry) Specific Gravity (Gsb) of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)".

If more than 20 percent of the test results for an individual parameter (individual sieves, G_{mm}, and/or asphalt binder content) are out of the above tolerances, the RAP/FRAP shall not be used in HMA unless the RAP/FRAP representing the failing tests is removed from the stockpile. All test data and acceptance ranges shall be sent to the Department for evaluation.

With the approval of the Engineer, the ignition oven may be substituted for solvent extractions according to the document "Calibration of the Ignition

Oven for the Purpose of Characterizing Reclaimed Asphalt Pavement (RAP)".

(c) Evaluation of RAS and RAS Blended with Manufactured Sand or Fine FRAP Test Results. All of the test results, with the exception of percent unacceptable materials, shall be compiled and averaged for asphalt binder content and gradation. Individual test results, when compared to the averages, will be accepted if within the tolerances listed below.

Parameter	RAS
# 8 (2.36 mm)	± 5 %
# 16 (1.18 mm)	± 5 %
# 30 (600 µm)	± 4 %
# 200 (75 µm)	± 2.5 %
Asphalt Binder Content	± 2.0 %

If more than 20 percent of the test results for an individual parameter (individual sieves and/or asphalt binder content) are out of the above tolerances, or if the unacceptable material exceeds 0.5 percent by weight of material retained on the No. 4 (4.75 mm) sieve, the RAS or RAS blend shall not be used in Department projects. All test data and acceptance ranges shall be sent to the Department for evaluation.

1031.05 Quality Designation of Aggregate in RAP/FRAP.

(a) RAP. The aggregate quality of the RAP for homogeneous, conglomerate, and conglomerate DQ stockpiles shall be set by the lowest quality of coarse aggregate in the RAP stockpile. RAP originating from roadways under state jurisdiction shall be designated as follows.

Class B Quality	Class C Quality	Class D Quality
Class I Surface	Class I Binder	Bituminous Aggregate Mixture (BAM) Stabilized Subbase
HMA (High ESAL) Surface	HMA (High ESAL) Binder	
SMA	HMA (Low ESAL)	BAM Shoulder

(b) FRAP. If the Engineer has documentation of the quality of the FRAP aggregate, the Contractor shall use the assigned quality provided by the Engineer.

If the quality is not known, the quality shall be determined as follows. Coarse and fine FRAP stockpiles containing plus No. 4 (4.75 mm) sieve coarse aggregate shall have a maximum tonnage of 5,000 tons (4,500 metric tons). The Contractor shall obtain a representative sample witnessed by the Engineer. The sample shall be a minimum of 50 lb (25 kg). The sample shall be extracted according to Illinois Modified AASHTO T 164 by a consultant laboratory prequalified by the Department for the specified testing. The consultant laboratory shall submit the test results along with the recovered aggregate sample to the District Office. Consultant laboratory services will be at no additional cost to the Department. The District will forward the sample to the Central Bureau of Materials Aggregate Lab for MicroDeval Testing, according to Illinois Modified AASHTO T 327. A maximum loss of 15.0 percent will be applied for all HMA applications.

1031.06 Use of RAP/FRAP and/or RAS in HMA. The use of RAP/FRAP and/or RAS shall be the Contractor's option when constructing HMA in all contracts.

(a) RAP/FRAP. The use of RAP/FRAP in HMA shall be as follows.

(1) Coarse Aggregate Size. The coarse aggregate in all RAP shall be equal to or less than the nominal maximum size requirement for the HMA mixture to be produced.

(2) Steel Slag Stockpiles. Homogeneous RAP stockpiles containing steel slag will be approved for use in all HMA (High ESAL and Low ESAL) surface and binder mixture applications.

(3) Use in HMA Surface Mixtures (High and Low ESAL). RAP/FRAP stockpiles for use in HMA surface mixtures (High and Low ESAL) shall be FRAP or homogeneous in which the coarse aggregate is Class B quality or better. FRAP from conglomerate stockpiles shall be considered equivalent to limestone for frictional considerations. Known frictional contributions from plus No. 4 (4.75 mm) homogeneous FRAP stockpiles will be accounted for in meeting frictional requirements in the specified mixture.

(4) Use in HMA Binder Mixtures (High and Low ESAL), HMA Base Course, and HMA Base Course Widening. RAP/FRAP stockpiles for use in HMA binder mixtures (High and Low ESAL), HMA base course, and HMA base course widening shall be FRAP, homogeneous, or conglomerate, in which the coarse aggregate is Class C quality or better.

(5) Use in Shoulders and Subbase. RAP/FRAP stockpiles for use in HMA shoulders and stabilized subbase (HMA) shall be FRAP, homogeneous, or conglomerate.

(6) When the Contractor chooses the RAP option, the percentage of asphalt binder replacement (ABR) shall not exceed the amounts indicated in Article 1031.06(c)(1) below for a given Ndesign.

(b) RAS. RAS meeting Type 1 or Type 2 requirements will be permitted in all HMA applications as specified herein.

(c) RAP/FRAP and/or RAS Usage Limits. Type 1 or Type 2 RAS may be used alone or in conjunction with RAP or FRAP in HMA mixtures up to a maximum of 5.0 percent by weight of the total mix.

(1) RAP/RAS. When RAP is used alone or RAP is used in conjunction with RAS, the percentage of virgin ABR shall not exceed the amounts listed in the following table.

HMA Mixtures - RAP/RAS Maximum ABR % 1/ 2/			
Ndesign	Binder	Surface	Polymer Modified Binder or Surface
30	30	30	10
50	25	15	10
70	15	10	10
90	10	10	10

1/ For Low ESAL HMA shoulder and stabilized subbase, the RAP/RAS ABR shall not exceed 50 percent of the mixture.

2/ When RAP/RAS ABR exceeds 20 percent, the high and low virgin asphalt binder grades shall each be reduced by one grade (i.e. 25 percent ABR would require a virgin asphalt binder grade of PG 64-22 to be reduced to a PG 58-28).

(2) FRAP/RAS. When FRAP is used alone or FRAP is used in conjunction with RAS, the percentage of virgin asphalt binder replacement shall not exceed the amounts listed in the following table.

HMA Mixtures - FRAP/RAS Maximum ABR % 1/ 2/			
Ndesign	Binder	Surface	Polymer Modified Binder or Surface
30	55	45	15
50	45	40	15
70	45	35	15
90	45	35	15
SMA	- -	- -	25
IL-4.75	- -	- -	35

1/ For Low ESAL HMA shoulder and stabilized subbase, the FRAP/RAS ABR shall not exceed 50 percent of the mixture.

2/ When FRAP/RAS ABR exceeds 20 percent for all mixes, the high and low virgin asphalt binder grades shall each be reduced by one grade (i.e. 25 percent ABR would require a virgin asphalt binder grade of PG 64-22 to be reduced to a PG 58-28).

1031.07 HMA Mix Designs. At the Contractor's option, HMA mixtures may be constructed utilizing RAP/FRAP and/or RAS material meeting the detailed requirements specified herein.

(a) RAP/FRAP and/or RAS. RAP/FRAP and/or RAS mix designs shall be submitted for verification. If additional RAP/FRAP and/or RAS stockpiles are tested and found that no more than 20 percent of the individual parameter test results, as defined in Article 1031.04, are outside of the control tolerances set for the original RAP/FRAP and/or RAS stockpile and HMA mix design, and meets all of the requirements herein, the additional

RAP/FRAP and/or RAS stockpiles may be used in the original mix design at the percent previously verified.

(b) RAS. Type 1 and Type 2 RAS are not interchangeable in a mix design.

The RAP, FRAP, and RAS stone bulk specific gravities (G_{sb}) shall be according to the "Determination of Aggregate Bulk (Dry) Specific Gravity (G_{sb}) of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)" procedure in the Department's Manual of Test Procedures for Materials.

1031.08 HMA Production. HMA production utilizing RAP/FRAP and/or RAS shall be as follows.

To remove or reduce agglomerated material, a scalping screen, gator, crushing unit, or comparable sizing device approved by the Engineer shall be used in the RAP/FRAP and/or RAS feed system to remove or reduce oversized material.

If the RAP/FRAP and/or RAS control tolerances or HMA test results require corrective action, the Contractor shall cease production of the mixture containing RAP/FRAP and/or RAS and either switch to the virgin aggregate design or submit a new mix design.

(a) RAP/FRAP. The coarse aggregate in all RAP/FRAP used shall be equal to or less than the nominal maximum size requirement for the HMA mixture being produced.

(b) RAS. RAS shall be incorporated into the HMA mixture either by a separate weight depletion system or by using the RAP weigh belt. Either feed system shall be interlocked with the aggregate feed or weigh system to maintain correct proportions for all rates of production and batch sizes. The portion of RAS shall be controlled accurately to within ± 0.5 percent of the amount of RAS utilized. When using the weight depletion system, flow indicators or sensing devices shall be provided and interlocked with the plant controls such that the mixture production is halted when RAS flow is interrupted.

(c) RAP/FRAP and/or RAS. HMA plants utilizing RAP/FRAP and/or RAS shall be capable of automatically recording and printing the following information.

(1) Dryer Drum Plants.

a. Date, month, year, and time to the nearest minute for each print.

b. HMA mix number assigned by the Department.

c. Accumulated weight of dry aggregate (combined or individual) in tons (metric tons) to the nearest 0.1 ton (0.1 metric ton).

d. Accumulated dry weight of RAP/FRAP/RAS in tons (metric tons) to the nearest 0.1 ton (0.1 metric ton).

e. Accumulated mineral filler in revolutions, tons (metric tons), etc. to the nearest 0.1 unit.

f. Accumulated asphalt binder in gallons (liters), tons (metric tons), etc. to the nearest 0.1 unit.

g. Residual asphalt binder in the RAP/FRAP/RAS material as a percent of the total mix to the nearest 0.1 percent.

h. Aggregate and RAP/FRAP/RAS moisture compensators in percent as set on the control panel. (Required when accumulated or individual aggregate and RAP/FRAP/RAS are recorded in a wet condition.)

i. A positive dust control system shall be utilized when the combined contribution of reclaimed material passing the No. 200 sieve exceeds 1.5 percent.

(2) Batch Plants.

a. Date, month, year, and time to the nearest minute for each print.

b. HMA mix number assigned by the Department.

c. Individual virgin aggregate hot bin batch weights to the nearest pound (kilogram).

d. Mineral filler weight to the nearest pound (kilogram).

e. RAP/FRAP/RAS weight to the nearest pound (kilogram).

f. Virgin asphalt binder weight to the nearest pound (kilogram).

g. Residual asphalt binder in the RAP/FRAP/RAS material as a percent of the total mix to the nearest 0.1 percent.

The printouts shall be maintained in a file at the plant for a minimum of one year or as directed by the Engineer and shall be made available upon request. The printing system will be inspected by the Engineer prior to production and verified at the beginning of each construction season thereafter.

1031.09 RAP in Aggregate Applications. RAP in aggregate applications shall be according to the Bureau of Materials Policy Memorandum, "Reclaimed Asphalt Pavement (RAP) for Aggregate Applications" and the following.

(a) RAP in Aggregate Surface Course and Aggregate Wedge Shoulders, Type B. The use of RAP in aggregate surface course (temporary access entrances only) and aggregate wedge shoulders, Type B shall be as follows.

(1) Stockpiles and Testing. RAP stockpiles may be any of those listed in Article 1031.02, except "Non-Quality" and "FRAP". The testing requirements of Article 1031.03 shall not apply.

(2) Gradation. One hundred percent of the RAP material shall pass the 1 1/2 in. (37.5 mm) sieve. The RAP material shall be reasonably well graded from coarse to fine. RAP material that is gap-graded or single sized will not be accepted.

SECTION 1032. BITUMINOUS MATERIALS

1032.01 Description. Bituminous materials shall include asphalt binders, emulsified asphalts, rapid curing liquid asphalt, medium curing liquid asphalts, slow curing liquid asphalts, asphalt fillers, and road oils. All bituminous materials used in a given construction shall be prepared from petroleum and be uniform in character, appearance, and consistency.

1032.02 Measurement. Asphalt binders, emulsified asphalts, rapid curing liquid asphalts, medium curing liquid asphalts, slow curing liquid asphalts, asphalt fillers, and road oils will be measured by weight.

A weight ticket for each truck load shall be furnished to the Engineer. The truck shall be weighed at a location approved by the Engineer. The ticket shall show the weight of the empty truck (the truck being weighed each time before it is loaded), the weight of the loaded truck, and the net weight of the bituminous material.

When an emulsion or cutback is used for prime or tack coat, the percentage of asphalt residue of the actual certified product shall be shown on the producer's bill of lading or attached certificate of analysis. If the producer adds extra water to an emulsion at the request of the purchaser, the amount of water shall also be shown on the bill of lading.

Payment will not be made for bituminous materials in excess of 105 percent of the amount specified by the Engineer.

1032.03 Delivery. When bituminous materials are not approved at their source by the Department, they shall be delivered far enough in advance of their use to permit the necessary tests to be made. When not delivered in tank cars or tank trucks, the bituminous materials shall be delivered in suitable containers or packages, plainly labeled to show the kind of material, the name of manufacturer, and the lot or batch number. Each shipment and each carload shall be kept separate until the material has been accepted.

Asphalt binder, when delivered in tank cars or tank trucks, shall be delivered at a temperature not to exceed 350 °F (175 °C).

Petroleum asphalts PAF-1 and PAF-2 shall be shipped in new, double end, metal drums. The thickness of the metal used shall not be less than 0.0149 in. (0.4 mm). The side seams of the drums shall be double lapped, spot welded single lapped, or stitch welded single lapped. The seams shall meet the approval of the Engineer. The drums shall be manufactured so that there will be no leakage during hot weather. The capacity of each drum shall be approximately 460 lb (210 kg), the drums being 35 in. (890 mm) maximum in height and approximately 22 in. (560 mm) in diameter.

Petroleum asphalts PAF-3 and PAF-4 shall be shipped in new, open end, metal drums. The thickness of the metal used shall be not less than the 0.0149 in. (0.4 mm). The seams shall be constructed so that the filled drums will withstand shipping and handling. The inside of the drums shall be coated with talc or other approved material to facilitate peeling. The capacity of each drum shall be approximately 460 lb (210 kg), the drums being 35 in. (890 mm) maximum in height and approximately 22 in. (560 mm) in diameter. Petroleum asphalts PAF-3 and PAF-4 may, when specified, be shipped in approved 100 lb (45 kg) cartons.

1032.04 Spraying Application. The spraying application temperature ranges for bituminous material applied by a pressure distributor shall be according to the following table.

Spraying Application Temperature Ranges		
Type and Grade of Bituminous Material	Temperature Ranges	
	°F min. - max.	°C min. - max.
PEP	60 - 130	15 - 55
MC-30, E-2	85 - 190	30 - 90
MC-70, RC-70, SC-70, E-3	120 - 225	50 - 105
MC-250, SC-250, E-4	165 - 270	75 - 130
MC-800, SC-800	200 - 305	95 - 150
MC-3000, SC-3000	230 - 345	110 - 175
PG 46-28	275 - 350	135 - 175
PG 52-28, PG 58-22, PG 58-28, PG 64-22	285 - 350	140 - 175
RS-1, CRS-1	75 - 130	25 - 55
RS-2, CRS-2	110 - 160	45 - 70
NTEA	160 - 180	70 - 80
SS-1, SS-1h, CSS-1, CSS-1h SS-1hP, CSS-1hP	75 - 130	25 - 55
HFE-90, HFE-150, HFE-300 HFRS-2P, CRS-2P, HFRS-2	150 - 180	65 - 80
LJS, FLS	265 - 330	130 - 165

1032.05 Performance Graded Asphalt Binder. These materials will be accepted according to the Bureau of Materials Policy Memorandum, "Performance Graded Asphalt Binder Qualification Procedure." The Department will maintain a qualified producer list. These materials shall be free from water and shall not foam when heated to any temperature below the actual flash point.

When requested, producers shall provide the Engineer with viscosity/temperature relationships for the performance graded asphalt binders delivered and incorporated in the work.

(a) Performance Graded (PG) Asphalt Binder. The asphalt binder shall meet the requirements of AASHTO M 320, Table 1 "Standard Specification for Performance Graded Asphalt Binder" for the grade shown on the plans. Air blown asphalt will not be allowed.

(b) Polymer Modified Performance Graded (PG) Asphalt Binder. The asphalt binder shall meet the requirements of AASHTO M 320, Table 1 "Standard Specification for Performance Graded Asphalt Binder" for the grade shown on the plans. Elastomers shall be added to the base asphalt binder to achieve the specified performance grade and shall be either a styrene-butadiene diblock or triblock copolymer without oil extension, or a styrene-butadiene rubber. Air blown asphalts, acid modification, and other modifiers will not be allowed. Asphalt modification at hot-mix asphalt plants will not be allowed. The modified asphalt binder shall be smooth, homogeneous, and be according to the requirements shown in Table 1 or 2 for the grade shown on the plans.

Table 1 - Requirements for Styrene-Butadiene Copolymer (SB/SBS) Modified Asphalt Binders

Test	Asphalt Grade SB/SBS PG 64-28 SB/SBS PG 70-22 SB/SBS PG 70-28	Asphalt Grade SB/SBS PG 76-22 SB/SBS PG 76-28
Separation of Polymer ITP, "Separation of Polymer from Asphalt Binder" Difference in °F (°C) of the softening point between top and bottom portions.	4 (2) max.	4 (2) max.
Force Ratio AASHTO T 300, f_2/f_1 1/	0.30 min.	0.35 min.
TESTS ON RESIDUE FROM ROLLING THIN FILM OVEN TEST (AASHTO T 240)		
Elastic Recovery ASTM D 6084, Procedure A, 77 °F (25 °C), 100 mm elongation, %	60 min.	70 min. 2/

1/ Shall have a minimum elongation of 300 mm prior to rupture.

2/ When SBS/SBR PG 76-22 or SBS/SBR PG 76-28 is specified for mixture IL-4.75, the elastic recovery shall be a minimum of 80.

Table 2 - Requirements for Styrene-Butadiene Rubber (SBR) Modified Asphalt Binders		
Test	Asphalt Grade SBR PG 64-28 SBR PG 70-22 SBR PG 70-28	Asphalt Grade SBR PG 76-22 SBR PG 76-28
Separation of Polymer ITP, "Separation of Polymer from Asphalt Binder" Difference in °F (°C) of the softening point between top and bottom portions.	4 (2) max.	4 (2) max.
Toughness ASTM D 5801, 77 °F (25 °C), 20 in./min. (500 mm/min.), in.-lbs (N-m).	110 (12.5) min.	110 (12.5) min.
Tenacity ASTM D 5801, 77 °F (25 °C), 20 in./min. (500 mm/min.), in.-lbs (N-m).	75 (8.5) min.	75 (8.5) min.
TESTS ON RESIDUE FROM ROLLING THIN FILM OVEN TEST (AASHTO T 240)		
Elastic Recovery ASTM D 6084, Procedure A, 77 °F (25 °C), 100 mm elongation, %	40 min.	50 min.

Note. When SBS/SBR PG 76-22 or SBS/SBR PG 76-28 is specified for mixture IL-4.75, the elastic recovery shall be a minimum of 80.

The following grades may be specified as tack coats.

Asphalt Grade	Use
PG 58-22, PG 58-28, PG 64-22	Tack Coat

1032.06 Emulsified Asphalts. Emulsified asphalts will be accepted according to the Bureau of Materials Policy Memorandum, "Emulsified Asphalt Qualification Procedure." The Department will maintain a qualified producer list. These materials shall be homogeneous and shall show no separation of asphalt after thorough mixing, within 30 days after delivery, provided separation has not been caused by freezing. The emulsified asphalts shall coat the aggregate to the satisfaction of the Engineer and be according to the following requirements.

(a) Anionic Emulsified Asphalt. Anionic emulsified asphalts shall be according to AASHTO M 140, except as follows.

(1) The cement mixing test will be waived when the emulsion is being used as a tack coat.

(2) The Solubility in Trichloroethylene test according to AASHTO T 44 may be run in lieu of Ash Content and shall meet a minimum of 97.5 percent.

(b) Cationic Emulsified Asphalt. Cationic emulsified asphalts shall be according to AASHTO M 208, except as follows.

(1) The cement mixing test will be waived when the emulsion is being used as a tack coat or slurry seal.

(2) The Solubility in Trichloroethylene test according to AASHTO T 44 may be run in lieu of Ash Content and shall meet a minimum of 97.5 percent.

(c) High Float Emulsion. High float emulsions are medium setting and shall be according to the following table.

Test	HFE-90	HFE-150	HFE-300
Viscosity, Saybolt Furol, at 122 °F (50 °C), (AASHTO T 59), SFS [1/]	50 min.	50 min.	50 min.
Sieve Test, retained on No. 20 (850 µm) sieve, (AASHTO T 59), %	0.10 max.	0.10 max.	0.10 max.
Storage Stability Test, 1 day, (AASHTO T 59), %	1 max.	1 max.	1 max.
Coating Test (All Grades), (AASHTO T 59), 3 minutes	stone coated thoroughly		
Distillation Test, (AASHTO T 59): Residue from distillation test to 500 °F (260 °C), % Oil distillate by volume, %	65 min. 7 max.	65 min. 7 max.	65 min. 7 max.
Characteristics of residue from distillation test to 500 °F (260 °C): Penetration at 77 °F (25 °C), (AASHTO T 49), 100 g, 5 sec, dmm	90-150	150-300	300 min.
Float Test at 140 °F (60 °C), (AASHTO T 50), sec.	1200 min.	1200 min.	1200 min.

1/ The emulsion shall be pumpable.

(d) Penetrating Emulsified Prime (PEP). The PEP shall be according to the following.

Test (AASHTO T 59)	Result
Viscosity, Saybolt Furol, at 77 °F (25 °C), SFS	75 max.
Sieve test, retained on No. 20 (850 µm) sieve, %	0.10 max.
Distillation to 500 °F (260 °C) residue, %	38 min.
Oil distillate by volume, %	4 max.

The PEP shall be tested according to the Bureau of Materials Illinois Laboratory Test Procedure (ILTP), "Sand Penetration Test of Penetrating Emulsified Prime (PEP)". The time of penetration shall be equal to or less than that of MC-30. The depth of penetration shall be equal to or greater than that of MC-30.

(e) Polymer-Modified Emulsified Asphalt. Polymer-modified emulsified asphalts shall be according to AASHTO M 316, except as follows.

(1) The cement mixing test will be waived when the polymer-modified emulsion is being used as a tack coat.

(2) CQS-1hP (formerly CSS-1h Latex Modified) emulsion for micro-surfacing treatments shall use latex as the modifier.

(3) Upon examination of the storage stability test cylinder after standing undisturbed for 24 hours, the surface shall show minimal to no white, milky colored substance and shall be a homogenous brown color throughout.

(4) The distillation for all polymer-modified emulsions shall be performed according to AASHTO T 59, except the temperature shall be 374 ± 9 °F (190 ± 5 °C) to be held for a period of 15 minutes and measured using an ASTM 16F (16C) thermometer.

(5) The specified temperature for the Elastic Recovery test for all polymer-modified emulsions shall be 50.0 ± 1.0 °F (10.0 ± 0.5 °C).

(6) The Solubility in Trichloroethylene test according to AASHTO T 44 may be run in lieu of Ash Content and shall meet a minimum of 97.5 percent.

(f) Non-Tracking Emulsified Asphalt. Non-Tracking Emulsified Asphalt (NTEA) shall be according to the following.

Test	Requirement
Saybolt Viscosity at 77 °F (25 °C), (AASHTO T 59), SFS	20-100
Storage Stability Test, 24 hr, (AASHTO T 59), %	1 max.
Residue by Distillation, 500 ± 10 °F (260 ± 5 °C), or Residue by Evaporation, 325 ± 5 °F (163 ± 3 °C), (AASHTO T 59), %	50 min.
Sieve Test, No. 20 (850 µm), (AASHTO T 59), %	0.3 max.
Tests on Residue from Distillation/Evaporation	
Penetration at 77 °F (25 °C), 100 g, 5 sec, (AASHTO T 49), dmm	40 max.
Softening Point, (AASHTO T 53), °F (°C)	135 (57) min.
Ash Content, (AASHTO T 111), % [1/]	1 max.

1/ The Solubility in Trichloroethylene test according to AASHTO T 44 may be run in lieu of Ash Content and shall meet a minimum of 97.5 percent.

The different grades are, in general, used for the following.

Grade	Use
SS-1, SS-1h, RS-1, RS-2, CSS-1, CRS-1, CRS-2, CSS-1h, HFE-90, SS-1hP, CSS-1hP, NTEA	Tack coat or fog seal
PEP	Prime coat
RS-2, HFE-90, HFE-150, HFE-300, CRS-2P, HFRS-2P, CRS-2, HFRS-2	Bituminous surface treatment
CQS-1hP	Micro-surfacing
CQS-1h	Slurry sealing
CRS-2P, HFRS-2P	Cape seal

1032.07 Rapid Curing Liquid Asphalt. Rapid curing liquid asphalt will be accepted according to the Bureau of Materials Policy Memorandum, "Cutback Asphalt and Road Oil Qualification Procedure." The Department will maintain a qualified producer list. These materials shall be a rapid curing cutback asphalt consisting of a petroleum residuum fluxed with a suitable distillate. The liquid asphalt shall be free from water, show no separation on standing, and shall be according to the requirements listed in the following table.

Test	Grade RC-70
Viscosity, Kinematic, at 140 °F (60 °C), (AASHTO T 201), cSt (mm^2/s)	70 to 140
Distillation Test: (AASHTO T 78)	
Distillate, percent by volume of total distillate to 680 °F (360 °C)	
Distillate to 374 °F (190 °C)	10 min.
Distillate to 437 °F (225 °C)	50 min.
Distillate to 500 °F (260 °C)	70 min.
Distillate to 600 °F (315 °C)	85 min.
Residue from distillation to 680 °F (360 °C), percent volume by difference	55 min.
Tests on residue from distillation:	
Penetration, 77 °F (25 °C), 100 g, 5 sec, (AASHTO T 49), dmm	80 to 120
Ductility at 77 °F (25 °C), (AASHTO T 51), mm[1/]	1000 min.
Solubility in trichloroethylene, (AASHTO T 44), %	99.5 min.

1/ If ductility is less than 1000 mm at 77 °F (25 °C), the material will be acceptable if the ductility is more than 1000 mm at 60 °F (15 °C).

The grade is, in general, used for the following.

Grade	Use
RC-70	Tack coat and soil curing

1032.08 Medium Curing Liquid Asphalts. Medium curing liquid asphalts will be accepted according to the Bureau of Materials Policy Memorandum, "Cutback Asphalt and Road Oil Qualification Procedure". The Department will maintain a qualified producer list. These materials shall be medium curing cutback asphalts consisting of a petroleum residuum fluxed with a suitable distillate. They shall be free from water, show no separation on standing, and shall be according to the requirements listed in the following table.

Test	Grades				
	MC-30	MC-70	MC-250	MC-800	MC-3000
Flash Point, (Tag open cup), (AASHTO T 79), °F (°C) 1/	100 min. (38 min.)	100 min. (38 min.)	-- --	-- --	-- --
Flash Point, (Cleveland open cup), (AASHTO T 48), °F (°C)	-- --	-- --	150 min. (65 min.)	150 min. (65 min.)	150 min. (65 min.)
Viscosity, Kinematic, at 140 °F (60 °C), (AASHTO T 201), cSt (mm^2/s)	30 to 60	70 to 140	250 to 500	800 to 1600	3000 to 6000
Distillation Test (AASHTO T 78): Distillate, % by volume of total distillate to 680 °F (360 °C): Distillate to 437 °F (225 °C) Distillate to 500 °F (260 °C) Distillate to 600 °F (315 °C) Residue from distillation to 680 °F (360 °C), % volume by difference	 25 max. 40 to 70 75 to 93 50 min.	 20 max. 20 to 60 70 to 90 55 min.	 10 max. 15 to 55 60 to 87 67 min.	 -- 35 max. 45 to 80 75 min.	 -- 15 max. 15 to 75 80 min.
Tests on residue from distillation: Penetration at 77 °F (25 °C), 100 g, 5 sec, (AASHTO T 49), dmm Ductility at 77 °F (25 °C), (AASHTO T 51), mm 2/ Solubility in trichloroethylene, (AASHTO T 44), %	 120 to 250 1000 min. 99.5 min.	 120 to 250 1000 min. 99.5 min.	 120 to 250 1000 min. 99.5 min.	 120 to 250 1000 min. 99.5 min.	 120 to 250 1000 min. 99.5 min.

1/ Flash point by Cleveland open cup may be used for products having a flash point above 175 °F (80 °C).

2/ If ductility is less than 1000 mm at 77 °F (25 °C), the material will be acceptable if the ductility is more than 1000 mm at 60 °F (15 °C).

The different grades are, in general, used for the following.

Grade	Use
MC-30	Prime coats
MC-70	Soil curing
MC-250, MC-800, MC-3000	Surface treatments and seal coats

1032.09 Slow Curing Liquid Asphalts. Slow curing liquid asphalts will be accepted according to the Bureau of Materials Policy Memorandum, "Cutback Asphalt and Road Oil Qualification Procedure." The Department will maintain a qualified producer list. These materials shall be slow curing liquid asphalts produced by the distillation of petroleum. The liquid asphalts shall be residues, distillates, or residues fluxed to the desired consistency with petroleum distillates. Each shipment of liquid asphalt shall be uniform in appearance and consistency. All grades shall be free from water and shall not foam when heated to 225 °F (107 °C). The residues of specified penetration shall be smooth and homogeneous in appearance. This material shall be according to the requirements listed in the following table.

Test	Grades			
	SC-70	SC-250	SC-800	SC-3000
Flash Point, Cleveland open cup, (AASHTO T 48), °F (°C)	150 min. (65 min.)	175 min. (80 min.)	200 min. (93 min.)	225 min. (107 min.)
Viscosity, Kinematic, at 140 °F (60 °C), (AASHTO T 201), cSt (mm^2/s)	70 to 140	250 to 500	800 to 1600	3000 to 6000
Residue of 100 penetration, (ASTM D 243), %	50 min.	60 min.	70 min.	80 min.
Ductility at 77 °F (25 °C), of residue of specified penetration, (AASHTO T 51), mm 1/	1000 min	1000 min	1000 min	1000 min.
Loss on heating at 325 °F (163 °C), 50 g, 5 hours, (ASTM D 6/D 6M), %	11 max.	8 max.	5 max.	4 max.
Solubility in trichloroethylene, (AASHTO T 44), %	99.0 min.	99.0 min.	99.0 min.	99.0 min.

1/ If ductility is less than 1000 mm at 77 °F (25 °C), the material will be acceptable if the ductility is more than 1000 mm at 60 °F (15 °C).

The different grades are, in general, used for the following.

Grade	Use
SC-70	For dust layer and for prime coats
SC-250	For road mix and traveling plant mix surfaces dense-graded aggregate type
SC-800	For plant mix surfaces dense-graded aggregate type
SC-3000	Surface treatments and seal coats

1032.10 Road Oils. Road oils will be accepted according to the Bureau of Materials Policy Memorandum, "Cutback Asphalt and Road Oil Qualification Procedure." The Department will maintain a qualified producer list. These materials shall be slow curing asphaltic oils. They shall show no separation on standing and shall be according to the requirements listed in the following table.

Test	Grades		
	E-2 Light	E-3 Medium	E-4 Heavy
Water, by volume, percent	0.5 max.	0.5 max.	0.5 max.
Flash Point, Cleveland open cup, (AASHTO T 48) °F (°C)	200 min. (93 min.)	200 min. (93 min.)	200 min. (93 min.)
Viscosity, Kinematic, at 122 °F (50 °C), (AASHTO T 201), cSt (mm^2/sec),	168 to 285	285 to 510	510 to 785
Viscosity, Saybolt Furol, at 122 °F (50 °C), (AASHTO T 59), SFS	80 to 135	135 to 240	240 to 370
Solubility in trichloroethylene, (AASHTO T 44), %	99.5 min.	99.5 min.	99.5 min.
Residue of 100 penetration, ASTM D 243, %	50 min.	55 min.	60 min.
Ductility at 77 °F (25 °C), (AASHTO T 51), of residue of specified penetration, mm	1000 min.	1000 min.	1000 min.

The different grades are used for surface treatment of earth roads.

1032.11 Asphalt Fillers (Prepared from Petroleum). These materials shall be free from water and shall not foam when heated to the flash point. They shall be according to the requirements listed in the following table.

Test	Grades			
	PAF-1	PAF-2	PAF-3	PAF-4
Flash Point, Cleveland open cup, (AASHTO T 48), °F (°C)	450 min. (232 min.)	450 min. (232 min.)	450 min. (232 min.)	475 min. (246 min.)
Softening Point, ring and ball method, (AASHTO T 53), °F (°C)	122 min. (50 min.)	135 min. (57 min.)	167 to 185 (75 to 85)	180 min. (82 min.)
Penetration at 32 °F (0 °C), 200g, 60 sec	30 min.	15 min.	10 min.	15 min.
Penetration at 77 °F (25 °C), (AASHTO T 49), 100g, 5 sec	80 to 100	40 to 55	25 to 40	30 to 50
Penetration at 115 °F (46.1 °C), 50g, 5 sec	--	190 max.	90 max.	80 max.
Loss on heating at 325 °F (163 °C), 50 g, 5 hrs., (ASTM D 6/D 6M), %	1.0 max.	1.0 max.	1.0 max.	1.0 max.
Penetration at 77 °F (25 °C), 100 g, 5 sec, of asphalt after heating at 325 °F (163 °C), as compared with penetration of asphalt before heating, %	70.0 min.	70.0 min.	70.0 min.	70.0 min.
Ductility at 77 °F (25 °C), (AASHTO T 51), mm	400 min.	150 min.	25 min.	25 min.
Bitumen soluble in trichloroethylene, (AASHTO T 44), %	99.0 min.	99.0 min.	99.0 min.	99.0 min.

The different grades are, in general, used for the following.

PAF-1 & PAF-2	For filling cracks in portland cement concrete pavement.
PAF-3	For sealing expansion and contraction joints in portland cement concrete pavement and for undersealing portland cement concrete pavement.
PAF-4	For sealing expansion and contraction joints in portland cement concrete pavement and for filler in brick pavement.

1032.12 Longitudinal Joint Sealant (LJS). Longitudinal joint sealant (LJS) in the form of spray applied liquid or pre-formed roll will be accepted according to the Bureau of Materials Policy Memorandum, "Performance Graded Asphalt Binder Qualification Procedure". The Department will maintain a qualified producer list. The bituminous material used for the LJS shall be according to the following table. Elastomers shall be added to a base asphalt and shall be either a styrene-butadiene diblock or triblock copolymer without oil extension, or a styrene-butadiene rubber. Air blown asphalt, acid modification, or other modifiers will not be allowed.

Test	Test Requirement	Test Method
Dynamic shear @ 88°C (unaged), G*/sin δ, kPa	1.00 min.	AASHTO T 315
Creep stiffness @ -18°C (unaged), Stiffness (S), MPa m-value	300 max. 0.300 min.	AASHTO T 313
Ash Content, %	1.0 – 4.0 1/	AASHTO T 111
Elastic Recovery, 100 mm elongation, cut immediately, 25°C, % 2/	70 min.	ASTM D 6084 (Procedure A)
Separation of Polymer, Difference in °C of the softening point (ring and ball) 2/	3 max.	ILTP "Separation of Polymer from Asphalt Binder"

1/ For LJS in a pre-formed roll, the ash content shall be a maximum of 20 percent.

2/ For LJS in a pre-formed roll, this test shall be waived.

1032.13 Full Lane Sealant (FLS). Full lane sealant (FLS) will be accepted according to the Bureau of Materials Policy Memorandum, "Performance Graded Asphalt Binder Qualification Procedure". The Department will maintain a qualified producer list. The bituminous material used for the FLS shall be according to Article 1032.12, except fillers shall not be added and the ash content test shall be waived.

SECTION 1033. TEMPORARY RUBBER AND TEMPORARY PLASTIC RAMPS

1033.01 Temporary Rubber Ramps. For butt joints, temporary rubber ramp material shall be according to the following.

Property	Test Method	Requirement
Durometer Hardness, Shore A	ASTM D 2240	80 ±10
Tensile Strength, psi (kPa)	ASTM D 412	800 (5500) min.
Elongation, %	ASTM D 412	100 min.
Specific Gravity	ASTM D 297	1.1 - 1.3
Brittleness, °F (°C)	ASTM D 746	-40 (-40)

HMA

SPECIFICATION

GUIDELINES

TABLE OF CONTENTS

I. Introduction

HMA, Hot Mix Asphalt Design, using Illinois Modified Strategic Highway Research Program(SHRP) superpavecriteria, is a system which was developed for specifying asphalt materials. It represents a basis for specifying component materials, asphalt mixture design and analysis, and pavement performance prediction.

Generically, it is an improvement to previous mixture design because HMA Mixture designs the asphalt mixture for a specific location, climate, and traffic.

The HMA 2022 Specification Guidelines have been developed to help explain HMA's purpose and basic components to the designer. Although the guidelines may list all of the available options allowed in HMA, the Materials Engineer should always be consulted for the determination of each aspect of the HMA criteria.

These guidelines are found in the January 1, 2022 edition of the Standard Specifications for Road and Bridge Construction, Article 1030.

previously resurfaced with HMA, the surface may be milled to correct profile irregularities and use the remaining existing HMA overlay as the interlayer. If the pavement is bare PCC, an interlayer shall be placed as a bond breaker.

Pavements that have high severity structural distresses (e.g., frequent, high severity transverse cracking) are suited for this treatment to reduce the potential for reflective cracking in the overlay.

This treatment has had limited use and is still considered experimental. The district must work with the Bureau of Research to design the PCC thickness, interlayer type and thickness, and joint spacing for the SCO.

Use of the SCO requires an experimental feature according to Construction Memo 02-2 and approval by the Bureau of Research. Contact the Engineer of Pavement Technology in the Bureau of Research for additional information on use and design of this treatment.

53-4.04 HMA Design Guidelines

These guidelines apply to all HMA construction.

53-4.04(a) Minimum HMA Lift Thickness

The mixture gradations and lift thicknesses shall be selected from Figure 53-4.J.

Mixture Gradation	Type of Lift	Minimum Compacted Lift Thickness (in.)
IL 4.75	Binder only	0.75 – Over HMA Surface 1.00 – Over PCC Surface
IL-9.5FG	Surface or Binder	1.25
IL-9.5, IL-9.5L	Surface or Binder	1.50
SMA-9.5	Surface or Binder	1.50
SMA 12.5	Surface or Binder	2.00
IL-19.0, IL 19.0L	Binder only	2.25

LIFT THICKNESS REQUIREMENTS FOR HMA OVERLAYS

Figure 53-4.J

53-4.04(b) HMA Mixture Requirements Table

Figure 53-4.K was designed to accommodate HMA mixtures and is required to be completed and inserted into the General Notes of the project plans for each HMA mixture application specified.

The following HMA mixture requirements are applicable for this project:

Location(s):	
Mixture Use(s):	
PG:	
Design Air Voids:	
Mixture Composition:	
Friction Aggregate:	
Mixture Weight:	
Quality Management Program:	
Sublot Size:	
Material Transfer Device (Required?)	

HMA MIXTURE REQUIREMENTS TABLE

Figure 53-4.K

Use the following guidelines to complete the table in Figure 53-4.K:

1. Location(s). Specify, by route number or stationing, the location(s) where the mix will be placed.

2. Mixture Use(s). Corresponds to the generic description of the mixture(s) (i.e., surface course, binder, base course, shoulders, etc.). On full-depth projects, specify the lift (e.g., "full-depth, lower binder," "full-depth, top binder," or "full-depth, surface").

3. PG. Specify the Performance-Graded (PG) binder for the mixture, including polymer modified asphalt binder (e.g., PG64-28, SBS-PG64-28, PG70-22, SBS-PG70-22). The PG binder grade shall be specified without consideration of RAP and/or RAS addition. Obtain the required PG binder designation from the District Materials Engineer.

4. Design Air Voids. Specify the target air void content for the mixture. For example, "4.0% @ N_{design} = 50", "4.0% @ N_{design} = 70", etc. All HMA mixtures will typically require 4.0% air voids; however, the N_{design} number will change. Obtain the N_{design} number from the District Materials Engineer.

5. Mixture Composition. Specify the aggregate gradation for the mixture design:

   - IL-19.0 – binder.
   - IL-19.0L – low volume binder.
   - IL-9.5 – surface or binder.
   - IL-9.5L – low volume surface.
   - IL-9.5FG – fine-graded surface or binder.

|

- IL-4.75 – binder.
- SMA-12.5 – surface or binder.
- SMA-9.5 – surface or binder.

6. Friction Aggregate. Specify the aggregate to be used to meet surface course friction requirements (i.e., Mixture C, Mixture D, Mixture E, Mixture F). Because there are no friction requirements for binder courses, leave this entry blank when specifying binder courses. Refer to Section 53-4.04(f) for additional information.

7. Mixture Weight. Specify the unit weight used to determine the plan quantities for HMA surface course. Use 112.0 lb/sq yd/in. thickness as the unit weight for typical standard mixes using natural aggregate. For a specialty mix design, such as those using synthetic aggregates with differing unit weights (e.g., air-cooled blast furnace slag (light) or steel slag (heavy)), the designer should consult the District Materials Engineer to determine the anticipated unit weight.

8. Quality Management Program. Specify which quality management program will be used for each mixture use listed in Item 2 above. If the same mixture has two QMPs, each QMP should be in separate columns in the mixture requirements table. Options include: Pay-For-Performance (PFP), Quality Control for Performance (QCP), and Quality Control/Quality Assurance (QC/QA).

    a. PFP. PFP utilizes pay adjustments based upon percent within limits statistical calculations. PFP should be specified for interstate, freeway and expressway resurfacing; and full-depth pavement projects having a minimum quantity of 8,000 tons per mix. PFP may also be considered for smaller projects where a more accurate measure of quality is desired. PFP should not be used on:

        - incidental surfacing (e.g., driveways, entrances, minor sideroads, and side road returns);
        - temporary pavements;
        - shoulders, unless they are used as auxiliary lanes;
        - patching;
        - turn lanes less than 500 ft in length; or
        - shared-use paths or bike lanes unless paved with the mainline pavement.

    b. QCP. QCP utilizes step-based pay adjustments and should be specified for:

        - mainline mixture quantities between 1,200 and 8,000 tons; or
        - shoulder applications that are greater than 8 feet wide and having quantities of 1,200 tons and greater.

        QCP should not be used on:

        - incidental surfacing (e.g., driveways, entrances, minor sideroads, and side road returns);
        - temporary pavements;

- patching;
- turn lanes less than 500 ft in length; or
- shared-use paths or bike lanes unless paved with the mainline pavement.

c. QC/QA. The use of QC/QA is limited to:

- mixtures with quantities less than 1,200 tons,
- shoulders placed with a road widener, and
- patching or incidental surfacing (e.g., entrances, minor sideroads).

9. Sublot Size. The sublot size for QCP and PFP will typically be 1,000 tons. On rare occasions, the sublot size may be reduced to lower the payment risk for smaller tonnage projects. Sublot size is not applicable when the QC/QA quality management program is used.

10. Material Transfer Device (MTD). Indicate whether or not the use of an MTD is required by placing either a "Yes" or a "No" in the box. MTDs are required for interstate HMA resurfacing and full-depth HMA contracts. For full-depth HMA contracts, an MTD is used for constructing all lifts of the pavement. MTDs may also be required in other types of HMA paving at the district's discretion.

53-4.04(c) ESAL Calculation

Use Section 54-2.01(c) and Section 54-5.01(g) to calculate ESALs for the design lane. To select the PG binder and design compactive effort (N_{design}), the ESAL value, equivalent to the Traffic Factor (TF), is calculated according to the equations in Figure 54-5.B. Use a Design Period (DP) of 20 years. In this application, the calculation is purely to determine the mixture design parameters; actual pavement/thickness design may require a different design period and/or TF calculation. Minimum structural design traffic levels should be ignored for mixture design purposes.

It is recommended that each district designate a single individual to coordinate ESAL calculations. In instances where major routes cross district borders, it is recommended that the ESAL counts be confirmed between districts.

53-4.04(d) Design Compactive Effort

The design compactive effort is expressed as an N_{design} number, which is selected based on the estimated 20-year ESAL loading of the traffic lane.

Figure 53-4.L lists the design compactive effort (N_{design}) required for the different levels of traffic loading and describes the typical roadway application. Consult the District Materials Engineer for the appropriate N_{design} value.

Design ESALs (millions) (20-yr. Design)	N_{ini}[1]	N_{des}	N_{max}[1]	Typical Roadway Application
< 0.3	5	30	42	Roadways with very light traffic volume such as local roads, county roads, and city streets where truck traffic is prohibited or at a very minimal level. (Considered local in nature; not regional, intrastate, or interstate.) Special purpose roadways serving recreational sites or areas may also be applicable.
0.3 to 3	6	50	74	Includes many collector roads or access streets. Medium-trafficked city streets and the majority of county roadways.
3 to 10	7	70	107	Includes many two-lane, multi-lane, divided, and partially or completely controlled access roadways. Among these are medium-to-highly trafficked streets, many state routes, US highways, and some rural Interstates.
> 10	8	90	141	Includes Interstates, both urban and rural in nature. Special applications such as truck-weighing stations or truck-climbing lanes on two-lane roadways may also be applicable to this level. May also include the class of roadways in the row above which have a high amount of truck traffic.

[1] N_{ini} and N_{max} are for informational purposes only. It is recommended the air voids at N_{ini} be greater than 11% to avoid mix tenderness. Also, air voids at N_{max} should be greater than 2% to prevent premature rutting.

DESIGN COMPACTIVE EFFORT FOR VARIOUS TRAFFIC CONDITIONS

Figure 53-4.L

53-4.04(e) Asphalt Binder Selection

Selection of Performance-Graded (PG) binders is based on temperature and traffic conditions. Figure 53-4.M lists the appropriate PG binders for use with all HMA mixtures. Consider the following when selecting the asphalt binder:

1. Polymer Modified PG Binders. Where polymer modifiers are required, designate “SBS” in front of the PG binder requirements in the General Notes table. The following grades of asphalt binder must be polymer modified: PG 64-28, PG 70-22, PG70-28, PG76-22, and PG76-28.

2. Overlays of PCC or Composite Pavements. Overlays of PCC or composite pavements should use the grades shown in Figure 53-4.M for a standard traffic level. Adjustments to this grade are dependent upon conditions such as slow moving traffic, high ESALs, or standing traffic. These modifications should be made for the corresponding N_{design} number and/or ESAL number. The appropriate asphalt binder grade should then be reported on the General Notes table of the plans.

3. Full-Depth HMA Pavements or Overlays of Full-Depth HMA Pavements. Full-depth HMA pavements or overlays of full-depth HMA pavements should be designed using the PG binders shown in Figure 53-4.M. The appropriate binder grade should be reported on the General Notes table of the project plans.

53-4.04(f) Friction Aggregate

An HMA surface course must be specified for each rehabilitation/resurfacing project. Section 11-2.02(f) gives safety analysis procedures to determine risks contributing to substantive safety problems.

Before the appropriate mix is selected, determine whether or not pavement surface friction is contributing to a substantive safety problem at the site. Presence of "wet pavement" crashes alone is not sufficient, as other risks related to wet weather may be present. For example, inadequate warning signage or visibility of stop or maneuver areas, unexpected geometric conditions, rutting, lack of surface drainage, inadequate pavement cross slope, or excess spray from vehicle tires may be more important than surface friction for locations of wet pavement crashes. Review of crash reports including narratives and sketches, site reviews during wet conditions, and surface friction testing should be included in an analysis of wet pavement crashes. Pavement friction testing may be requested according to the Bureau of Research Pavement Technology Advisory-"Testing Pavement Friction" (PTA-T3), http://idot.illinois.gov/Assets/uploads/files/Transportation-System/Research/Pavement-Technology-Advisories/Testing-and-Data-Collection-Series/PTAT3.pdf.

If the segment demonstrates a pattern of wet pavement crashes, identification of the risks contributing to the crash pattern will help to indicate the appropriate countermeasures, possibly including improved positive guidance, geometric changes, surface to full-depth repairs of rutting, improved drainage or cross slope, or improved surface texture (pavement grooving) or resurfacing with appropriate friction aggregate.

Type of HMA Pavement	Layer	Illinois N_{design} Number	Design ESALs[1] (million)	PG Binder Grade[2][3]		
				Traffic Loading Rate		
				Standard[4]	Slow[5] or High ESALs[6]	Standing[7]
IL-4.75	Surface[8] and Binder	50	≤ 10	SBS PG 70-22	SBS PG 70-22	SBS PG 70-22
			> 10	SBS PG 76-22	SBS PG 76-22	SBS PG 76-22
SMA Overlay of PCC or Composite Pavement	Surface and Binder	50	≤ 10	SBS PG 76-22	SBS PG 76-22	SBS PG 76-22
		80	> 10	SBS PG 76-22	SBS PG 76-22	SBS PG 76-22
SMA for Full-Depth Pavement and Overlays of Full-Depth Pavement	Surface and Binder	50	≤ 10	SBS PG 76-28	SBS PG 76-28	SBS PG 76-28
		80	> 10	SBS PG 76-28	SBS PG 76-28	SBS PG 76-28
Overlay of PCC or Composite Pavement	Surface or Binder	30	≤ 0.3	PG 58-22	PG 64-22	PG 64-22
		50	> 0.3 to 3	PG 64-22	SBS PG 70-22	SBS PG 76-22
		70	> 3 to 10	PG 64-22	SBS PG 70-22	SBS PG 76-22
		90	> 10	SBS PG 70-22	SBS PG 70-22	SBS PG 76-22
Districts 1-6 Full-Depth Pavement and Overlays of Full-Depth Pavement	Surface and Top Binder	All	All Levels	SBS PG 64-28[9]	SBS PG 70-28	SBS PG 76-28
	Lower Binder	All	All Levels	PG 64-22	PG 64-22	PG 64-22
Districts 7-9 Full-Depth Pavement and Overlays of Full-Depth Pavement	Surface and Top Binder	All	All Levels	PG 64-22[9]	SBS PG 70-22	SBS PG 76-22
	Lower Binder	All	All Levels	PG 64-22	PG 64-22	PG 64-22

PG BINDER GRADE SELECTION - ALL APPLICATIONS

Figure 53-4.M (1 of 2)

1. *Design ESALs are the anticipated project traffic level expected on the design lane over a 20-year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years and choose the appropriate N_{design} level.*
2. *The binder grade provided in the table is based on the recommendations given in Illinois-Modified AASHTO M 323, Table 1, "Binder Selection on the Basis of Traffic Speed and Traffic Level."*
3. *Consider increasing the high temperature grade by one grade and/or use polymer modified binder within 2,500 ft upstream of the exit terminal stub to 2,500 ft downstream of the entrance stub at weigh stations.*
4. *Standard Traffic - where the average traffic speed is greater than 43 mph.*
5. *Slow Traffic - where the average traffic speed ranges from 12 mph to 43 mph.*
6. *High ESALs – where ESALs are > 30 million.*
7. *Standing Traffic - where the average traffic speed is less than 12 mph.*
8. *For pavements with a posted speed limit ≤ 30 mph.*
9. *Consider increasing the high temperature grade by one grade for ESALs 10 to 30 million.*

PG BINDER GRADE SELECTION - ALL APPLICATIONS

Figure 53-4.M (2 of 2)

It is not desirable to specify short, closely spaced segments of special high-quality friction mixes (i.e., patchwork surfacing). If a higher-quality friction mix treatment is required at more than one location on a project and the distance between locations is less than 1,000 ft, the gaps should also be treated with the higher-quality mix. Also, if the special treatment is required on more than 50 percent of the project, it should be used throughout the entire project.

Four surface course mixtures have been developed that will provide adequate skid resistance for various Average Daily Traffic (ADT) levels: Mixtures C, D, E, and F. Figure 53-4.N designates the ADT levels allowable for each of the surface course mixtures.

It is expected that the application of friction aggregate according to Figure 53-4.N will address most pavement friction needs. However, some conditions create friction demands exceeding typical conditions anticipated by this tabulation. Examples include locations where problem identification shows a pattern of wet pavement related crashes and one of the following conditions:

- on grades exceeding 3.5%;
- locations with a heavy commercial vehicle (HCV) volume (Single Units plus Multiple Units) exceeding 400 per day and equal to 25% or more of the total ADT (Note – 25% HCV represents about 15% of State System mileage);
- locations that are shadowed or otherwise tend to remain wet for an extended time compared to typical locations; or
- other sites where similar friction demands or pavement conditions exist. At such locations, the Mixture designation may be increased by one step (e.g., from Mixture D to Mixture E).

Number of Lanes in Both Directions	Frictional Requirements (ADT)			
	Mixture C	Mixture D	Mixture E	Mixture F
≤ 2	≤ 5,000	> 5,000	N/A	N/A
4	≤ 5,000	5,001 to 25,000	25,001 to 100,000	> 100,000
≥ 6	N/A	5,001 to 60,000	60,001 to 100,000	> 100,000

Note: ADT levels are for the expected year of construction.

FRICTIONAL REQUIREMENTS FOR SURFACE MIXTURES

Figure 53-4.N

53-4.04(g) Longtidudinal Joint Sealant

Longitudinal Joint Sealant improves the performance of centerline and lane-to-lane joints of full-depth HMA pavements and HMA overlays. The specific lifts of HMA that will receive the sealant must be identified on the plans.

- Full-Depth HMA Pavements – under the surface lift and under the top binder lift
- Two-Lift Interstate HMA overlays – under both the surface and binder lifts
- Two-Lift Non-interstate HMA overlays – under the surface lift
- Single-Lift HMA Overlays – under the surface lift.

PG Binder Grade Selection[1]			
Districts 1 – 4	Traffic Loading Rate (Adjustment)		
	Standard [2]	Slow [3]	Standing [4]
Surface[5]	PG 58-28	PG 64-28 or SBS PG 64-28	SBS PG 70-28
Remaining Lifts[5]	PG 64-22 or PG 58-22	PG 64-22 or PG 58-22	PG 64-22 or PG 58-22
Districts 5 – 9			
Surface[5]	PG 64-22	PG 70-22 or SBS PG 70-22	SBS PG 76-22
Remaining Lifts[5]	PG 64-22	PG 64-22	PG 64-22

Notes:

1. *The binder grades provided in Figure 44-3B are based on the recommendations given in Illinois-Modified AASHTO MP-2, Table 1, "Binder Selection on the Basis of Traffic Speed and Traffic Level."*
2. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*
3. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*
4. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*
5. *Surface includes the top 2 in. (50 mm) of HMA. The remaining lifts of HMA may be the same PG binder grade as surface; however, this may increase or decrease the pavement design thickness. If multiple PG Binder grades are used in a HMA design, the predominant PG Binder grade should be used for determining HMA Modulus on Figure 44-3E.*

PG BINDER GRADE SELECTION FOR CONVENTIONAL FLEXIBLE PAVEMENTS

Figure 44-3B

Road Class	Minimum Reliability Level	Reliability (%)
Class I, II, III, and IV	Medium	~75%

Note: The estimated percent reliability is based on a representative 9-kip Falling Weight Deflectometer surface deflection coefficient of 25%.

RELIABILITY LEVEL (TF $\leq$ 0.5)

Figure 44-3C

Illinois N_{design} Number	Flexible Design ESALs, millions(1) (Flexible TF)	PG Binder Grade Selection(2)(3) Traffic Loading Rate (Adjustment)		
		Standard(4)	Slow(5)	Standing(6)
30	< 0.3	PG 58-22	PG 58-22(7)	PG 64-22(7)
50	0.3 to < 3	PG 58-22	PG 64-22	PG 70-22 or SBS PG 70-22
70	3 to < 10	PG 58-22	PG 64-22	PG 70-22 or SBS PG 70-22
90	10 to < 30	PG 58-22(7)	PG 64-22(7)	PG 70-22 or SBS PG 70-22

Notes:

1. *Design ESALs are the anticipated project traffic level expected on the design lane over a 20 year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years and choose the appropriate N_{design} level. For N_{design} and PG binder grade selection purposes only, the design ESALs are calculated using the flexible traffic factor equations given in Figure 44-5E. Rigid traffic factors given in Figure 44-5A thru Figure 44-5C are required to determine the PCC slab thickness portion of the composite pavement design.*
2. *The binder grades provided in Figure 44-5F are based on the recommendations given in Illinois-Modified AASHTO MP-2, Table 1, "Binder Selection on the Basis of Traffic Speed and Traffic Level".*
3. *Use these grades for composite pavements and all overlays.*
4. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*
5. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*
6. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*
7. *Consideration should be given to increasing the high temperature grade by one grade equivalent.*

PG BINDER GRADE SELECTION FOR COMPOSITE PAVEMENTS (DISTRICTS 1-4)

Figure 44-5F

Illinois N_{design} Number	Flexible Design ESALs, millions (1) (Flexible T.F.)	PG Binder Grade Selection (2)(3)		
		Traffic Loading Rate (Adjustment)		
		Standard(4)	Slow(5)	Standing(6)
30	< 0.3	PG 58-22	PG 64-22(7)	PG 64-22(7)
50	0.3 to < 3	PG 64-22	PG 64-22(7)	PG 70-22 or SBS PG 70-22
70	3 to < 10	PG 64-22	PG 70-22 or SBS PG 70-22	SBS PG 76-22
90	10 to < 30	PG 64-22(7)	PG 70-22 or SBS PG 70-22	SBS PG 76-22

Notes:

1. *Design ESALs are the anticipated project traffic level expected on the design lane over a 20 year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years and choose the appropriate N_{design} level. For N_{design} and PG binder grade selection purposes only, the design ESALs are calculated using the flexible traffic factor equations given in Figure 44-5E. Rigid traffic factors given in Figure 44-5A thru Figure 44-5C are required to determine the PCC slab thickness portion of the composite pavement design.*
2. *The binder grades provided in Figure 44-5F are based on the recommendations given in Illinois-Modified AASHTO MP-2, Table 1, "Binder Selection on the Basis of Traffic Speed and Traffic Level."*
3. *Use these grades for composite pavements and all overlays.*
4. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*
5. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*
6. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*
7. *Consideration should be given to increasing the high temperature grade by one grade equivalent.*

PG BINDER GRADE SELECTION FOR COMPOSITE PAVEMENTS (DISTRICTS 5-9)

Figure 44-5G

This Page Is Reserved

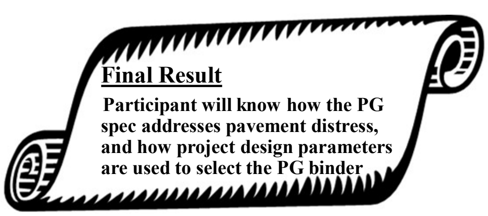
HMA Performance Graded Binders

Performance Based Asphalt Selection primarily based on Traffic, Climate and Pavement Structure

Superpave Binder Specification and Selection

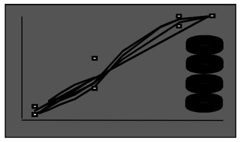
- **Section Objectives**
  - **Describe how the PG spec addresses pavement distress**
  - **Explain the PG binder selection process**
  - **Provide the various PG grade selections**

Superpave Binder Specification and Selection

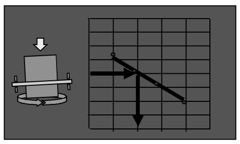


4 Steps of Superpave Mix Design

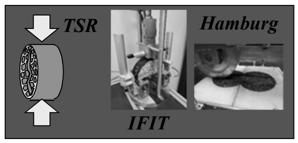
1. Materials Selection



2. Design Aggregate Structure



3. Design Binder Content



4. Performance Tests

Performance Grades

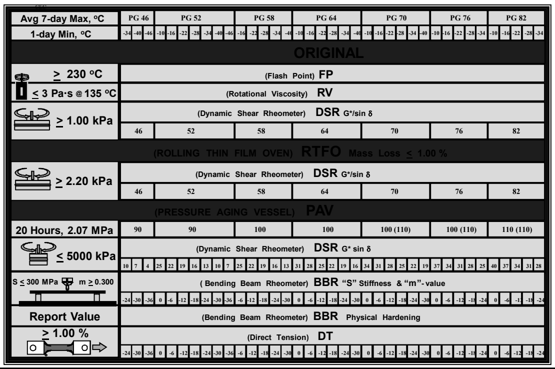
- The PG binder grade numbers describe the pavement temperatures (ºC) for which the binder was designed.
- First number is the average 7-day
- maximum pavement temperature (e.g.64ºC).
- Second number is the minimum 1-daypavement temperature (e.g.-22ºC).

Performance Grades

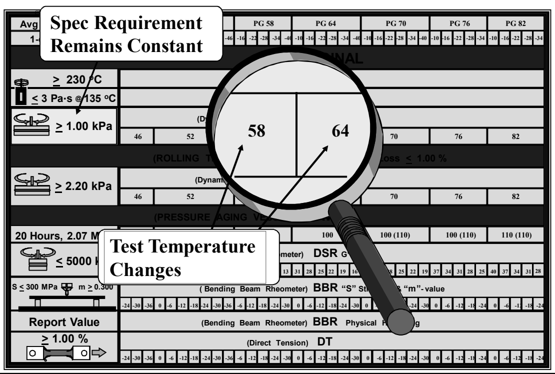
- Proper pronunciation is 64 minus 22.
- Grades are separated by increments of 6ºC.
- Formulas are used to convert measured air temperatures to pavement temperatures.
- Binder will be specified by IDOT for state projects.

Performance Grades

▪http://www.asphaltinstitute.org/laboratory/testing-services/asphalt-binder-specification-tests/

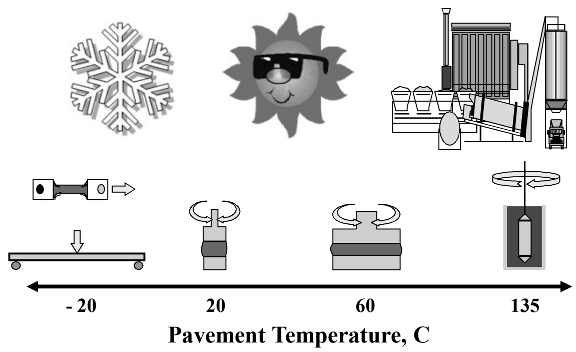


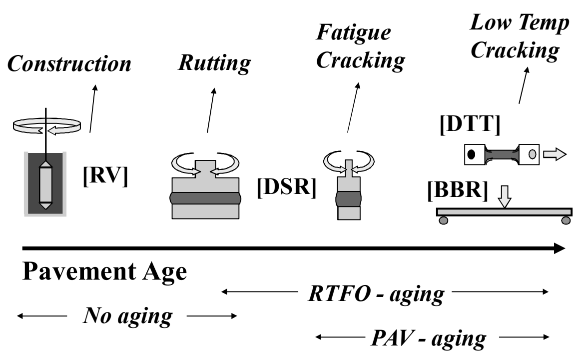
How the PG Spec Works



Performance Grades

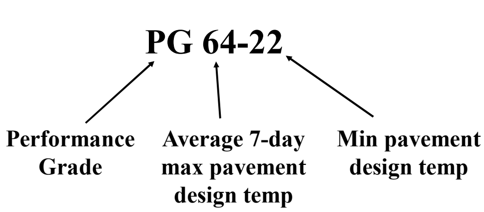
- The binder specification criteria remain constant, while the testing temperature varies.
- Typically for asphalt testing, the test temperature has remained constant while the test requirement has been varied (e.g. AC-10 vs. AC-20).





Superpave Asphalt Binder Specification

- Grading System Based on Climate



Is a PG a Modified Binder ?

Effect of Loading Rate

Reliability

"Rule of 90"

PG 64 - 34 > 64 - - 34 = 98

Probably modified !!

(Depends on Asphalt Source!)

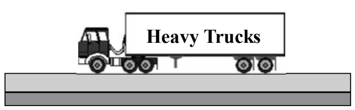
Rounding

Effect of Traffic

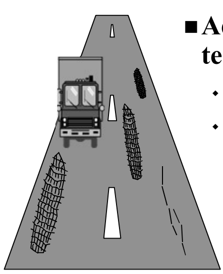
Permanent Deformation

- **Addressed by high temperature stiffness**
  - **unaged binder**
  - **RTFO aged binder**

> ***Early part of pavement service life***



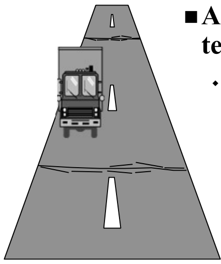
Fatigue Cracking



- **Addressed by intermediate temperature stiffness**
  - **RTFO aged binder**
  - **PAV aged binder**

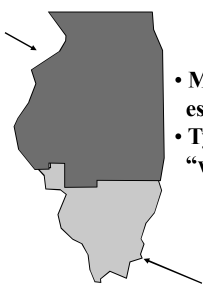
> ***Later part of pavement service life***

Low Temperature Cracking



- Addressed by low temperature elasticity
  - PAV aged binder

> *Later part of pavement service life*

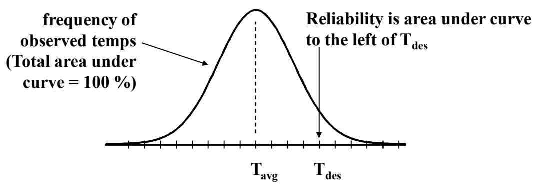


- Most agencies have established binder zones.
- Typically two to three "workhorse" grades exist.

- District will determine the grade required
- The "Break" is typically District 1 – 6 and Districts 7 - 9

Reliability

- Percent Probability of Not Exceeding Design Temp
  - > using Normal Distribution



•An important issue concerning binder selection is the question of what reliability should be used.

•A normal distribution is used to describe the range of temperatures at a site. The mean temperature is 50% reliability (half higher, half lower).

•The standard deviation relates to the width of the "bell".

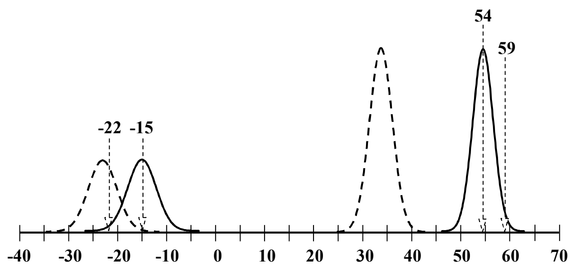
•An important issue concerning binder selection is the question of what reliability should be used.

•A normal distribution is used to describe the range of temperatures at a site. The mean temperature is 50% reliability (half higher, half lower).

•The standard deviation relates to the width of the "bell".

Calculated Pavement Temperatures

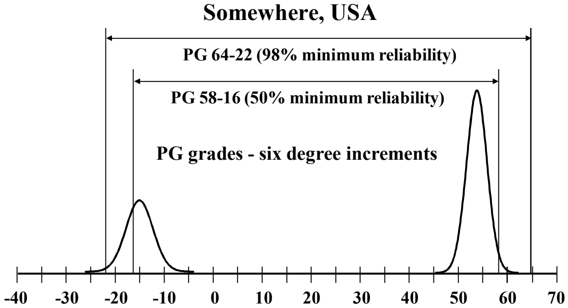
Somewhere, USA



- Air temperatures are converted to pavement temperatures to determine the PG grading.
- In this case, the high pavement temperatures are shifted about 20°C higher than the air temperatures. Low temperatures are shifted about 7°C higher.
- Different pavement depths can yield different PG grades.

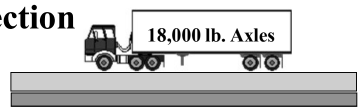
PG Binder Grades

Somewhere, USA



- Because the PG spec is set up in 6 degree increments, when you specify a minimum reliability, you may actually be getting more reliability because you round up (conservatively).
- For example, the 50% minimum lines do not pass through the peaks (means) of the curves.
- A PG 54-15 does not exist, so a PG 58-16 is selected.
- You can select different reliabilities, depending on distress concerns (rutting vs. cracking).
- Reliability choice can greatly affect asphalt cost.

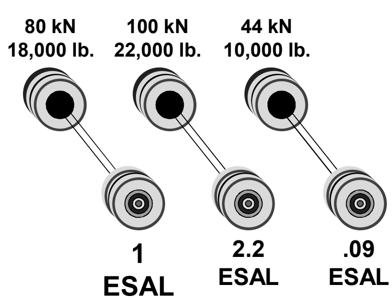
Effect of Traffic Amount on Binder Selection



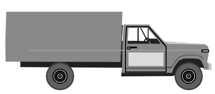
- Heavier truck traffic (more ESALs)
  - Increase the high temp grade, to help against rutting

> Equivalent Single Axle Loads

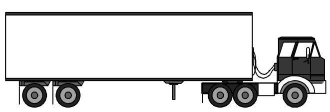
ESAL Comparison



- The term ESAL was developed at the AASHO Road Test in the early 1960's and is used to equate all types of vehicle weights and their relationship to pavement damage.
- The relationship between axle load and ESAL is not linear (actually about the 4^{th} power of load).
- A slight change in axle load makes a large impact on the number of ESAL.



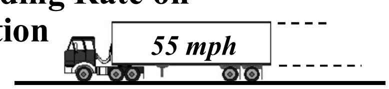
67 kN 15,000 lb 0.48 ESAL + 27 kN 6,000 lb 0.01 ESAL = 0.49 ESALs



151 kN 34,000 lb 1.10 + 151 kN 34,000 lb 1.10 + 54 kN 12,000 lb 0.19 = 2.39 ESALs

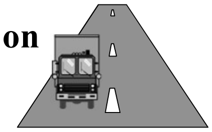
- Truck lanes require more structure and higher quality materials than car passing lanes.
- A design period of 20 years is used to determine traffic levels for mixture requirements, regardless of the design life of the roadway.

Effect of Loading Rate on Binder Selection



- For slower traffic speeds, use binder with more stiffness at higher temps
  - slow - - increase one high temp grade
  - standing - - increase two high temp grades
  - *no effect on low temp grade*

Effect of Loading Rate on Binder Selection



- **Example**
  - **for toll road** — **PG 64-XX** ← *55 mph*
  - **for toll booth** — **PG 70-XX** ← **Slow**
  - **for weigh stations** — **PG 76-XX** ← **Stopping**

PG Grades for Overlays, Sample Chart

Ndesign	Standard	Slow Traffic	Standing Traffic
30	PG 58-22	PG 64-22	PG 64-22*
50	PG 64-22	PG 70-22 or SBS PG 70-22	SBS PG 76-22
70	PG 64-22	PG 70-22 or SBS PG 70-22	SBS PG 76-22
90	PG 64-22*	PG 70-22 or SBS PG 70-22	SBS PG 76-22
105	PG 70-22 or SBS PG 70-22	PG 70-22 or SBS PG 70-22	SBS PG 76-22

PG Grades for Full Depth, Sample Chart (North)

	Standard	Slow Traffic or High ESALs	Standing Traffic
Surface and Top Binder	SBS-PG 64-28	SBS-PG 70-28	SBS-PG 76-28
Lower Binders	PG 64-22	PG 64-22	PG 64-22

PG Grades for Full Depth, Sample Chart (South)

	Standard	Slow Traffic or High ESALs	Standing Traffic
Surface and Top Binder	PG 64-22	SBS-PG 70-22	SBS-PG 76-22
Lower Binders	PG 64-22	PG 64-22	PG 64-22

Asphalt Grade Translation - Neat (Unmodified) Asphalts

AC-40	PG 70-22
AC-20	PG 64-22
AC-20 (Soft Pen)	PG 64-28
AC-10	PG 58-22
AC-7.5	PG 58-28
AC-5	PG 52-28
AC-2.5	PG 46-28

Asphalt Grade Translation - Polymer Modified

MAC-10HD+	SBS-PG 76-28
MAC-20HD	SBS-PG 76-22
MAC-10HD	SBS-PG 70-28
MAC-20	SBS-PG 70-22
MAC-10	SBS-PG 64-28

- **These are the grade translations between polymer modified viscosity grades and PG grades for many locations.**
- **Some agencies require SBS or SBR use for modified Superpave binders.**
- **Research is showing that not all of the binder tests are appropriate for modified binders.**

RAP in Superpave Mixes

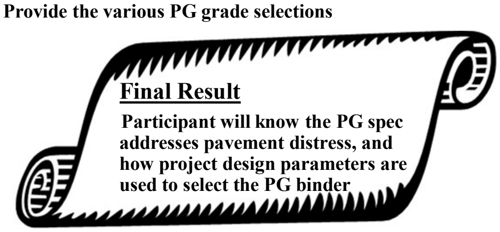
- **Some agencies allow no RAP in mixtures containing polymer modifiers**
- **Some agencies specify no RAP in surface mixes with synthetic aggregates**
- **If more than 20% RAP, a softer PG asphalt may be required**
- **Maximum allowable RAP based on mix type and gyrations**

Binder Selection Example

- Location: Northern Part of State County
- ADT: 25,000 (w/25% Heavy Trucks)
- Project: Remove and Replace 8 inches, 10-miles of reconstruction, Intersection for inter-modal facility at the center of project.

Superpave Binder Selection

- Section Objectives
  - Describe how the PG spec addresses pavement distress
  - Explain the PG binder selection process
  - Provide the various PG grade selections



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Specific Gravity of Mineral Aggregates

Importance of Volumetric Properties

Past experience:

% air voids relates to performance

- Lower than 3% - mixes unstable
- Higher than 5% - mixes not durable enough

Importance of Volumetric Properties

Past experience:

- %VMA must be high enough to allow sufficient room for 4.0% air voids
- Proper % asphalt to provide stability, durability, and impermeability

Importance of Volumetric Properties

Past Experience has shown that volumetric properties give some indication of the mixture's probable pavement service life.

Importance of Volumetric Properties

Volumetric Properties:

- Air voids & VMA are both volumetric properties that cannot be weighed.
- To use as mix design criteria, mix designs must be done on a volumetric basis.
- Specific gravity is used as the link between mass or weight and volume

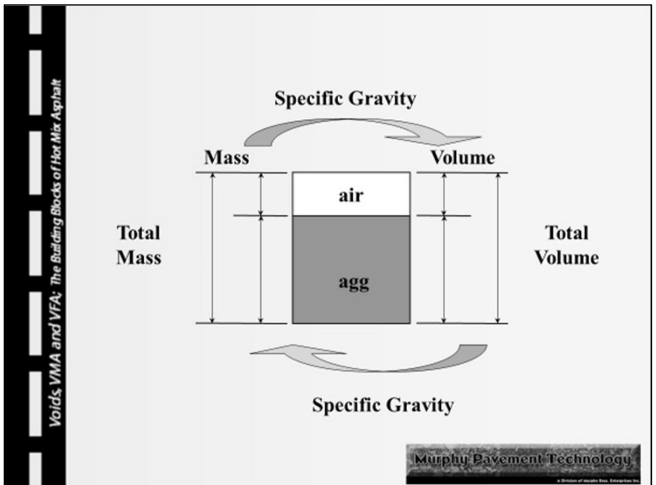
Specific Gravity

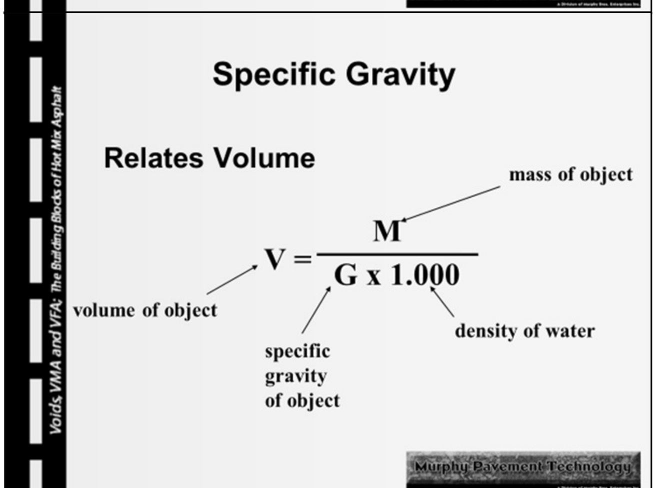
Definition:

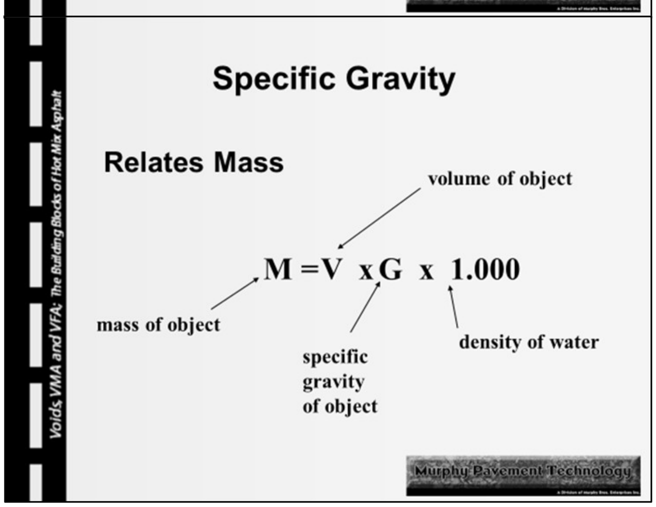
The ratio of the mass of a given volume of a substance to the mass of an equal volume of water, both at the same temperature.

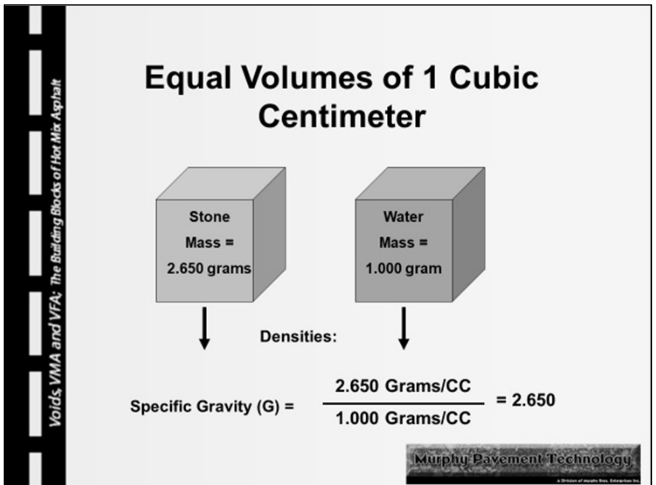
$$G = \frac{M}{V \times 1.000}$$

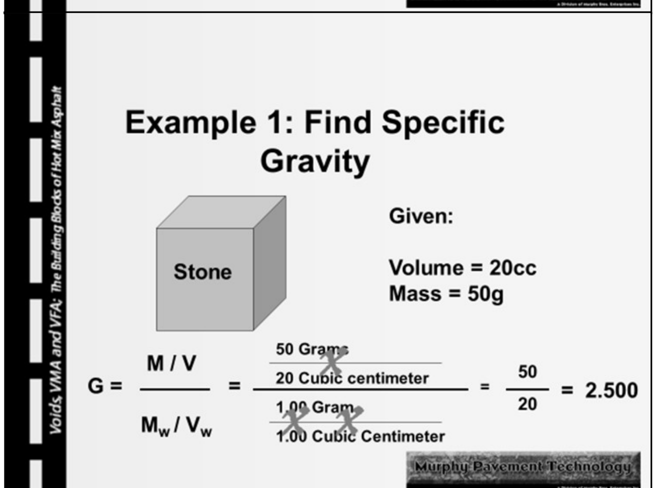
- G: specific gravity of object
- M: mass of object
- V: volume of object
- 1.000: density of water (g/cc)

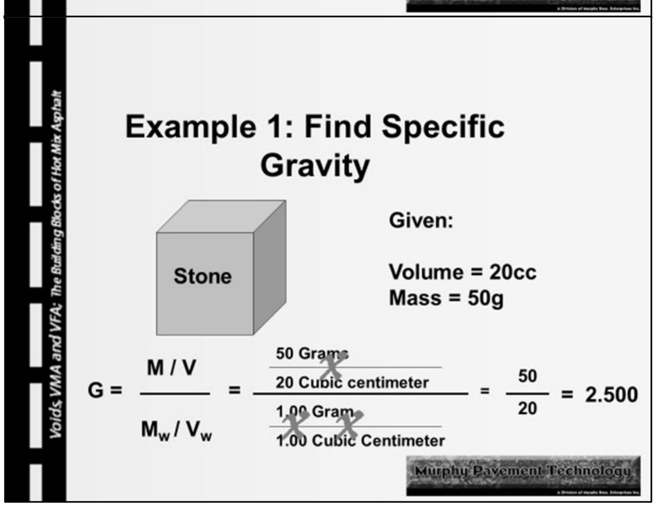

Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt
Specific Gravity
Mass
Volume
air
agg
Total Mass
Total Volume
Specific Gravity
Murphy Pavement Technology


Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt
Specific Gravity
Relates Volume
mass of object
V = M / G x 1.000
volume of object
specific gravity of object
density of water
Murphy Pavement Technology


Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt
Specific Gravity
Relates Mass
volume of object
M =V x G x 1.000
mass of object
specific gravity of object
density of water
Murphy Pavement Technology


Equal Volumes of 1 Cubic Centimeter
Stone
Mass =
2.650 grams
Water
Mass =
1.000 gram
Densities:
Specific Gravity (G) = 2.650 Grams/CC / 1.000 Grams/CC = 2.650
Voids VMA and VFA: The Building Blocks of Hot Mix Asphalt
Murphy Pavement Technology


Example 1: Find Specific Gravity
Stone
Given:
Volume = 20cc
Mass = 50g
G = M / V / Mw / Vw = (50 Grams / 20 Cubic centimeter) / (1.00 Gram / 1.00 Cubic Centimeter) = 50 / 20 = 2.500
Voids VMA and VFA: The Building Blocks of Hot Mix Asphalt
Murphy Pavement Technology


Example 1: Find Specific Gravity
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Given:
Volume = 20cc
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Voids VMA and VFA: The Building Blocks of Hot Mix Asphalt
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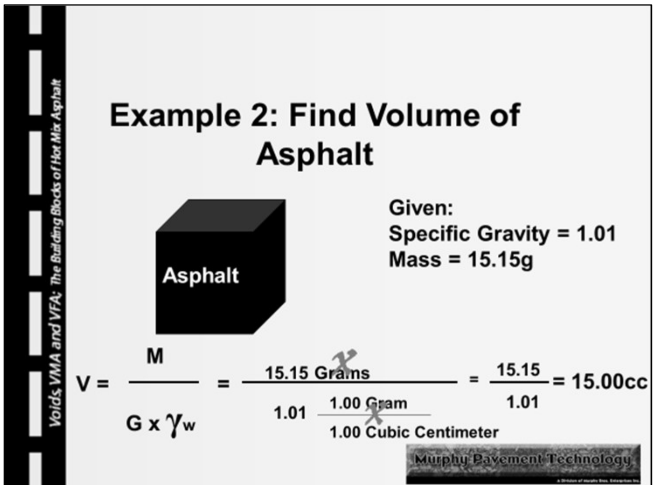
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt
Example 2: Find Volume of Asphalt
Asphalt
Given:
Specific Gravity = 1.01
Mass = 15.15g
V = M / G x γw = 15.15 Grams / 1.01 (1.00 Gram / 1.00 Cubic Centimeter) = 15.15 / 1.01 = 15.00cc
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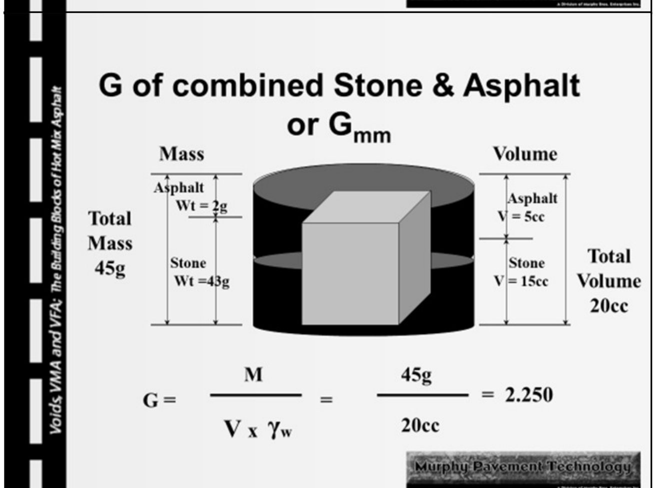
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt
G of combined Stone & Asphalt or Gmm
Mass
Volume
Total Mass 45g
Asphalt Wt = 2g
Stone Wt = 43g
Asphalt V = 5cc
Stone V = 15cc
Total Volume 20cc
G = M / V x γw = 45g / 20cc = 2.250
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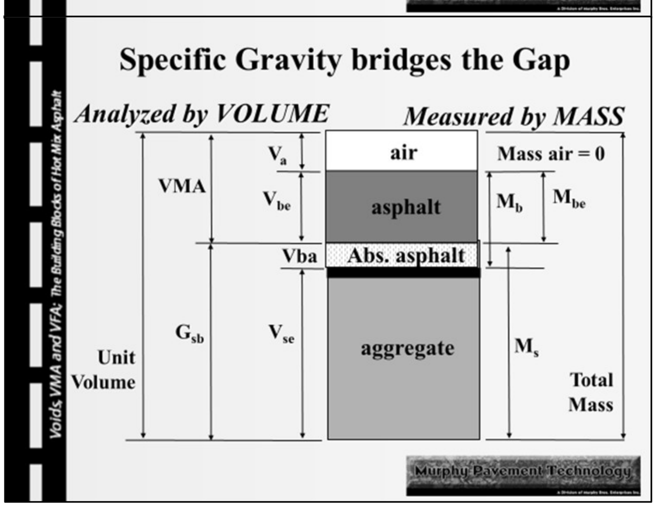
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt
Specific Gravity bridges the Gap
Analyzed by VOLUME
Measured by MASS
Va
air
Mass air = 0
VMA
Vbe
asphalt
Mb
Mbe
Vba
Abs. asphalt
Gsb
Vse
aggregate
Ms
Unit Volume
Total Mass
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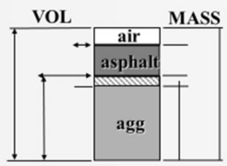
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Specific Gravity

- {mix, agg, and binder}
- Bridge between Mass and Volume



$$G = \frac{\left(\frac{M_x}{V_x}\right)}{\left(\frac{M_w}{V_w}\right)}$$

approx. density of water at 77°F (25° C) $= 62.245\ lb./ft^3$ $(1.000\ g/cm^3)$

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Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Example

A perfectly cut stone:

- Measures 1 ft. x 1 ft. x 1 ft.
- Weighs 156 lbs.
- What is the density of the cut stone?

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Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Example

A perfectly cut stone:

- Measures 1 ft. x 1 ft. x 1 ft.
- Weighs 156 lbs.
- What is the density of the cut stone?
- What is the specific gravity of the stone?

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Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

- The accuracy of volume is a critical operation in determining specific gravity
  - MS – 2, Page 44, Note
- How do you determine the volume of an irregular shaped object?

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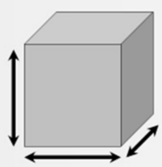
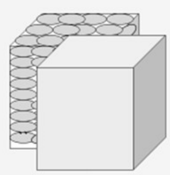
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Direct Measurement:

Volume = L x W x H



Volume of Loose Aggregate



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Archimedes' Principle:

- The fundamental natural law of buoyancy.
- First identified by the Greek mathematician and inventor Archimedes in the 3rd century BC.

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Archimedes' Principle:

– A body immersed in a fluid is buoyed up by a force equal to the mass of the displaced fluid.

– When the fluid is water, the mass of the displaced fluid is equal to the displaced volume.

Archimedes' Principle:

- The difference in weight of an irregular shaped object weighed in air and in water yields it volume.
- With an object's weight and its volume, its specific gravity can be determined.
- Buoyancy is the loss in weight an object seems to undergo when it is placed in a liquid.

SSD method & Archimedes' Principle

(A force equal to the mass of the displaced fluid buoys up a material immersed in fluid.)

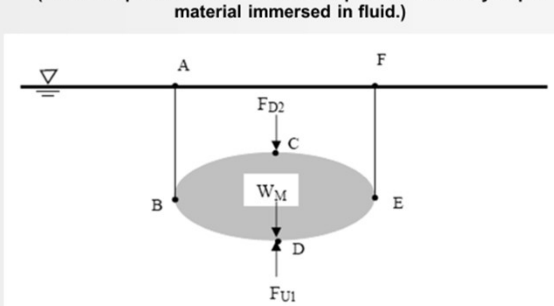

Figure: Hydrostatic Forces on a Submerged Material

Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Aggregate Specific Gravity
3 Types for HMA

- Bulk Volume (G_{sb})
  - Includes absorbed water volume
- Effective Volume (G_{se})
  - excludes absorbed asphalt volume
- Apparent Volume (G_{sa})
  - excludes absorbed water volume

Same Mass

Different Volumes

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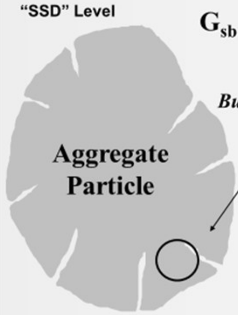
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Aggregate Dry Bulk Specific Gravity



$$G_{sb} = \frac{\text{Dry Mass}}{\text{Bulk Vol}} \Big/ \begin{matrix}1.000\ g/cm^3 \\ (62.245\ lbs./ft^3)\end{matrix}$$

Bulk Volume = solid volume + water permeable pore volume

-Largest volume

-Lowest Gravity numerically

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Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Combined Aggregate
Dry Bulk Specific Gravity

$$G_{sb}\ (\text{combined}) = \frac{P_1 + P_2 + P_3 + P_4}{\frac{P_1}{G_{sb1}} + \frac{P_2}{G_{sb2}} + \frac{P_3}{G_{sb3}} + \frac{P_4}{G_{sb4}}}$$

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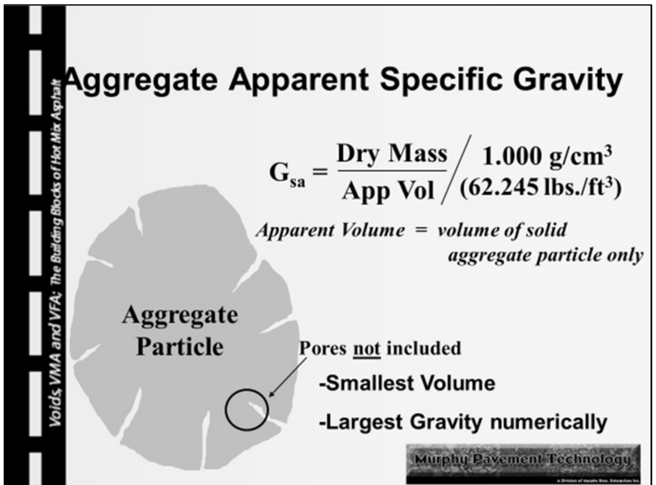
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt
Aggregate Apparent Specific Gravity
$G_{sa} = \frac{\text{Dry Mass}}{\text{App Vol}} \Big/ \frac{1.000\ g/cm^3}{(62.245\ lbs./ft^3)}$
Apparent Volume = volume of solid aggregate particle only
Aggregate Particle
Pores not included
-Smallest Volume
-Largest Gravity numerically
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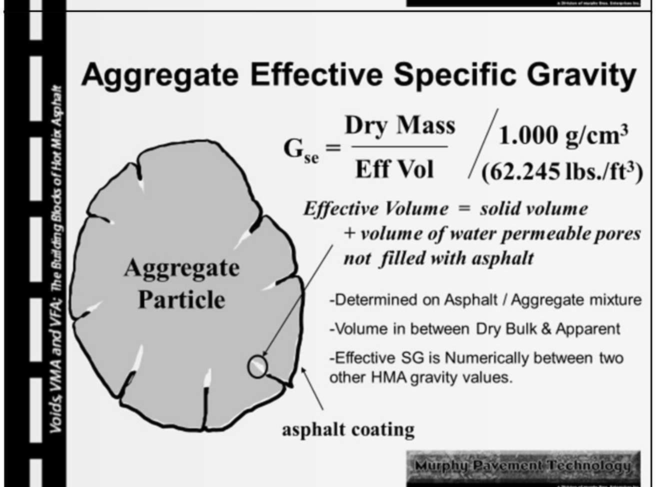
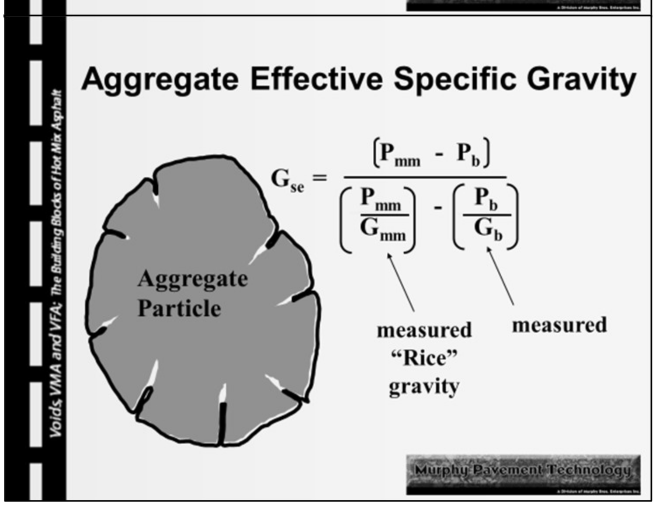

Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt
Aggregate Effective Specific Gravity
$G_{se} = \frac{\text{Dry Mass}}{\text{Eff Vol}} \Big/ \frac{1.000\ g/cm^3}{(62.245\ lbs./ft^3)}$
Effective Volume = solid volume + volume of water permeable pores not filled with asphalt
Aggregate Particle
-Determined on Asphalt / Aggregate mixture
-Volume in between Dry Bulk & Apparent
-Effective SG is Numerically between two other HMA gravity values.
asphalt coating
Murphy Pavement Technology


Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt
Aggregate Effective Specific Gravity
$G_{se} = \frac{(P_{mm} - P_b)}{\left(\frac{P_{mm}}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)}$
Aggregate Particle
measured "Rice" gravity
measured
Murphy Pavement Technology

Asphalt Institute Recommendations

- MS-2, Page 46, first full paragraph
- VMA calculations based only on aggregate dry bulk specific gravity
- Effective specific gravity used to back-calculate asphalt content in compacted mixture
- Table 4.1 shows how different aggregate G affect values reported for VMA & V_a
- Otherwise, AI mix design criteria do not apply (end of paragraph two)

Specific Gravity = $\dfrac{\text{Mass of Material}}{\text{Mass of an Equal Volume of } H_2 0}$

Bulk (dry) Specific Gravity

= $\dfrac{\text{Mass of Dry Aggregate}}{\text{Bulk Volume}}$

= $\dfrac{\text{Oven Dry Mass of Aggregate}}{\text{SSD Mass - Mass in } H_2 0}$

Effective Specific Gravity

= $\dfrac{\text{Oven Dry Mass of Aggregate}}{\text{Vol. of Solid Agg.} + \text{Vol. of } H_2 0 \text{ Perm Pores}}$
(**not** Filled w/AC)

Apparent Specific Gravity

= $\dfrac{\text{Mass of Dry Aggregate}}{\text{Vol. of Solid Aggregate}}$

= $\dfrac{\text{Oven Dry Mass of Aggregate}}{\text{Oven Dry Mass - Mass in } H_2 0}$

Why isn't Aggregate Specific Gravity a weighted average?

Because specific gravity is directly dependent on volume.

Why isn't Aggregate Specific Gravity a weighted average?

	G_{sb}	Mass, g	Volume
Fine Aggregate	2.000	40	40/2 = 20
Coarse Aggregate	3.000	60	60/3 = 20
Combined	100/40 = 2.500	100	40

Why isn't Aggregate Specific Gravity a weighted average?

- Px : Percent Aggregate in decimal format
- Gx : Specific Gravity of Aggregate
- Weighted Average Equation is:

$$\frac{P_1(G_1) + P_2(G_2)}{P_1 + P_2} = \frac{0.40\,(2.000) + 0.6\,(3.000)}{0.40 + 0.60}$$

$$= 2.600$$

Voids, VMA and VFA: *The Building Blocks of Hot Mix Asphalt*

Equations

$$G = \frac{\left(\frac{M_x}{V_x}\right)}{\left(\frac{M_w}{V_w}\right)}$$

$$G_{sb} = \frac{(P_1 + P_2 + \cdots + P_n)}{\left[\left(\frac{P_1}{G_1}\right) + \left(\frac{P_2}{G_2}\right) + \cdots + \left(\frac{P_n}{G_n}\right)\right]}$$

Developed in AASHTO T85, Appendix X1

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Voids, VMA and VFA: *The Building Blocks of Hot Mix Asphalt*

Nomenclature for Specific Gravity

G_{xy} - Where G Equals Specific Gravity
- x - Designates Material
- y - Designates Type of Specific Gravity

For (x):
- s - Aggregate
- m- Mixture
- b - Binder

For (y):
- m- Maximum
- a - Apparent
- b - Bulk
- e - Effective

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Voids, VMA and VFA: *The Building Blocks of Hot Mix Asphalt*

Nomenclature for Percentage of Material

- P_{xy} - Where P equals Percentage
  - x - Designates material
  - y - Designates amount
- For (x):
  - b - Binder
  - s - Aggregate
  - m- Mixture
- For (y):
  - e - Effective
  - a - Absorbed
  - m- Total

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Rap Specific Gravity as Ingredient

– Run G_{mm} on minimum of 2 samples & average

– Calc G_{se} = RAP Oven-dried Gravities

$$= \frac{(100 - \%\ AC\ in\ RAP)}{\left[\frac{100}{G_{mm}}\right] - \left[\frac{\%AC\ in\ RAP}{G_b}\right]}$$

where G_b = 1.040

Voids VMA and VFA: The Building Blocks of Hot Mix Asphalt

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Rap Specific Gravity as Ingredient

– Determine G_{sb} from G_{se} by subtracting 0.1 from the calculated value using the following formula:

G_{sb} (RAP) = RAP G_{se} – 0.1

Voids VMA and VFA: The Building Blocks of Hot Mix Asphalt

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I. MINERAL AGGREGATE: SPECIFIC GRAVITY CONCEPTS

Specific gravity is the ratio of the weight of a given volume of a substance to the weight of an equal volume of water, both at the same temperature. It is an essential aggregate property since it converts between weight and volume in mix design calculations.

Actual specific gravity tests involve immersing aggregates in water and using principles of buoyancy to calculate specific gravity. These tests are well established in ASTM, AASHTO, and Agency specifications.

When used for HMA mix design calculations, there are three distinct aggregate specific gravities: bulk, effective, and apparent. The aggregate particle shown in the diagram on the last page of this chapter illustrates the weight and volumes used to determine each of these specific gravities. Bulk and apparent specific gravities reflect aggregate volumes as measured by water immersion.

Bulk specific gravity includes the entire aggregate volume including solid volume and the volume of pores that are permeable and impermeable to water. The bulk volume is the largest aggregate volume measured. Thus, the bulk specific gravity is numerically the lowest among the three.

Apparent specific gravity includes only the solid aggregate volume. It does not include the volume of water-permeable pores. Since its volume is the smallest, apparent specific gravity is numerically the largest specific gravity.

Effective specific gravity is not measured by immersing aggregate in water. Instead it is determined during the mix design phase based on properties of a voidless asphalt and aggregate mixture. The effective volume is the solid aggregate volume and the volume of pores that are not permeable to asphalt binder. Thus, effective specific gravity recognizes the difference between water- and asphalt-permeable pores and is a very important property. Because this volume is between the bulk and apparent volumes, the effective specific gravity is numerically between these two values.

Before the 1960's, unsophisticated asphalt mixture tests did not accurately measure the effective specific gravity. Consequently, it was common to approximate effective specific gravity by averaging bulk and apparent. Notable approximations were long and successfully used by various state and federal agencies. If an aggregate did not absorb significant quantities of asphalt, these and similar approximations did not result in significant errors in mixture calculations. However, highly absorptive aggregates results in larger errors. Modern mixture tests, particularly the Rice Procedure (ASTM D 2041) for determining maximum theoretical specific gravity, allow for accurate and precise determination of aggregate effective specific gravity. Approximations are no longer necessary.

All designs submitted to the Agency for verification shall use aggregate specific gravities and absorption data obtained from the Agency aggregate specific gravity/absorption listing. The Agency typically publishes this listing of average specific gravities and absorptions by aggregate source and ledge on a semiannual basis. If question or disagreement, contact the Agency through the District Materials Engineer.

II. CALCULATING MINERAL AGGREGATE SPECIFIC GRAVITY

Agency's typically use the following specifications to calculate aggregate specific gravity:

Coarse Aggregate: Illinois Test Procedure 85

Fine Aggregate: Illinois Test Procedure 84

Q: *Why do it?*

A: *To calculate properties of mixture (Ref. MS-2, Chapter 5.6 & 5.8 p.54-55, 57)*

Voids in Mineral Aggregate (VMA) = 100 – $(G_{mb} \times P_s)/G_{sb}$

$$\text{Asphalt Absorption} = 100 \times \frac{(G_{se} - G_{sb})}{(G_{sb} \times G_{se})} \times G_b$$

where G_{sb} = **b**ulk specific **G**ravity of **s**tone

Q: *How do you get G_{sb} for **one** mix when **several** aggregates are used?*

A: *Calculate the average G_{sb} for mix weighted by aggregate blend percentages (Ref. MS-2, Chapter 5.3.4, p. 50)*

$$Gsb = \frac{100}{(P_1/G_1) + (P_2/G_2) + \ldots + (P_n/G_n)}$$

where P_1 = Percent by weight of aggregate of aggregate 1 in blend

and $G_1 = G_{sb}$ of aggregate 1

Q: *How do you determine the G_n when RAP is an ingredient?*

A: *Run G_{mm} on a minimum of 2 RAP samples and average the values. Calculate G_n as follows:*

$$G_n = G_{se} = \text{RAP Oven-dried Gravity} = \frac{(100 - \%\ \text{AC in RAP})}{\left(\frac{100}{G_{mm}}\right) - \left(\frac{\%\ \text{AC in RAP}}{G_b}\right)}$$

where, $G_b = 1.040$

$G_{sb} = G_{se} - 0.100$

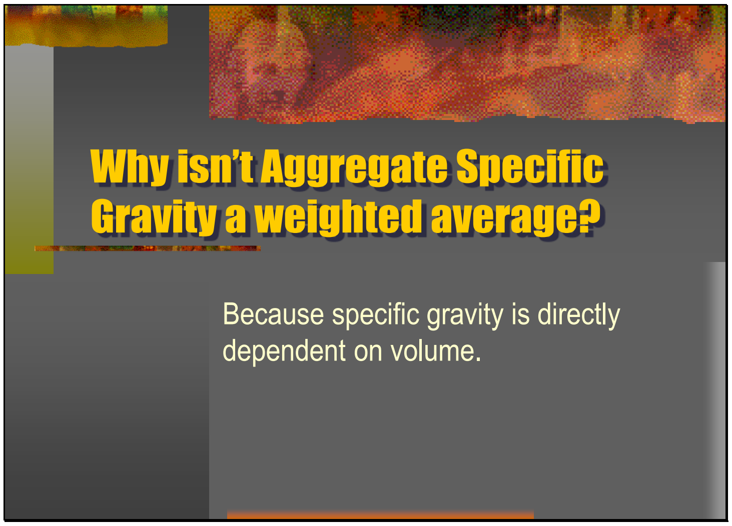
Specific Gravity and Absorption of Coarse Aggregate

A sample of coarse aggregate (*) is immersed in water for approximately 15 hours to essentially fill the pores. It is then removed from the water, the water is dried from the surface of the particles, and weighed (B). Subsequently sample is weighed (C) while submerged in water. Finally, the sample is oven-dried and weighed (A) a third time. Using the weight measurements thus obtained and formulas in the method, it is possible to calculate three types of specific gravity and absorption.

(*) Reject all material passing a 2.36–mm sieve by dry sieving and thoroughly washing to remove dust or other coatings from the surface. Alternatively, separate the material finer than the 4.75-mm sieve and test the finer material according to T 84

$$\text{Bulk Specific Gravity} = A / (B-C)$$

$$\text{Absorption, percent} = \{(B-A) / A\} \times 100$$


Why isn't Aggregate Specific Gravity a weighted average?
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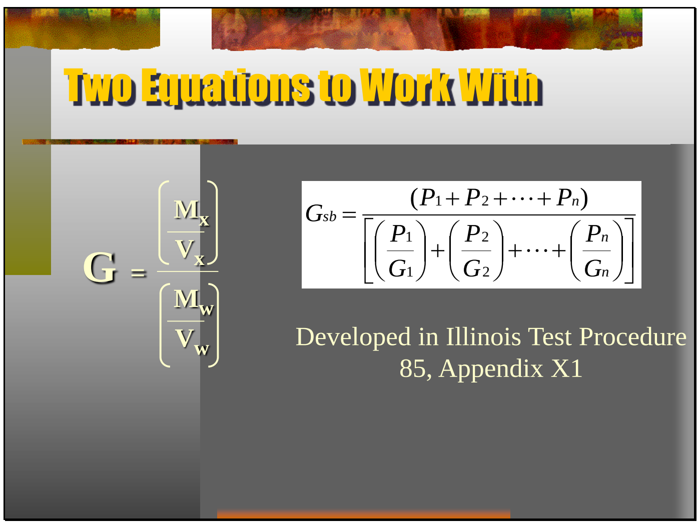
Two Equations to Work With
$G = \dfrac{\left(\frac{M_x}{V_x}\right)}{\left(\frac{M_w}{V_w}\right)}$
$G_{sb} = \dfrac{(P_1 + P_2 + \cdots + P_n)}{\left[\left(\frac{P_1}{G_1}\right) + \left(\frac{P_2}{G_2}\right) + \cdots + \left(\frac{P_n}{G_n}\right)\right]}$
Developed in Illinois Test Procedure 85, Appendix X1

Why isn't Aggregate Specific Gravity a weighted average?

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$$= 2.600$$

Mix Design Terminology / Symbols Used in Analyzing a Compacted Paving Mixture

G = Specific Gravity

G_b = specific gravity of asphalt

G_{sb} = bulk specific gravity of combined aggregate

G_{se} = effective specific gravity of combined aggregate

G_{sa} = apparent specific gravity of combined aggregate

G_{mb} = bulk specific gravity of compacted mixture

G_{mm} = maximum theoretical specific gravity of mixture

P = Percentage

P_b = asphalt, percent by total weight of mixture

P_s = aggregate, percent by total weight of mixture

P_{mm} = loose mix, percent by total weight of mixture (= 100%)

P_{be} = effective AC, percent by total weight of mixture

P_a = air voids in compacted mixture, percent of total volume

P_{ba} = absorbed AC, percent by total weight of aggregate

Mix Design Volumetric Concepts

Timothy R. Murphy, P.E.
President
Murphy Pavement Technology

Important HMA Mix Properties

- Stability
- Durability
- Impermeability
- Workability
- Flexibility
- Fatigue Resistance
- Skid Resistance

We want them all!
How?

- Materials Selection
- Volumetric design

Materials Selection

Aggregate

- Makes up 93 to 96% of the mixture
- Acts as the skeleton of the pavement mixture
  - Skid resistance
  - Stability
  - Workability

Asphalt Binder

- Makes up 4 – 7% of the mixture
- Acts as the “glue” or “muscle” of the mix
  - Flexibility
  - Durability

Materials Selection

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  - Workability

Asphalt Binder

- Makes up 4 – 7% of the mixture
- Acts as the "glue" or "muscle" of the mix
  - Flexibility
  - Durability

Obtaining the right balance

Achieved through:

- Volumetric Analysis of the Mixture
- Performance Testing
  - Hamburg Wheel
  - Illinois Flexibility Index Test (I-FIT)

Volumetric Analysis Definition:

- The measurement or calculation of the relative volumes occupied by the aggregate, asphalt binder, and air voids in a laboratory compacted asphalt mixture

Intent of laboratory compaction?

Simulate the in-place density of HMA after it has endured several years of traffic in the roadway.

In-place Density

Design Density

Future Traffic

Air Voids

15-25% Before Rolling

6 – 9% After Rolling

Air Voids

3 – 5% Marshall

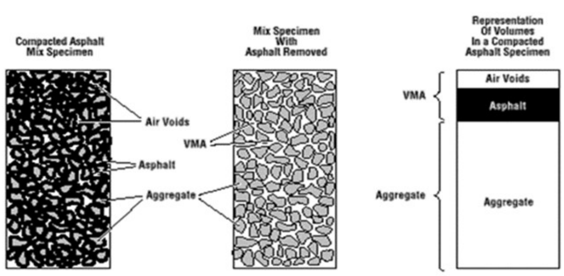
4.0% Superpave

What compactor simulates this best?

- SHRP research identified the best practical compactor - Superpave Gyratory compactor
- SGC better than Marshall or Hveem

Importance of Volumetric Properties

Experience shows that % air voids and the voids in the mineral aggregate relate to performance



Note: For simplification, the volume of absorbed asphalt is not shown.

Importance of Air Voids

- Field performance has shown that mixtures designed below 3% air voids are susceptible to rutting and shoving
- Mixtures designed over 5% Air Voids are susceptible to raveling, oxidation and a general lack of durability
- 4% Air Void Design allows for thermal expansion of the binder along with a cushion for future compaction

Importance of VMA

- VMA is the volume of the voids in a compacted aggregate sample to accommodate asphalt and air.
  - Assure sufficient binder coating
  - Maintain 4% Air voids

Volumetric Analysis History:

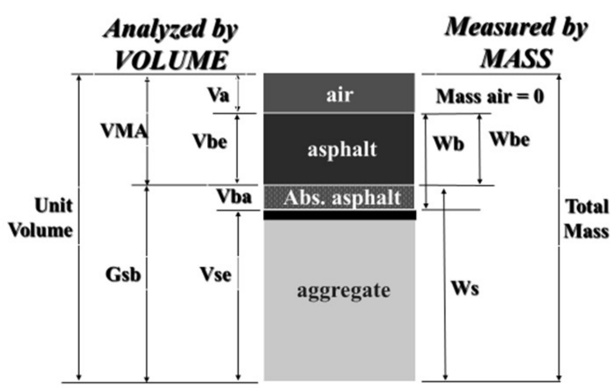
- Not a new concept; has played a role in most mixture design methods
- Is currently the best available method to readily measure mixture properties in the field on plant produced mix.

HMA Volumetric Terms

- Bulk specific gravity of mix, G_{mb}
- Maximum specific gravity of mix, G_{mm}
- Air voids of mix, V_a
- Voids in mineral aggregate, VMA
- Voids filled with asphalt, VFA
- Bulk specific gravity of aggregate, G_{sb}
- Effective specific gravity of aggregate, G_{se}
- Dust to binder ratio

Nomenclature for Specific Gravity

- G_{xy} - Where G Equals Specific Gravity
  - x - Designates Material
  - y - Designates Type of Specific Gravity
- For (x):
  - s - Aggregate
  - m- Mixture
  - b - Binder
- For (y):
  - m- Maximum
  - a - Apparent
  - b - Bulk
  - e - Effective



Specific Gravity bridges the Gap

$$G_{mm} = \frac{100}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

$$V_a = \left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right) x\ 100$$

$$VMA = 100 - \frac{G_{mb}\ x\ P_s}{G_{sb}}$$

$$VFA = \left(\frac{VMA - V_a}{VMA}\right) x\ 100$$

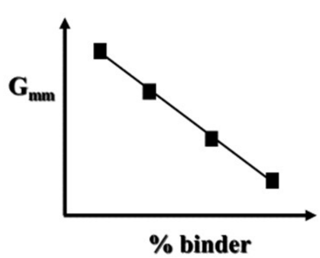
$$P_{be} = P_b - \frac{P_{ba}\ x\ P_s}{100}$$

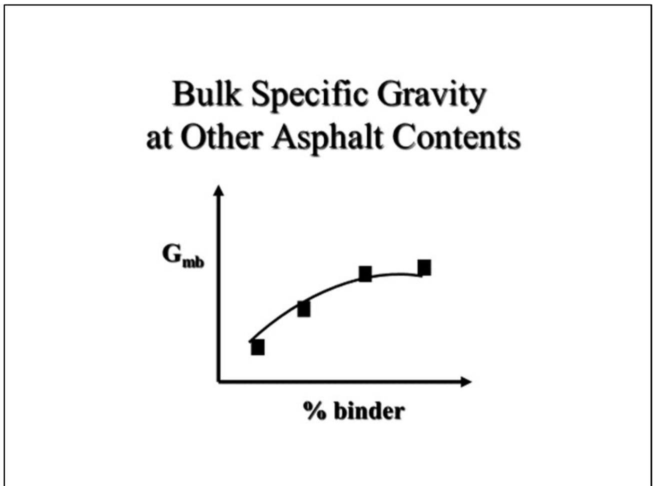
$$P_{ba} = 100\ x \left(\frac{G_{se} - G_{sb}}{G_{se}\ x\ G_{sb}}\right) x\ G_b$$

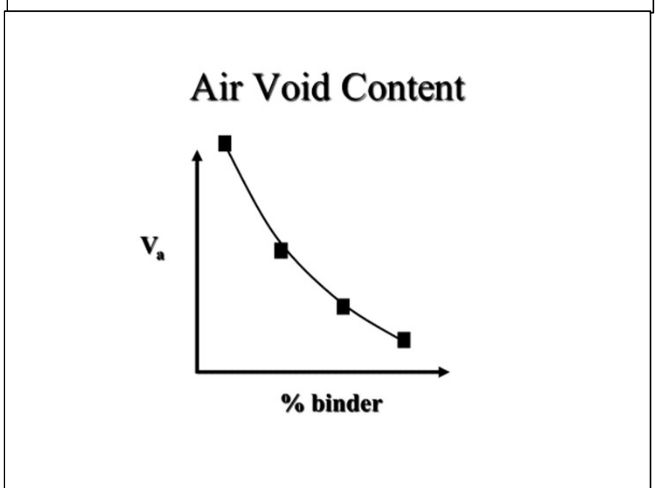
$$Eff.\ Vol. = VMA - V_a$$

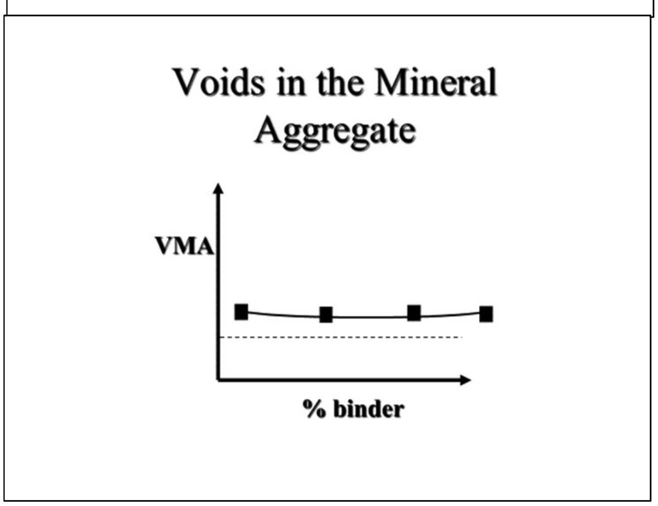
What the Heck did Murphy Say?

Maximum Theoretical Gravity at Other Asphalt Contents

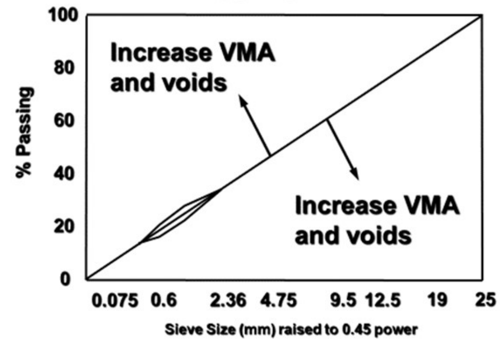



Bulk Specific Gravity
at Other Asphalt Contents
G_{mb}
% binder


Air Void Content
V_a
% binder


Voids in the Mineral
Aggregate
VMA
% binder

Voids in the Mineral Aggregate

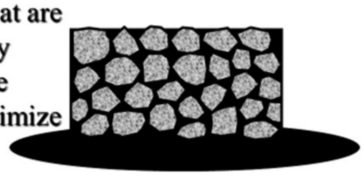


VMA Adjustments

1. Increase or decrease manufactured/natural sand blend.
   - Changes 600 µm
   - Changes on minus 75 µm
2. Increase or decrease chips in intermediate or base mixture
   - Changes 4.75 mm to 2.36 mm material
3. Increase or decrease minus 75 µm (MF)
4. Change sources

• Too Much VMA

- SMA and OGFC are specialty mixes that are designed with very high VMA and are engineered to minimize drain down



Many Elements affect Volumetric Properties

Binder Quantity

Binder Properties
- Stiffness
- Modification
- Temperature

Every Mixture can be Different!!

Aggregate characteristics
- Gradation
- Particle shape
- Surface texture
- Hardness
- Absorption

Mix Design Process

- Evaluate Materials Properties
  - Determine Asphalt Binder Type
  - Determine Aggregate gradations
  - Determine Aggregate quality properties
- Conduct Design Aggregate Structure Trial Blend Design
- Conduct In-Depth Mix Design
- Conduct Performance Testing

Have We Conquered Introductory Items?

This Page is Reserved

Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Aggregate and Asphalt

Aggregate Properties

Developed by:
Timothy R. Murphy
President

Murphy Pavement Technology

Blending Aggregate and Asphalt

Q. Why do we blend?

A. No single shelf gradation aggregate will meet the required blend composition for a HMA mixture.

United States Bureau of Public Roads 0.45 Power Chart

Sieve Sizes Raised to the 0.45 Power

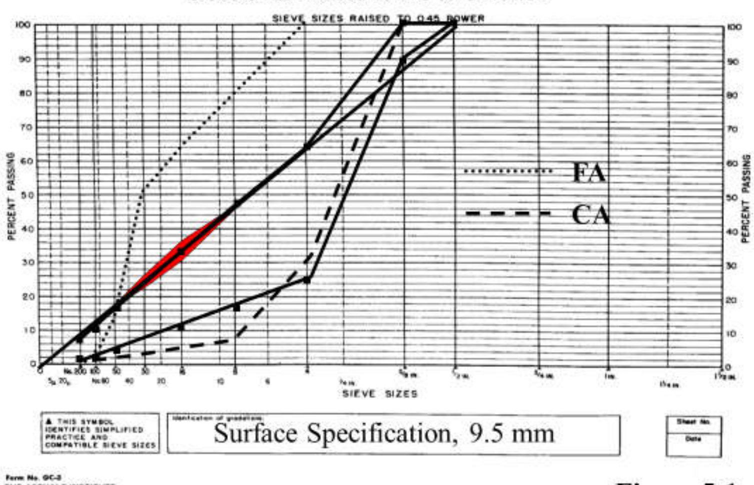
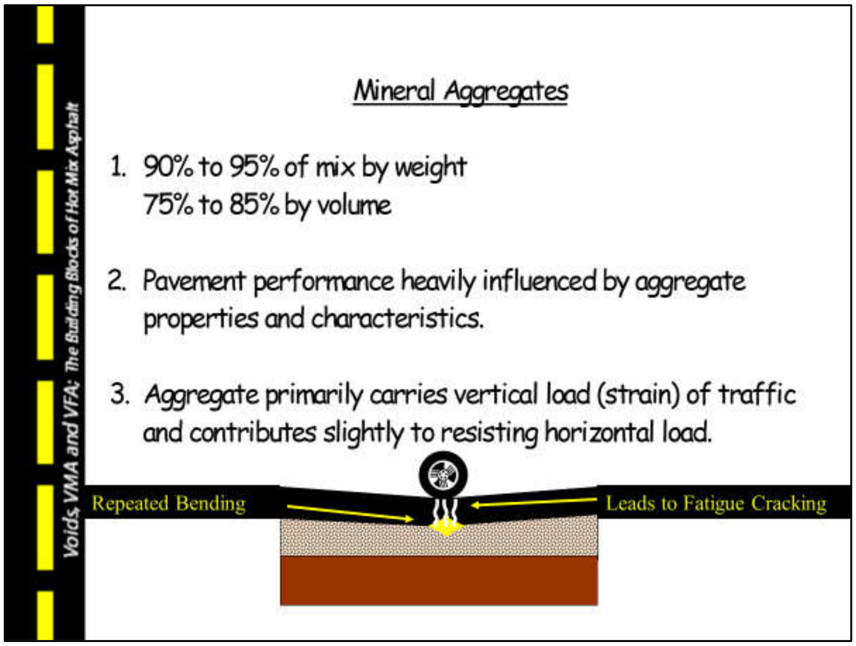
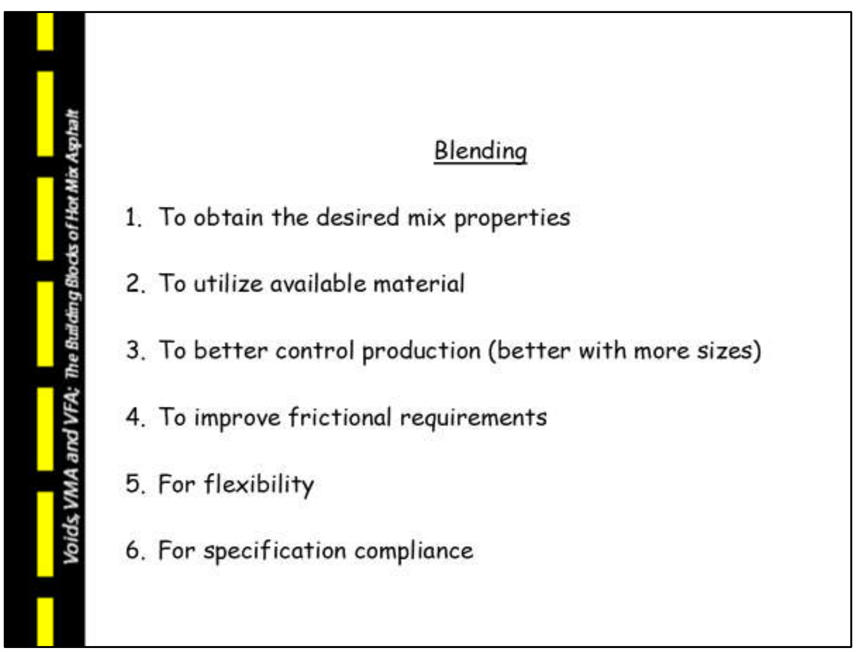


Figure 5-1



In a dense-graded asphalt hot-mix pavement, aggregate makes up 90% to 95% by weight of the paving mixture. This makes the quality of the aggregate used a critical factor in pavement performance. However, in addition to quality, there are other criteria that go into the selection of an aggregate for a particular paving job; criteria such as cost and availability. An aggregate that meets cost and availability requirements, however, must still have certain properties to be considered suitable for use in quality hot-mix asphalt pavement. These properties include the following:



- Maximum particle size and gradation
- Cleanliness
- Toughness
- Particle shape
- Surface texture
- Absorptive capacity
- Affinity for asphalt

Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Size and Grading

1. Size Designations:
   - Maximum size
   - Nominal maximum size
2. Standard Sieve Sizes:
   - Customary or metric units
   - Inch or millimeter size openings
   - Openings (per inch or millimeter size)
3. Used to control distribution of particle size (specification).
4. Described by grading.

A. Maximum Particle Size and Gradation

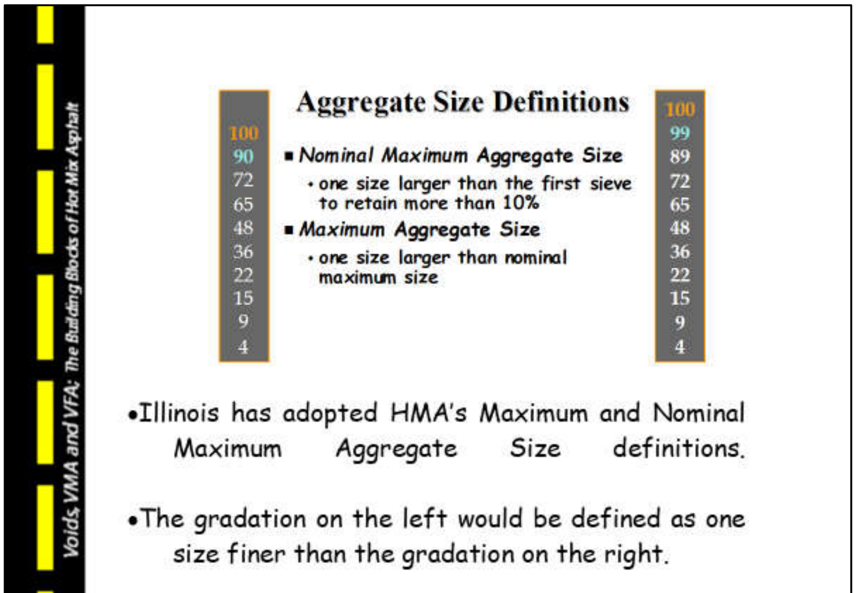
All hot-mix asphalt pavement specifications require aggregate particles to be within a certain range of sizes and for each size of particle to be present in a certain proportion. This distribution of various particles sizes within the aggregate used is called the aggregate gradation or mix gradation. To determine whether or not an aggregate gradation meets specifications requires an under-standing of how particle size and gradation are measured.

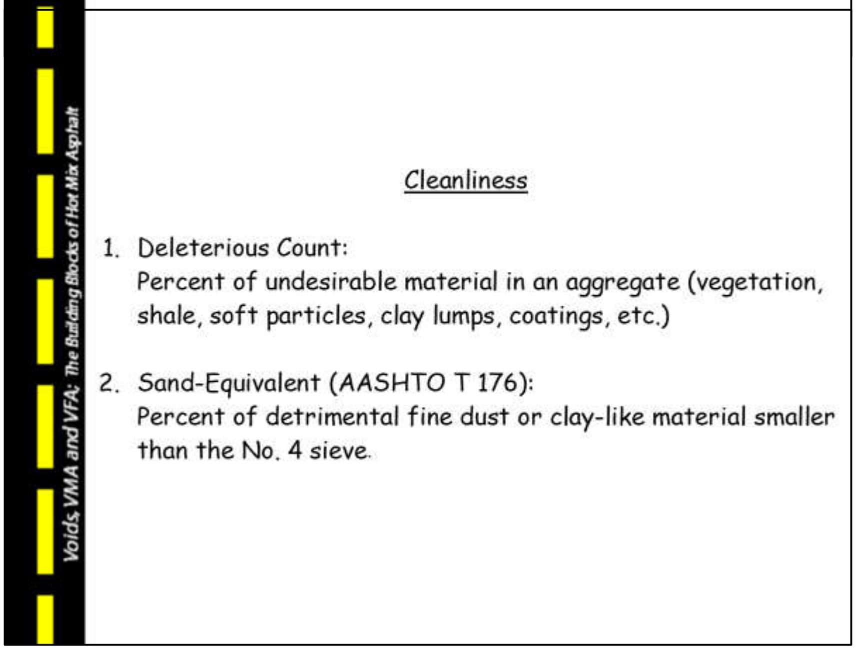
Articles 1003.03and 1004.03 of the current edition: IDOT Standard Specifications for Road and Bridge Construction discuss these criteria.

Because specifications list a maximum particle size for each aggregate used, the size of the largest particles in the sample must be determined. There are two designations for maximum particles size.

1.Nominal Maximum Aggregate Size. This is one size larger than the first sieve to retain more than 10%.

2.Maximum Aggregate Size. This is one size larger than nominal maximum size.

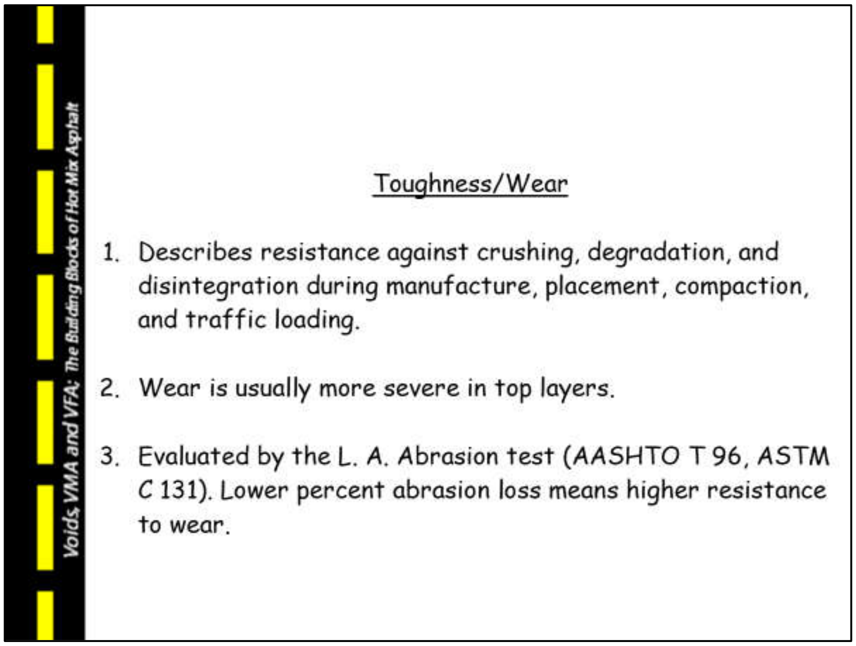




B. Cleanliness

Job specifications usually place a limit on the types and amounts of unsuitable material (vegetation, shale, soft particles, lumps of clay, etc.) permitted in the aggregate, particularly if the aggregate is known to contain quantities of such material. Excessive amounts of such material can have an adverse effect on pavement performance.

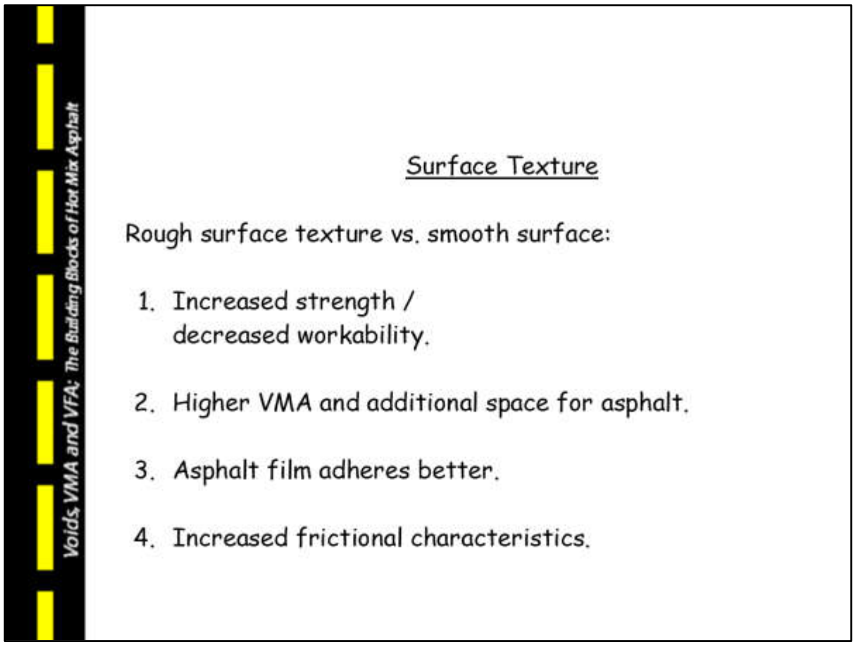
Aggregate cleanliness can be determined often by visual inspection, but a washed sieve analysis, in which the weight of an aggregate sample before washing is compared to its weight after washing, gives an accurate measurement of the percentage of material finer than 75 µm(No. 200). The sand-equivalent test(AASHTO T176) is a method of determining the relative proportion of detrimental fine dust and clay-like material in the fraction (portion) of aggregate passing the4.75-mm (No. 4) sieve.
Articles 1003.03and 1004.03 of the current edition: Standard Specifications for Road and Bridge Construction list the amount of deleterious materials coarse and fine aggregates may contain.



C. Toughness

Aggregates must be able to resist abrasion (wearing away) and degradation(breaking apart) during manufacture, placing, and compaction of the pavement mixture and during the service life of the pavement under actual traffic. Aggregates at or near the pavement surface must be tougher (more resistant) than aggregates used in the lower layers of the pavement structure. This is because upper pavement layers receive the full stress and wear from traffic loads.

The Los Angeles Abrasion test (AASHTOT96) measures an aggregate's resistance to wear or abrasion. Article 1004.03 of the current edition: Standard Specifications for Road and Bridge Construction
discusses the criteria for maximum percent loss that is allowed in AASHTOT96 for the various classes of coarse aggregate.



5ɸ Surface Texture

Surface texture of aggregate particles is another factor that determines not only the workability and final strength of a paving mixture but also the skid-resistant characteristics of the pavement surface. Some consider it more important than particle shape. A rough, sandpaper-like texture increases pavement strength because it prevents particles from moving easily past one another and provides a higher coefficient of surface friction for safer traffic operations.

In addition, asphalt films cling more readily to rough surfaces than to smooth ones.

Because natural gravels usually have smooth surface textures, they are often crushed during processing. Crushing produces rough surface texture on the fractured faces, as well as changing particle shape.

There is no standard method for directly evaluating surface texture. Like particle shape, it is a characteristic reflected in mixture strength tests and in workability of the mixture during construction.

Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Particle Shape

1. Influences workability and strength as well as compactive effort to obtain a density.
2. Coarse aggregate:
   - round
   - cubical
   - elongated

   Fine aggregate:
   - round
   - angular
3. Best interlock and highest strength from angular and cubical particles.

Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Particle Shape (cont'd.)

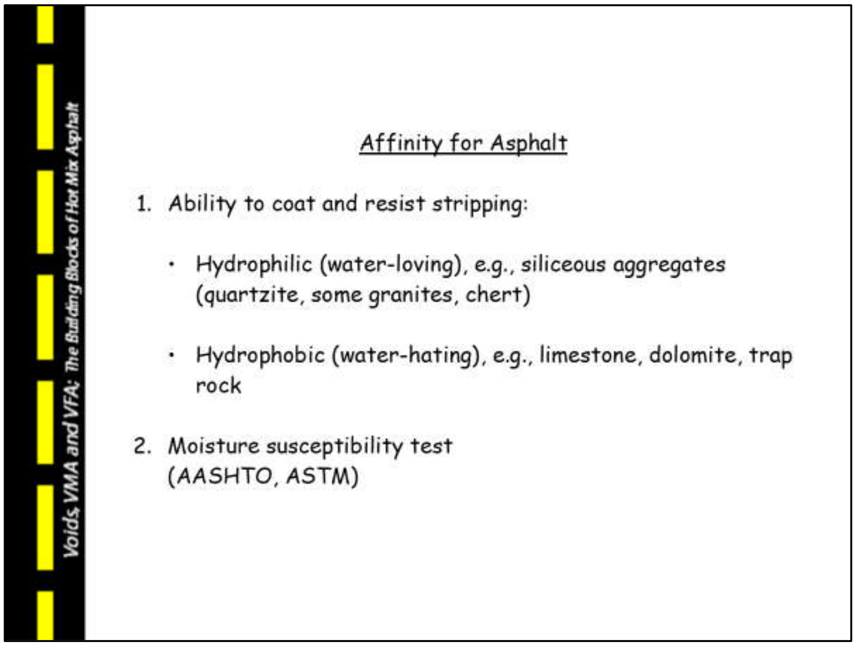
4. Rounded sand for workability and ease of compaction.
5. Round and cubical shapes have higher surface area which requires more asphalt but results in less breakdown.
6. Crushing affects particle shape (compression vs. impact).

E. Particle Shape

Particle shape influences the work ability of the paving mixture during placement as well as the amount of force necessary to compact the mixture to the required density. During pavement life, particle shape also influences the strength of the pavement structure.

Because irregular, angular particles tend to interlock when compacted, they usually resist displacement (movement) in the final pavement. Best interlocking is generally obtained with sharp cornered, cubical-shaped particles obtained by crushing. However, round particles, such as those comprising most natural gravel sand sands, are used successfully in asphalt paving mixtures, particularly in dense-graded types.

Many asphalt pavement mixtures contain both angular and round particles. The coarse (large) aggregate particles are usually crushed stone or crushed gravel that give the pavement strength; the fine(small) aggregate particles are usually natural sand which gives the mixture necessary workability. IDOT requires100% crushed coarse aggregate.

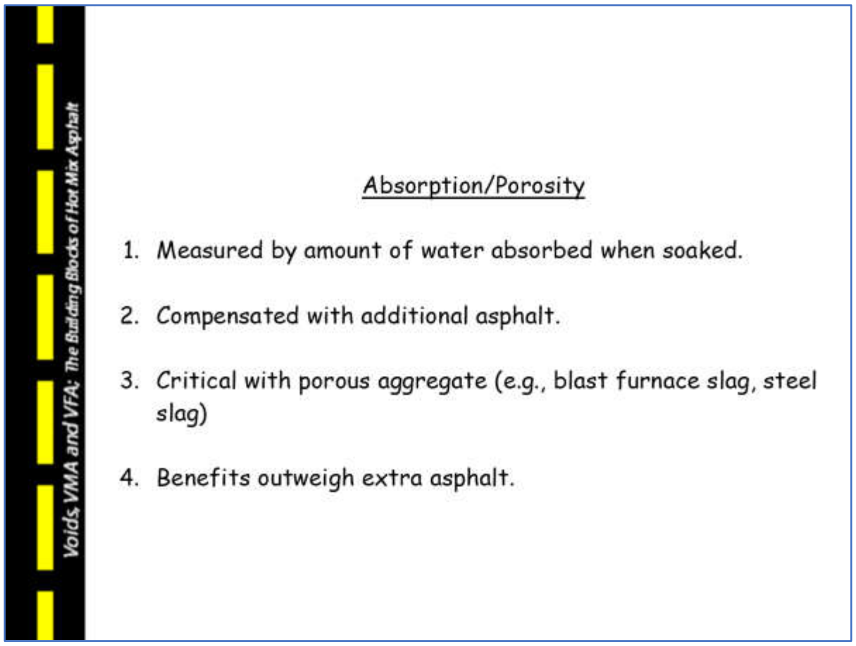


F. Affinity for Asphalt

An aggregate's affinity for asphalt is its tendency to accept and retain an asphalt coating. Limestone, dolomite, and traprock have affinities for asphalt and are referred to as hydrophobic (water-hating)because they resist the effects of water to strip asphalt from them.

Hydrophilic (water-loving) aggregates have low affinities for asphalt. Consequently, they tend to separate from asphalt films when exposed to water. For example, siliceous aggregates (quartzite, chert, and some granite) are prone to stripping and must be used cautiously.

Why hydrophobic and hydrophilic aggregates behave as they do is not clearly understood. Nonetheless, there are several test methods for determining their affinity for asphalt and the tendency toward stripping. In one such test, the uncompacted aggregate asphalt mixture ìă soaked in water, and the coated particles are then evaluated visually. In another test, commonly known as the immersion-compression test, two specimens of the mixture are prepared. One is soaked in water and the other is not. Both are then tested for strength. The difference in strength between the two samples is considered to indicate the aggregate’s susceptibility to stripping. IDOT uses Illinois Modified AASHTO T283 to determine the moisture sensitivity of I 2ǘπ a ìÈ !ăLJK I·fǘφ

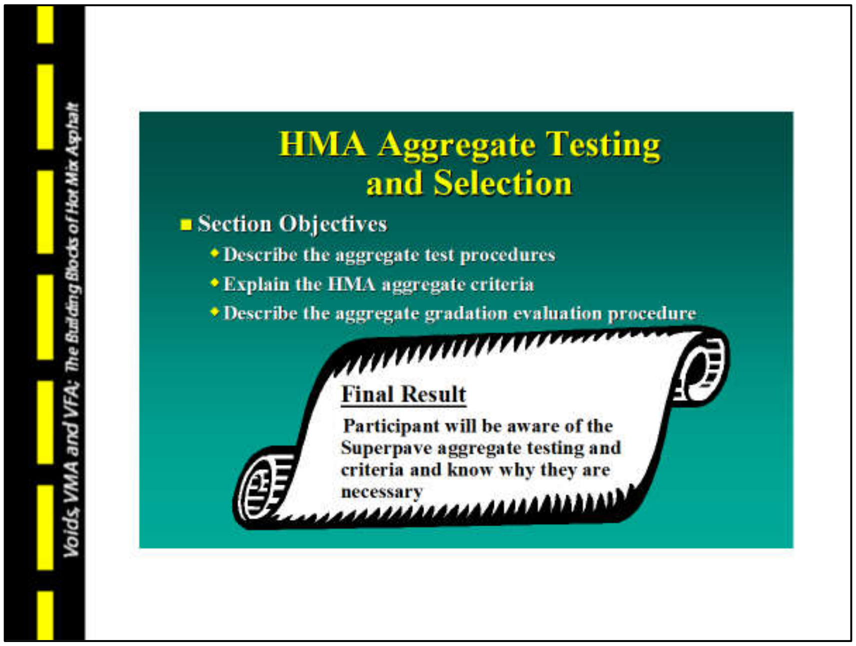


G. Absorptive Capacity

How porous an aggregate is determines how much liquid it absorbs when soaked in a bath.

The capacity of an aggregate to absorb water (or asphalt) is important information. If an aggregate is highly absorptive, it will continue to absorb asphalt after initial mixing at the plant, leaving less asphalt on its surface to bond aggregate particles together. Because of this, a porous aggregate requires significantly more asphalt to make a suitable mixture than a less porous aggregate does.

Highly absorptive aggregates are defined as aggregates with an absorption greater than 2.5%. These aggregates result in higher asphalt content in mixture design but are used because they possess high friction characteristics which make them desirable. Examples of such materials are steel slag, blast furnace slag, and other synthetic or manufactured aggregates. IDOT makes use of these materials in surface mixtures.



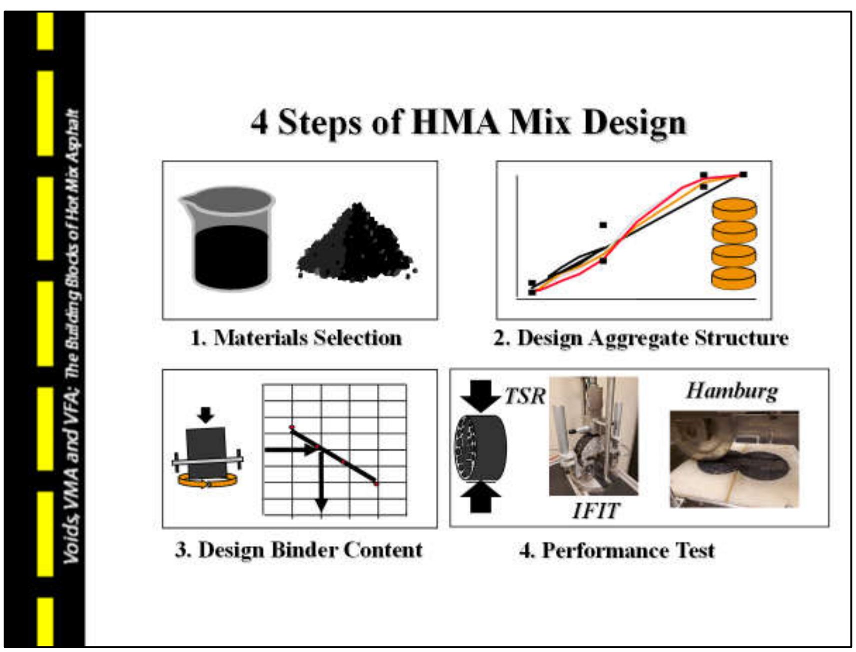
H. HMA Aggregates

HMA aggregate selection is a part of the first step in the HMA mix design process. As such, it involves the following:

Aggregate testing procedures

HMA aggregate criteria

Aggregate gradation evaluation procedure



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HMA Aggregates

- **Consensus Properties** - *required*
  - coarse aggregate angularity (CAA)
  - fine aggregate angularity (FAA)
  - flat, elongated particles
  - clay content
- **Source Properties** - *agency option*
  - toughness
  - soundness
  - deleterious materials

In addition to the aggregate source properties already discussed in this chapter, some HMA aggregate properties are required; some are optional for the agency.

Generally, Illinois is not specifying the HMA aggregate consensus properties, although Illinois believes the spirit of the HMA specification is met by the current aggregate specifications for CAA, FAA , and clay content. Illinois is not specifying F&E at this point

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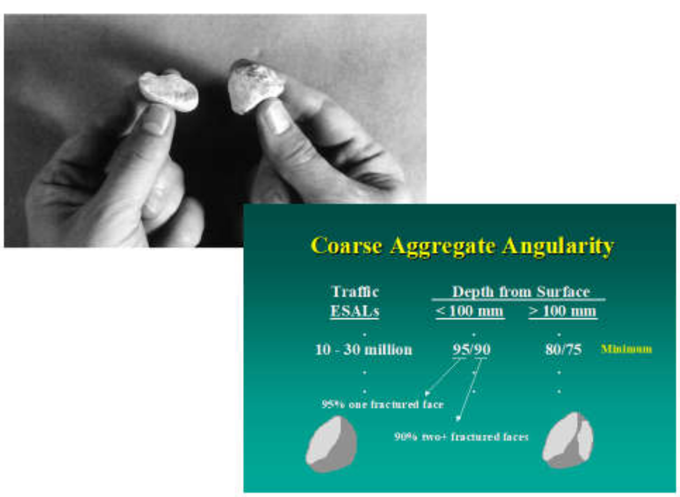
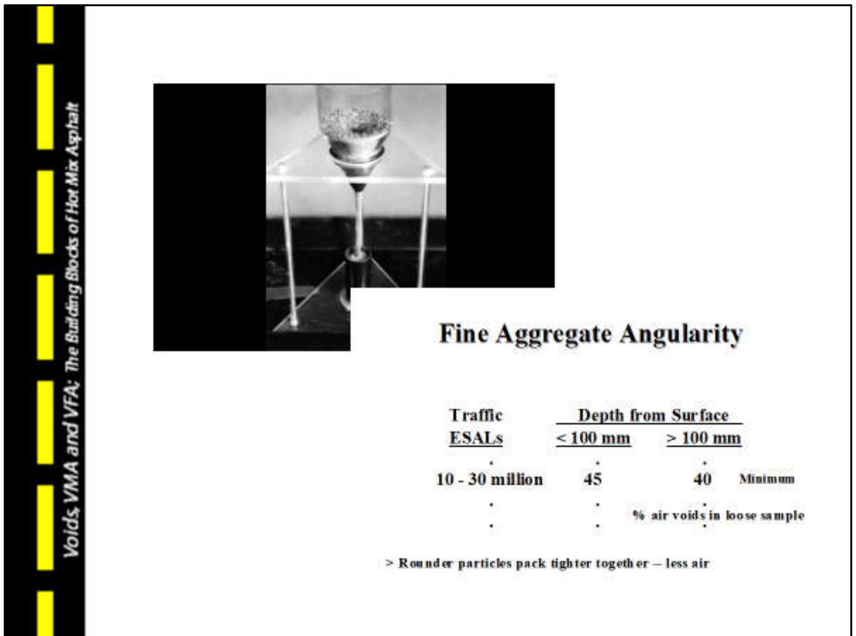


Coarse Aggregate Angularity (CAA)measures the fractured faces on the+4.75mm material.

AA requirements depend on traffic level and depth into pavement.

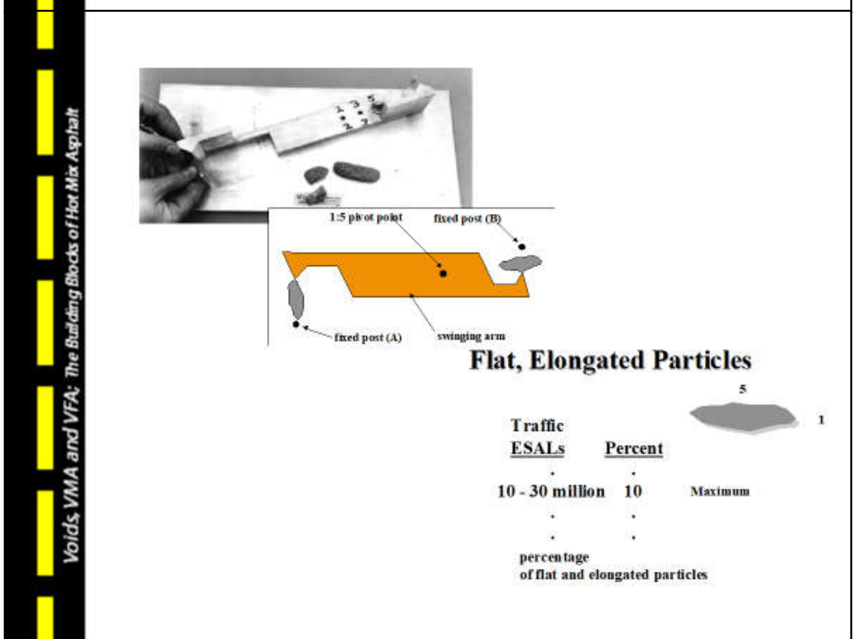
Illinois currently requires 100% crushed coarse aggregate for high type mixes, and believes this complies with the intent of HMA.



2. Fine Aggregate Angularity (FAA) is measured on the-2.36 mm material.

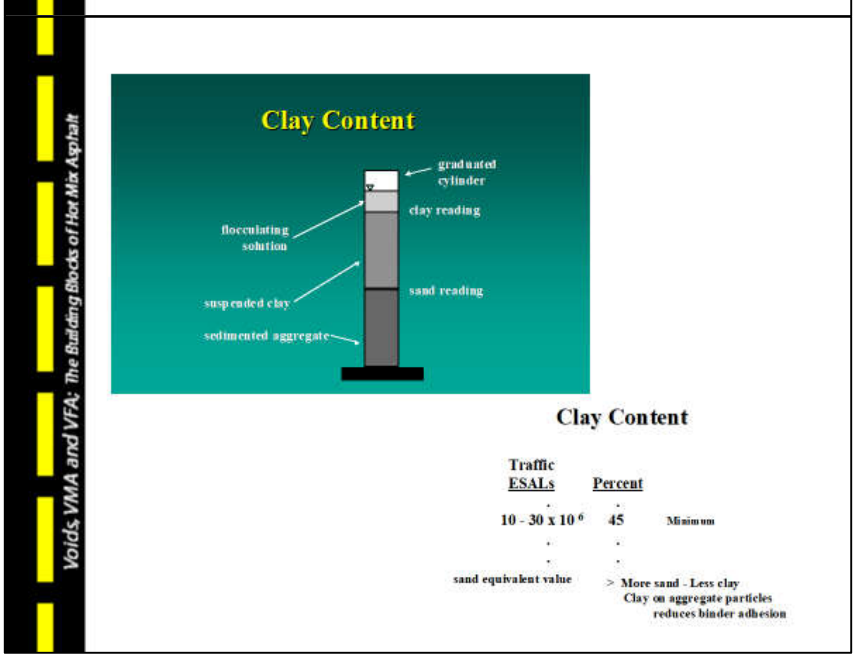
Illinois is not measuring FAA. The testis currently being nationally evaluated for validity.
Illinois requires at least 50% manufactured sand for high types mixes (Ndesign=90), and feels this complies with the intent of HMA.

FAA requirements vary with traffic level and pavement depth.



3. Flat and Elongated (F&E) particles measure the ratio between the "long" and "short" sides of +4.75mm aggregate particles.

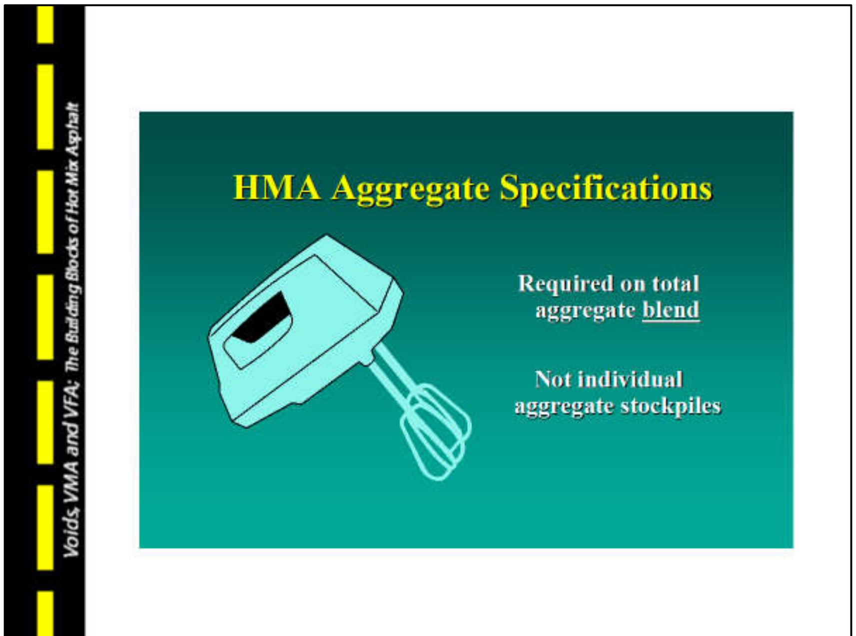
The F&E specification varies with traffic level, and is based on 5:1 ratio.
Illinois does not currently use F&E. The University of Illinois is currently researching the effect of F&E on volumetrics.
Illinois generally meets 5:1, and is cautious about proposed 3:1, as are other states and procedures.

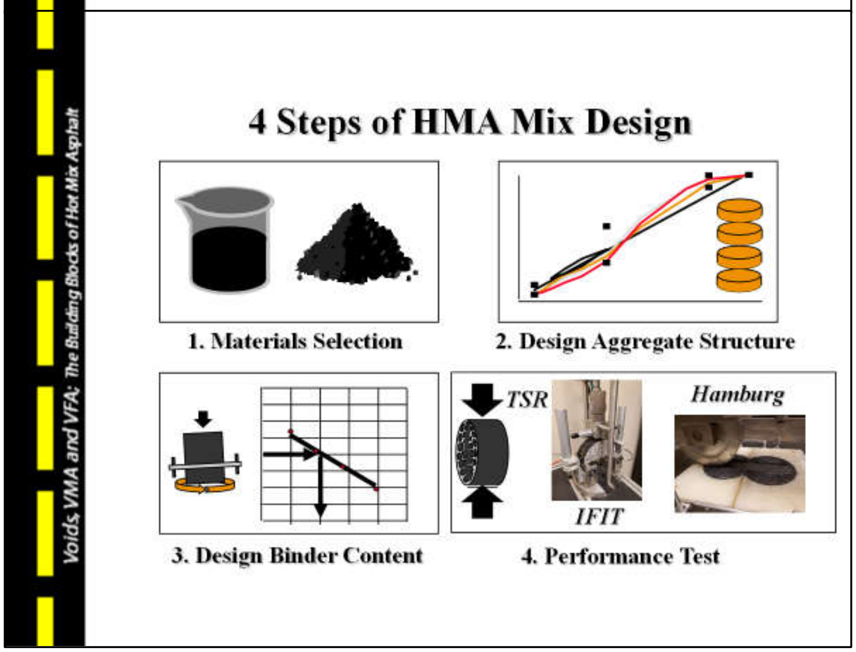


4. Clay content is measured using the and equivalency test. Illinois does not measure clay content using this test.

To control clay content, Illinois limits %passing #200 and limits clay size material to 3.0% max in manufactured sand.

Clay content varies with traffic level.





The second step in HMA mix design is selection of the design aggregate structure.

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Illinois Friction Policy

In 2000, Illinois developed a new friction policy for the four friction aggregate mixtures. Although the Department's TRA-16, "Skid-Accident Reduction Program", dictates their use. The following defines their use:

Mixture C: ADT ≤ 5,000

Mixture D:
- 2 lanes: ADT > 5,000
- 4 lanes: 5,001≤ ADT ≤ 25,000
- 6 lanes: ADT ≤ 60,000

Mixture E:
- 4 lanes: 25,001≤ ADT ≤ 100,000
- 6 lanes: 60,001≤ ADT ≤ 100,000

Mixture F: ADT > 100,000

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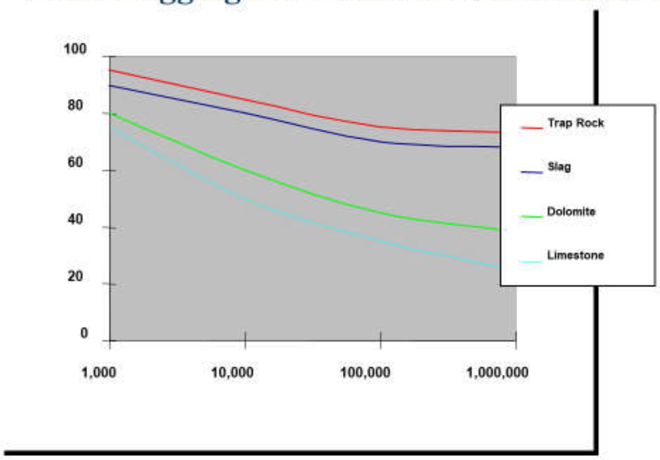
Coarse Aggregate Frictional Characteristics



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Aggregate Size Definitions

- *Nominal Maximum Aggregate Size*
  - one size larger than the first sieve to retain more than 10%
- *Maximum Aggregate Size*
  - one size larger than nominal maximum size

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IDOT Mixture Designation	Maximum Size	Nominal Maximum Size
IL-25.0 Binder	37.5 mm (1 1/2")	25 mm (1")
IL-19.0 Binder	25 mm (1")	19 mm (3/4")
IL-12.5 & IL-9.5 Surface		
CA13	19 mm (3/4")	12.5 mm (1/2")
CA16	12.5 mm (1/2")	9.5 mm (3/8")

II. 0.45 POWER CURVE - A TOOL TO AID IN BLENDING

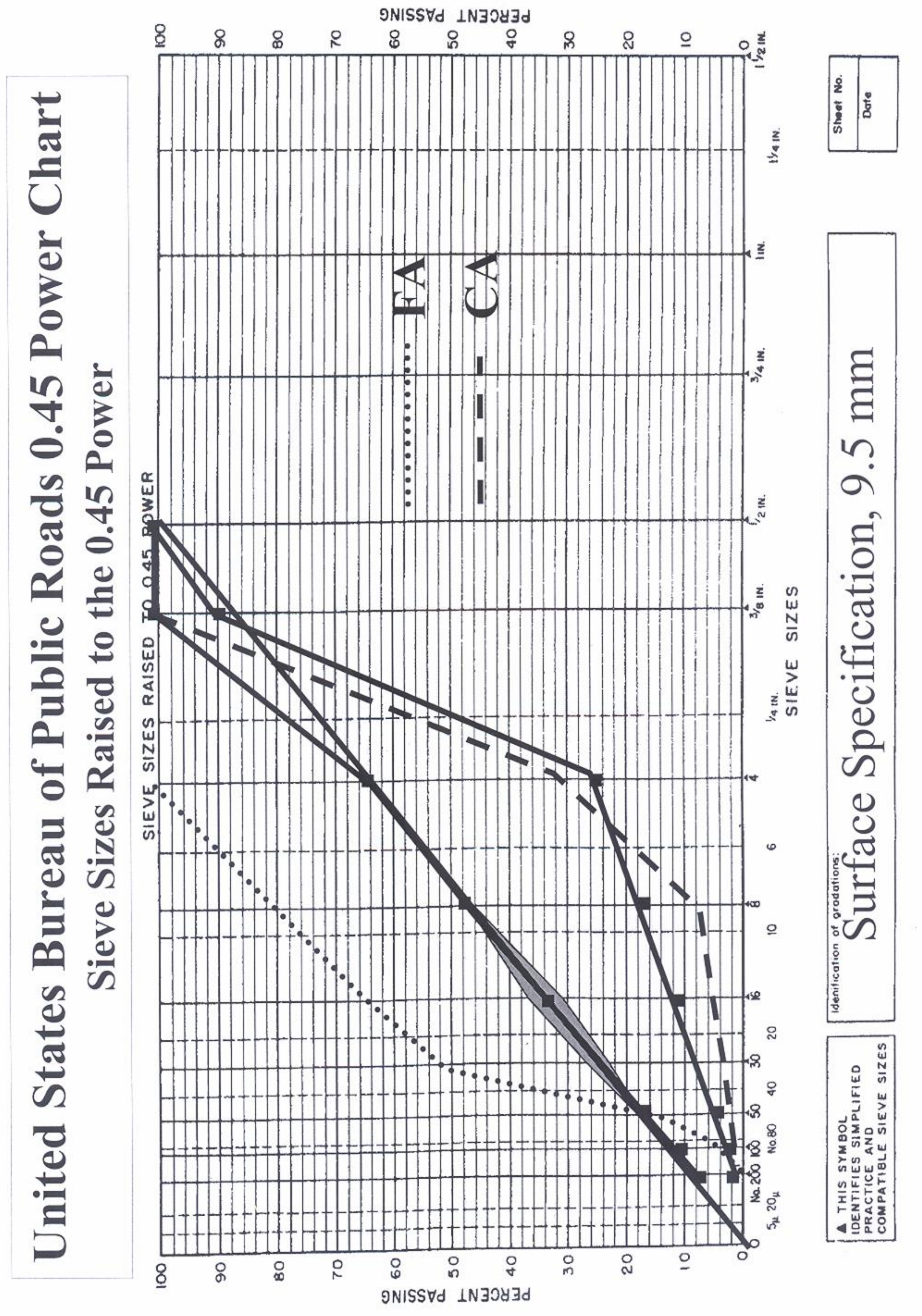
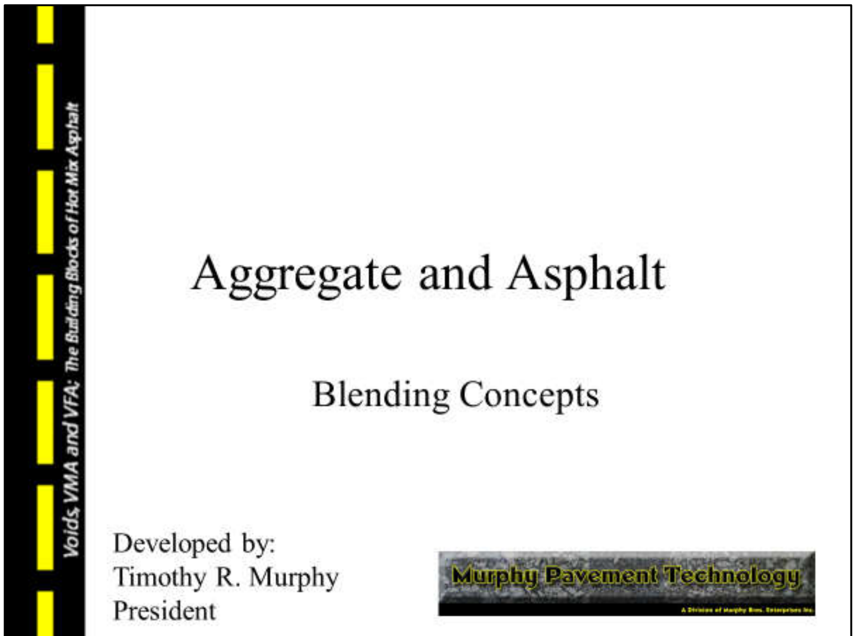
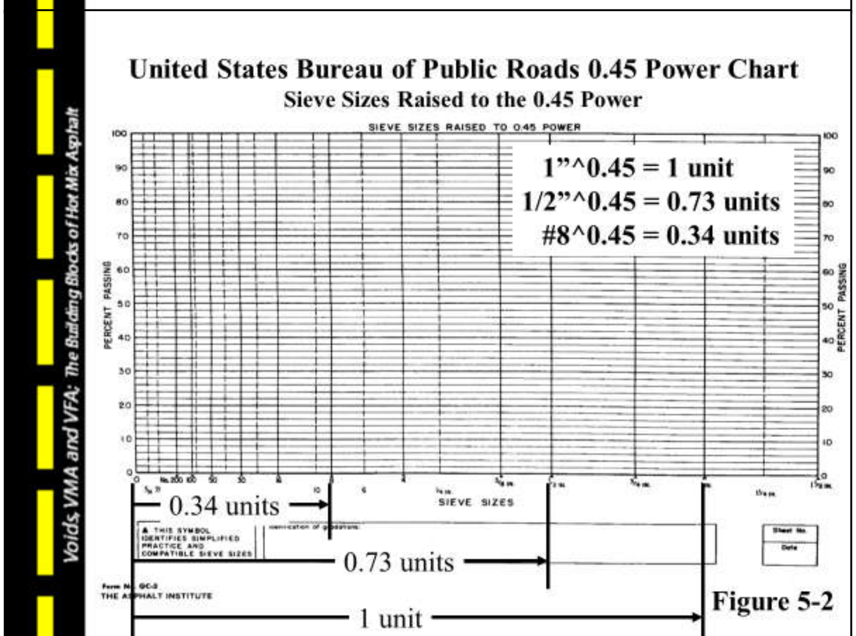
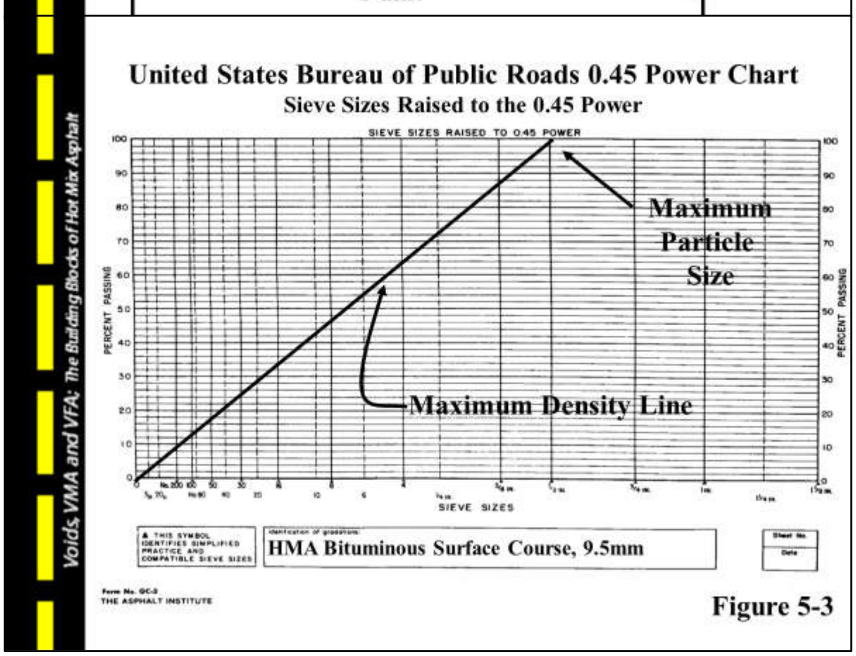


Figure 5-1







0.45 POWER CURVE–A TOOL TO AID IN BLENDING

The 0.45 power curve was developed by the Federal Highway Administration (FHWA) as a method to determine how densely round particles of the same specific gravity can be packed in a given volume.

A. Developing the Curve

The line originates at the bottom left corner and extends upward to the maximum particle size at 100%. This should be used as a tool, not an absolute rule, because of two problems.

Asphalt mixtures do not use round rocks of the same specific gravities.

There are numerous philosophies as to where the top of the line should be drawn.

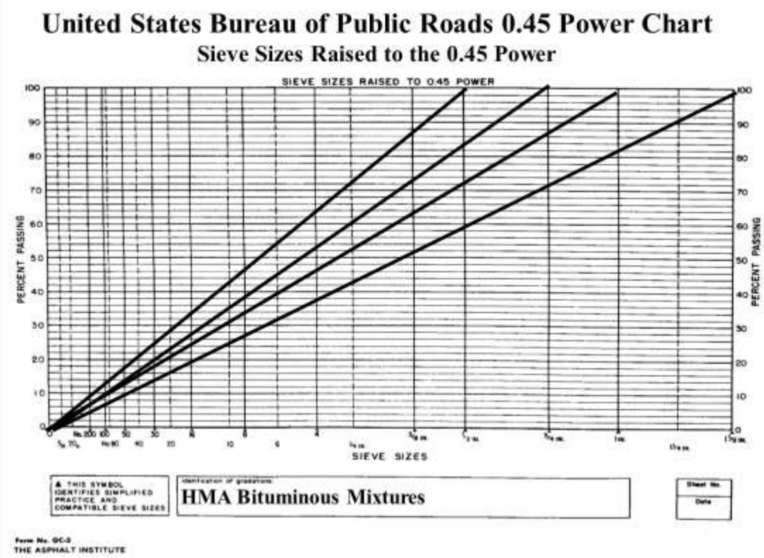
Following is a table showing the maximum and nominal maximum size designations for IDOT mixtures.

IDOT Mixture Designation	Maximum Size	Nominal Maximum Size
IL-25.0 Binder	37.5 mm (1 1/2")	25 mm (1")
IL-19.0 Binder	25 mm (1")	19 mm (3/4")
IL-12.5 & IL-9.5 Surface		
CA13	19 mm (3/4")	12.5 mm (1/2")
CA16	12.5 mm (1/2")	9.5 mm (3/8")

1. Illinois has developed "high-type" gradation bands for each of these mix sizes, plus finer "low-volume" gradations for the 19.0 and 9.5 mm mixes.

2. Illinois "recommends" that gradations not pass through the restricted zone.

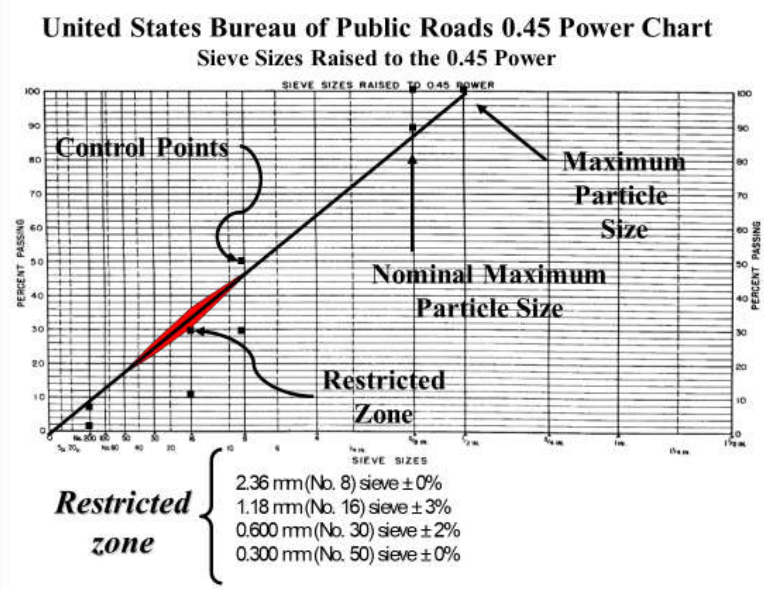
3. Illinois HMA gradations are contained in the January 1, 2022 Standard Specification for Road and Bridge Construction



Control points and the restricted zone are used as gradation boundaries.

Illinois believes current specs comply with the intent of HMA gradations.

National research is being conducted on the restricted zone.



The restricted zone is plotted on these sieves.

The ± values are applied to the maximum density line on the 0.45 power chart where it crosses the identified sieves.

2.36 mm (No. 8) sieve ± 0%
1.18 mm (No. 16) sieve ± 3%
0.600 mm (No. 30) sieve ± 2%
0.300 mm (No. 50) sieve ± 0%

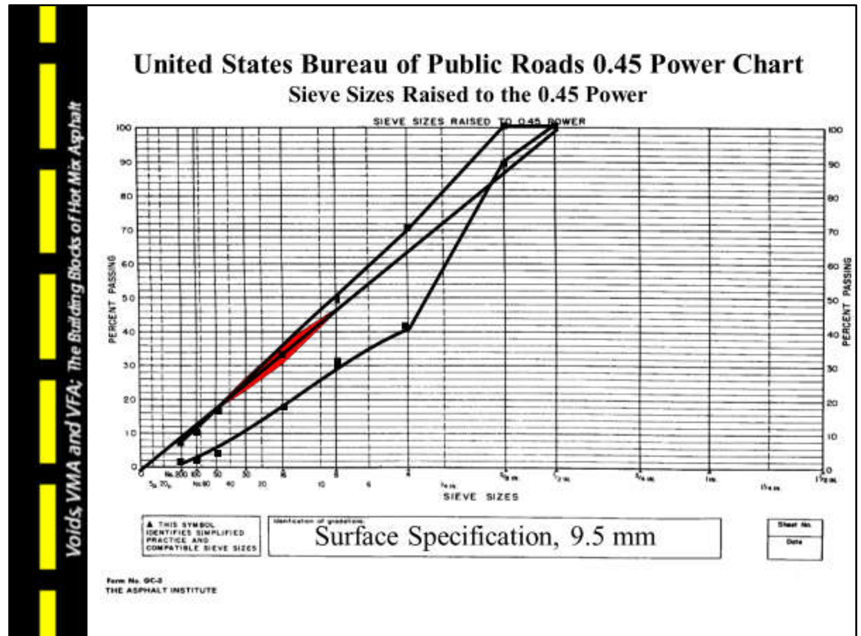
B. Combined Gradation Specification Ranges for Binder and Surface Mixtures

Specification limits surface mixtures are located primarily below the maximum density line on the 0.45 curve chart. This ensures coarse aggregate interlock; however, fine aggregate interlock using crushed sands has also made mixtures stronger.

See Figure 5.4

See Figure 5.5

C. 0.45 Power Curve Examples



This is the middle of the spec gradation for the 9.5 mm surface mix.

IDOT does not use the control points; they are shown for information only.

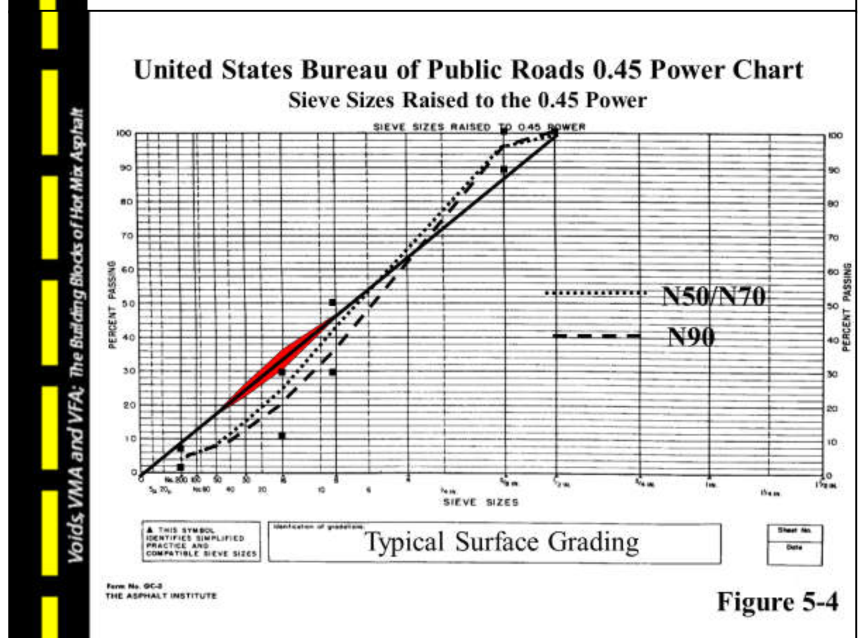


Figure 5-4

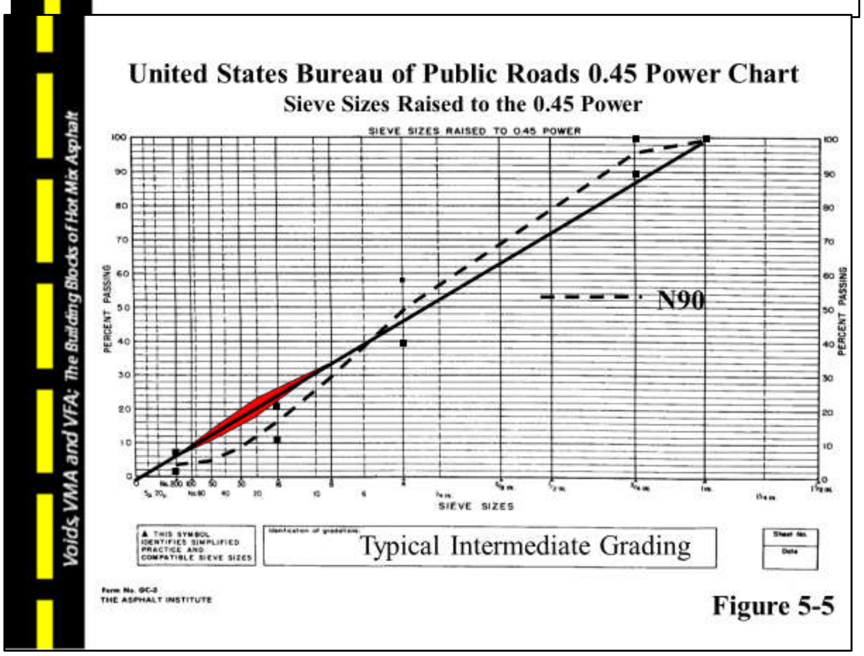


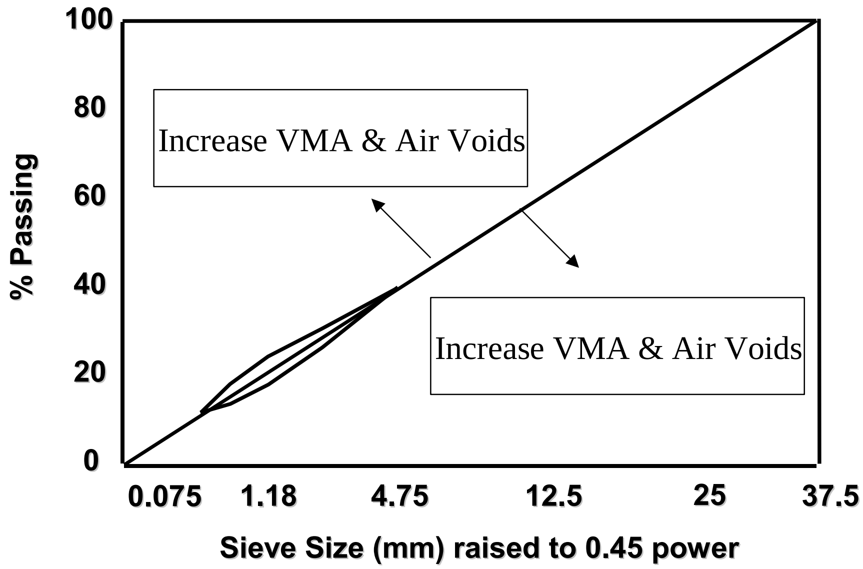
Figure 5-5

This is the middle of the spec gradation for the 19.0 mm binder mix.

IDOT does not use the control points; they are shown for information only.

D. Hints on Using 0.45 Curve

1. As the gradation moves away from the "maximum density" line, the VMA and air voids increase.



2. Plot of aggregate gradations should form a smooth line. Gap-graded mixtures, as shown, have a significant portion of material missing. The mix tends to segregate, and density can be difficult to achieve.

See Figure 5.6

3. Open-graded mixtures are coarse mixtures with little sand-sized (4.75-mm [No. 4] or 2.36-mm [No. 8]) material. This produces a high-void, open-textured mixture; it is difficult to keep the asphalt on the rocks during production and construction.

See Figure 5.7

4. Tender mix, which is also referred to as a mix containing a sand hump, is susceptible to rutting, is difficult to roll, and density is difficult to achieve. The problem and/or solution come from the sand blend. Increased manufactured sand reduces the problem while more natural sand increases the problem.

See Figure 5.8

The Strategic Highway Research Program (SHRP) also recognizes the problem and describes an area called the "restricted zone" through which gradations are not permitted to pass. This zone is described by limits placed on certain key sieves shown below.

See Figure 5.9

2.36 mm (No. 8) sieve ± 0%

1.18 mm (No. 16) sieve ± 3%

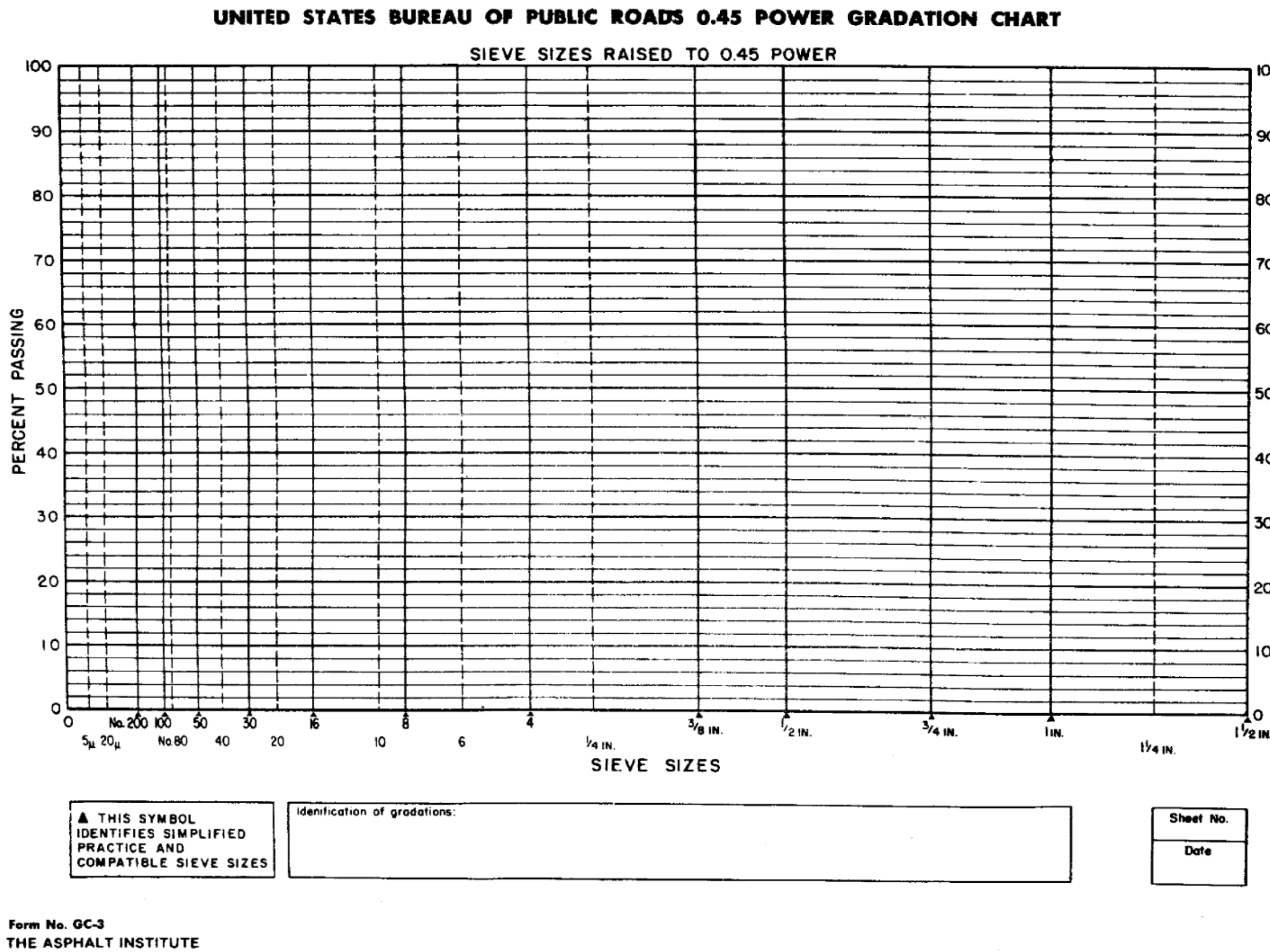
600 µm (No. 30) sieve ± 2%

300 µm (No. 50) sieve ± 0%

The ± values are applied to the maximum density line on the 0.45 power chart and where it crosses the identified sieves.

HMA Aggregate Gradation Example

E. Example



Sieve	Gradation
25.0 mm/1”	100
19.0 mm/3/4”	98
12.5 mm/1/2”	82
9.5 mm /3/8”	65
4.75 mm/;#4	44
2.36 mm/#8	28
1.18 mm#16	18
.600 mm/#30	12
.300 mm/#50	8
.150 mm/100	4
.075 mm/#200	3.5

Ndes = 90

Nominal Maximum Aggregate Size –

Maximum Size –

Draw Maximum Density Line

Plot Gradation Limits –

Plot Restricted Zone –

Plot Gradation –

Meet Criteria?

III. ACCURATE GRADATIONS FOR MIX DESIGN

- Most important phase of mix design.
- All aggregate used in Hot-Mix Asphalt must be produced under the "Aggregate Gradation Control System".
- Gradations must be based on the average of a minimum of 5 tests describing each specific aggregate - not a single test.
- All gradations shall be based on washed test samples.

A. Methods to Determine Aggregate Gradations of Material Stockpiled at the Asphalt Plant

1. "New" gradation test results from the stockpiles for each of the aggregate materials.
2. Gradations of each stockpile taken during production of previous projects (weekly tests of incoming materials).
3. Gradations taken from cold feed during previous projects.
4. Percent degradation of aggregates due to handling at the aggregate source and asphalt plant should be determined on previous projects. Typically, this degradation ranges from 1% to 3%. If an aggregate producer modifies his gradations for the next season, etc., use this percent degradation and the aggregate producer's new gradations to predict the gradation of each material at the asphalt plant.

B. Gradation of a New Source of Aggregate

Approximate the anticipated percent degradation by discussions with IDOT, aggregate supplier, or other users of the material. This percent degradation should be used to adjust the aggregate producer's gradations finer. Never adjust aggregate producer's gradation coarser.

C. Gradation of Mineral Filler (MF), Fly Ash, or Baghouse Fines (BHF)

1. MF and fly ash gradations can be obtained from IDOT district offices.

2. BHF must be sampled at the plant with a washed gradation performed. IDOT will perform specific gravity on the BHF.

3. BHF should be the same material as the coarse aggregate in the mix. (Example: Limestone CA and Limestone BHF - not Limestone CA and Slag or RAP BHF.)

D. Gradation of RAP Stockpiles

RAP gradations must be determined using the results from washed extractions, as set forth in Article 1031 of the current: *Standard Specifications for Road and Bridge Construction.*

IV. TRIAL AND ERROR BLENDING AND GRAPHICAL SOLUTIONS

A. Graphical solutions work well for mixtures containing 2 or maybe 3 ingredient materials. The steps are as follows:

See Figure 5.10

1. The percents passing the various sizes for aggregate "A" are plotted on the right-hand vertical scale. Percents passing the various sizes for aggregate "B" are plotted on the left-hand side.

See Figure 5.11

2. Connect the points common to the same sieve size with straight lines and label them.

3. Plot the specification limits on the appropriate sieve line as measured from the vertical scale. The portion of the line between the two points represents the proportions of aggregates "B" and "A", indicated on the top and bottom horizontal scales, that will not exceed specification limits for that particular sieve size.

4. The portion of the horizontal scale designated by two vertical lines, when projected within specification limits for all sizes, represents the limits of the proportions possible for satisfactory blends.

See Figure5.12

5. This procedure can be used when adding a third ingredient, but only in small proportions, such as mineral filler. The proportions of aggregate "A" and/or "B" may be decreased by a small percentage but should still give a good concept of the range of acceptable blend percent.

6. Plot on 0.45 power curve of potential gradation.

See Figure 5.13

B. Trial and Error Blending

In this method of blending aggregates, a range of possible blend percentages is not determined. A single blend percentage is evaluated. Additional calculations are required to determine other potential blend percentages.

1. Basic Equation. This equation is used for each sieve for any number of ingredient materials and is very time-consuming.

See Figure 5.14

2. Look at the gradation of each of the different aggregate materials and determine which contributes most to a particular size fraction.

Fine Aggregates				
	% Passing			
Sieve	FA01	FA02	FA20	FA21
4.75 mm (No. 4)	97 ± 3	97 ± 3	97 ± 3	97 ± 3
2.36 mm (No. 8)			80 ± 20	80 ± 20
1.18 mm (No. 16)	65 ± 20	65 ± 20	50 ± 15	57 ± 18
300 µm (No. 50)	16 ± 13	20 ± 10	19 ± 11	30 ± 10
150 µm (No. 100)	5 ± 5	5 ± 5	10 ± 7	20 ± 10
75 µm (No. 200)			4 ± 4	9 ± 9

Coarse Aggregates				
	% Passing			
Sieve	CA07	CA11	CA13	CA16
25 mm (1")	95 ± 5			
19 mm (3/4")		92 ± 8		
12.5 mm (1/2")	45 ± 15	45 ± 15	97 ± 3	
9.5 mm (3/8")			80 ± 10	97 ± 3
4.75 mm (No. 4)	5 ± 5	6 ± 6	30 ± 15	30 ± 15
1.18 mm (No. 16)		4 ± 4	4 ± 4	4 ± 4

See Figure 5.15

3. Using almost the same design as shown in the graphical solution, let's look at the trial and error method. In this case we have two sands to work with instead of one. Pick two or three key sieves to look at first and aim at the target values. The 4.75-mm (No. 4) and 2.36-mm (No. 8) are key sieves when controlling the CM13.

4. Maximum amount of sand should be determined. Try 100%, 50%, then slight variations usually less than 50%.

5. Complete the remainder of the blending chart and check to make sure the other sieves are within specifications. Consider adding MF. This is only one possible solution. Performing this same analysis and changing the target values could yield additional alternatives.

6. For a three-ingredient material blend, obtain the most possible combinations using aggregates with gradations in the middle of the specification band. The least amount of possible combinations consist of a coarsely graded material and a finely graded material.

C. Example Binder Problem -
Key Sieves: 12.5 mm (1/2"),
4.75 mm (No. 4), 600 µm (No. 30),
minus 75 µm (minus No. 200)

1. The first step is to determine the percent of material passing the 4.75-mm (No. 4) sieve. Next, select the percent material passing the 4.75-mm (No. 4) sieve and retained on the 2.36-mm (No. 8) sieve. Generally, for Ndesign = 90 mixes this is 12% ± 2%, and for Ndesign ≤ 70 mixes this is 10.5% ± 2%. The larger the amount between the 4.75-mm (No. 4) and 2.36-mm (No. 8), generally the higher the voids and VMA up to a maximum of 15% to 16%. This will allow determination of the split on the coarse and fine material. Try 100% sand, 50% sand, and lower percents until below the target on the 2.36-mm (No. 8) sieve.

See Figure 5.16

2. A 69% coarse aggregate and 31% fine aggregate split should be close. Next, determine the percent chips (CM16) using the 12.5-mm (1/2") and 4.75-mm (No. 4) sieves.

3. Chips in the range of 20% to 30% would be adequate.

4. The 12.5-mm (1/2") and 4.75-mm (No. 4) sieves look adequate. Now let's determine our sand blend. Start at 50/50 while looking at the 600-µm (No. 30) and 75-µm (No. 200) sieves. Once the sand blends are close to the 600-µm (No. 30) target and are not exceeding the minus 75-µm (minus No. 200) target, complete the remainder of the worksheet. Check the other sieves for specification compliance.

5. Plot on the 0.45 power curve. Should we do any fine tuning? Should we add MF or BHF?

See Figure 5.17

6. Fine Tuning. The problem is near the 2.36-mm (No. 8) to 600-µm (No. 30) sieves; the plot does not follow a straight line. To reduce this material for a binder, look at either the sand blend, the coarse-to-fine percent, or the CM11 and chip blend. Slight changes should result in getting closer to initial target values. In this situation, change the sand blends slightly.

7. Complete the remainder of the work-sheet and check the other sieves for specification compliance. Notice the minus 75 µm (minus No. 200) is low (target = 4%, gradation = 2%).

8. Evaluate the use of mineral filler (MF) or baghouse fines (BHF) in the design stage. This stage of the mix design correlates specifically to the field production of the mixture. This design needs approximately 1% more minus 75-µm (minus No. 200) material. By adding 1% of the total minus 75-µm (minus No. 200) and by reducing the sands (FM20 and FA01) by 1%, the total minus 75-µm (minus No. 200) equals 3%.

9. Complete the remainder of the work-sheet to check for specification com-pliance. This is only one solution or trial gradation that could work for this combination of aggregates.

See Figure 5.18

10. Let's discuss the use of MF or BHF in more detail because it is relatively important. Aggregates typically break down and become finer during the field mixing process. The use of MF or BHF in the design stage attempts to replace the anticipated breakdown seen in the field. This is generally in the range of 1% to 3% MF or BHF for unwashed aggregate products and 0.5% to 3% for washed aggregates. The mix as designed in the lab must be reproducible in the field or production will cease and a new design will be required. If a design indicates no MF or BHF is required, the design will not be reproducible in the field.

11. Initial minus 75-µm (minus No. 200) in the design stage should have a minimum of about 3-4% for binder and 4-5% for surface. The maximum should be a dust content creating a dust/AC ratio of no more than 1.0. This is based on the combined blend of washed aggregate gradations.

12. The last item to look at is meeting the minimum 67/33 sand blends by weight for Ndesign = 90 and 50/50 sand blends for N50 and N70 mixes. In no case shall the percent for the natural sand exceed the crushed or manufactured sand by weight.

<u>Use of Mineral Filler or Baghouse Fines</u>

1. Attempts to replace anticipated breakdown of aggregate during field production in the design stage.

2. Non-reproducible designs require plant shutdown.

3. Aggregate combinations not utilizing MF or BHF have high potential of being non-reproducible.

4. Minimum and maximum minus 75 µm (minus No. 200) values in the design stage.

V. COST

It is easy to determine how total price of combined aggregate is influenced by the less expensive aggregate. This cost is misleading because asphalt is the most expensive material, so the absorption, size, and shape of the aggregate should be considered to determine the least expensive mixture price.

Generally, the least expensive aggregate materials give reduced performance characteristics. Therefore, if there is trouble meeting design criteria, the addition of more expensive, better quality aggregate will be required. This may also require a change to another source of material.

Insert two more example problems

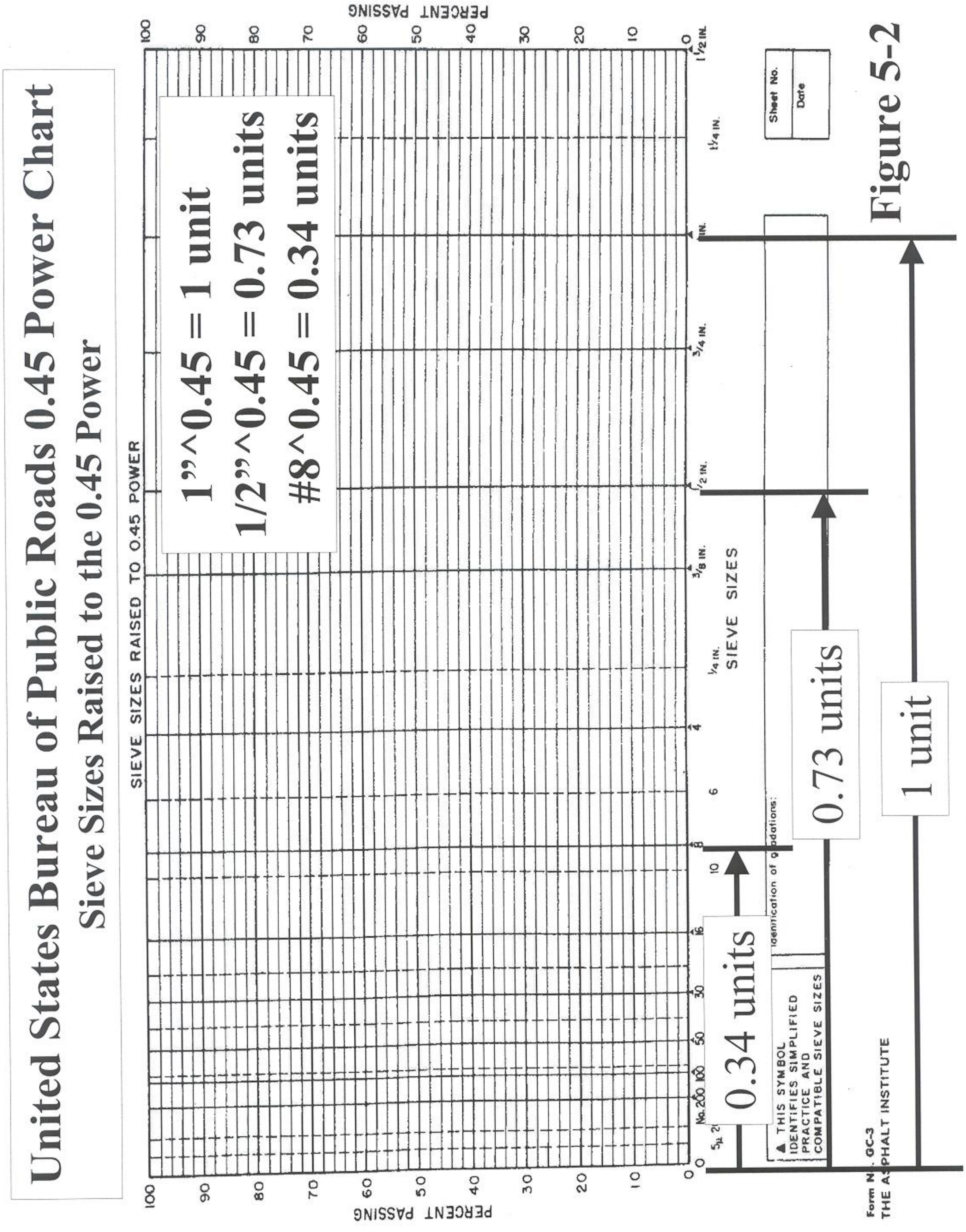

United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
1"^0.45 = 1 unit
1/2"^0.45 = 0.73 units
#8^0.45 = 0.34 units
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
SIEVE SIZES
0.34 units
0.73 units
1 unit
Sheet No.
Date
THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Form No. GC-3
THE ASPHALT INSTITUTE

Figure 5-2

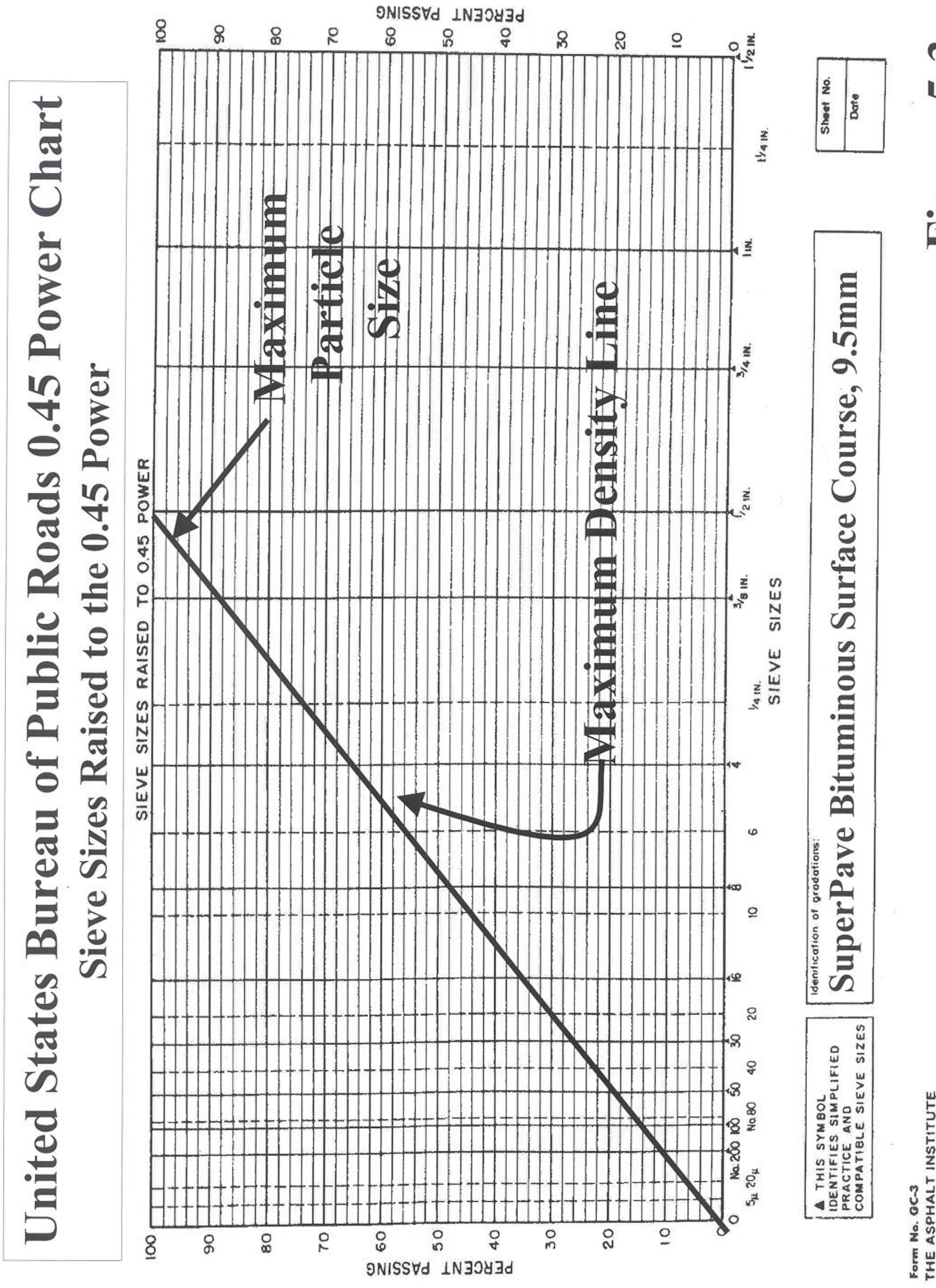

United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
SIEVE SIZES RAISED TO 0.45 POWER
Maximum Particle Size
Maximum Density Line
PERCENT PASSING
0
10
20
30
40
50
60
70
80
90
100
5µ 20µ
No.200 100
No.80
50
40
30
20
16
10
8
6
4
1/4 IN.
3/8 IN.
1/2 IN.
3/4 IN.
1 IN.
1 1/4 IN.
1 1/2 IN.
SIEVE SIZES
▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Identification of gradations:
SuperPave Bituminous Surface Course, 9.5mm
Sheet No.
Date
Form No. GC-3
THE ASPHALT INSTITUTE

Figure 5-3

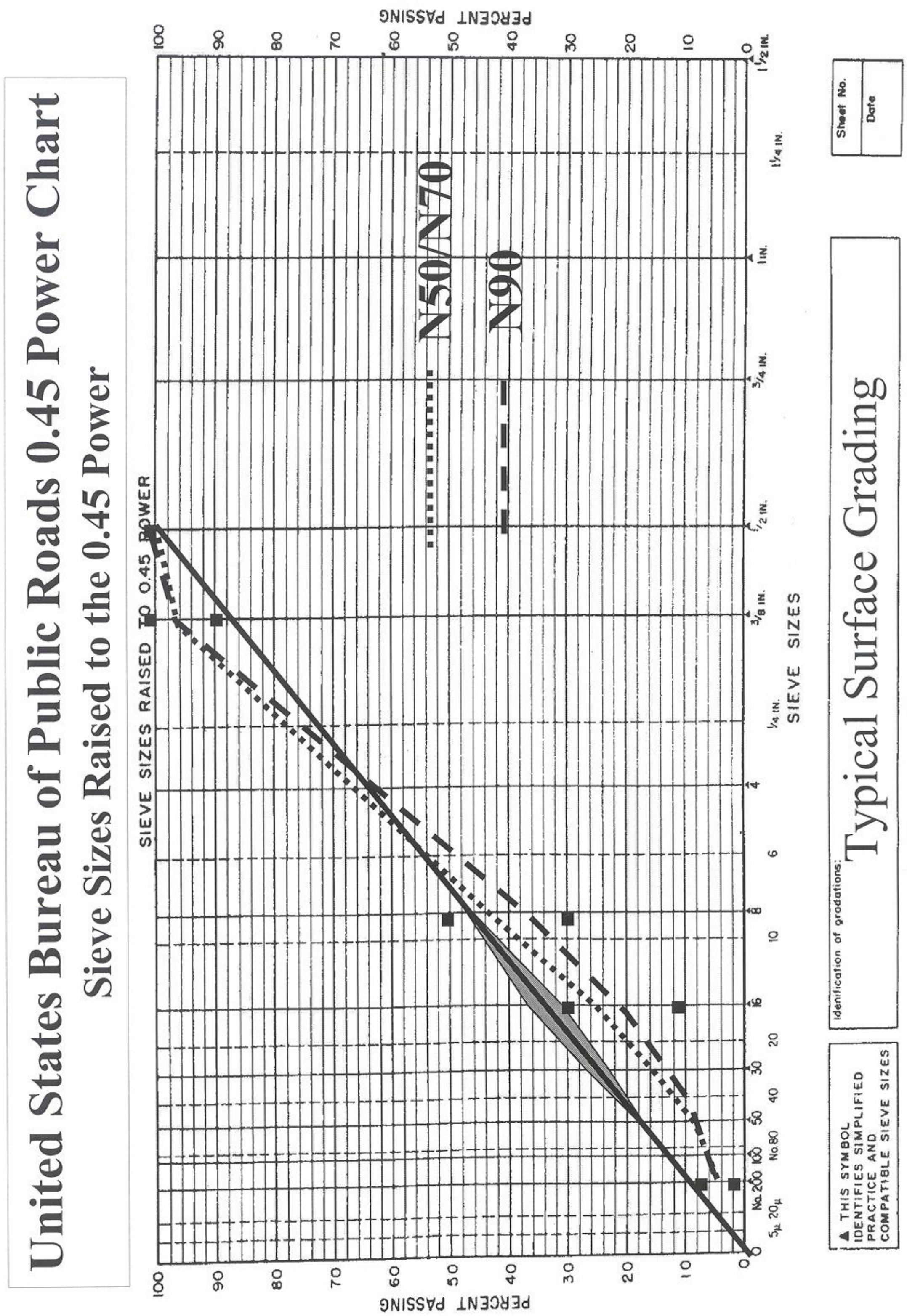

United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
SIEVE SIZES
N50/N70
N90
THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Identification of gradations:
Typical Surface Grading
Sheet No.
Date
Form No. GC-3
THE ASPHALT INSTITUTE

Figure 5-4

United States Bureau of Public Roads 0.45 Power Chart

Sieve Sizes Raised to the 0.45 Power

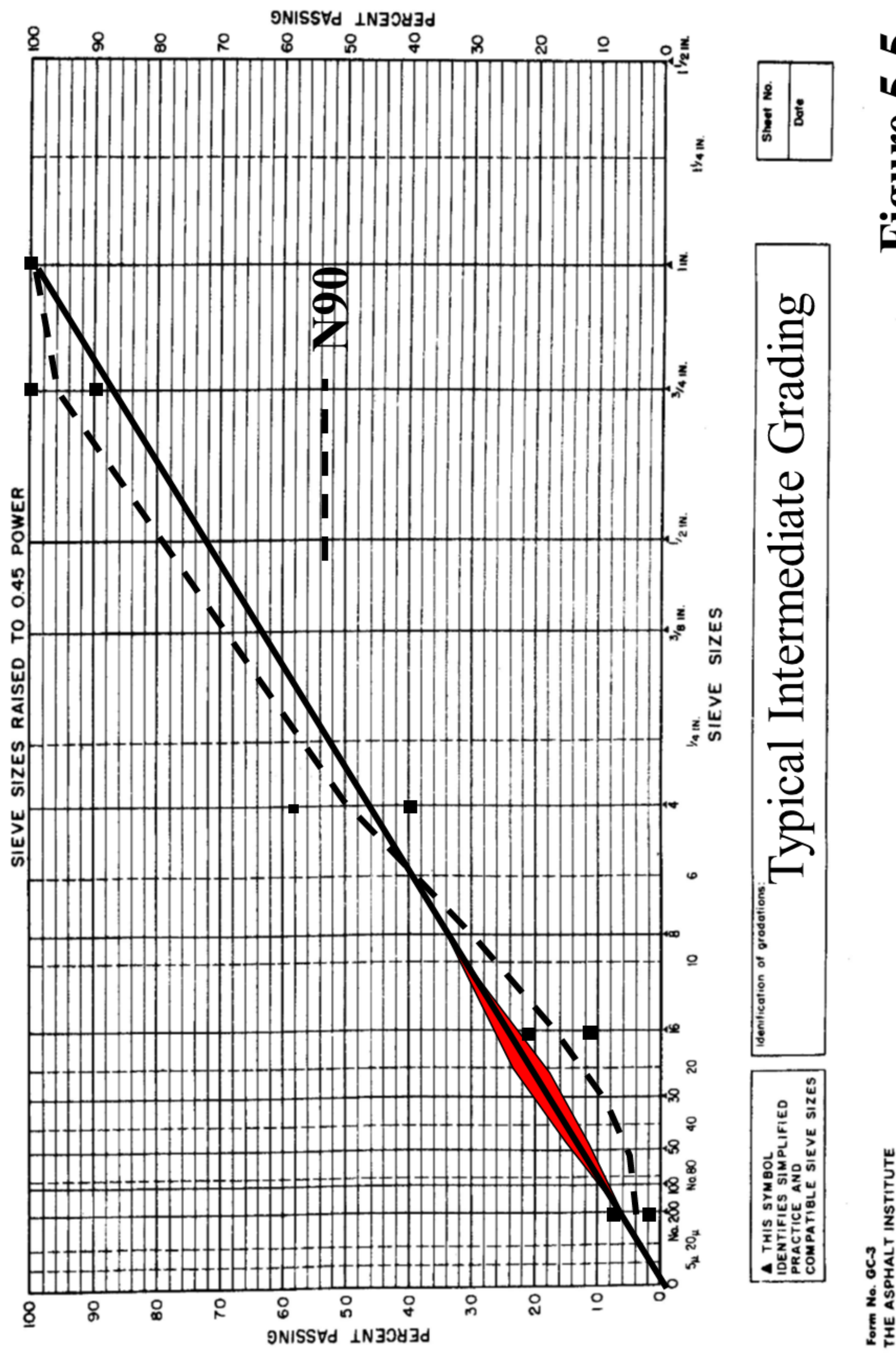
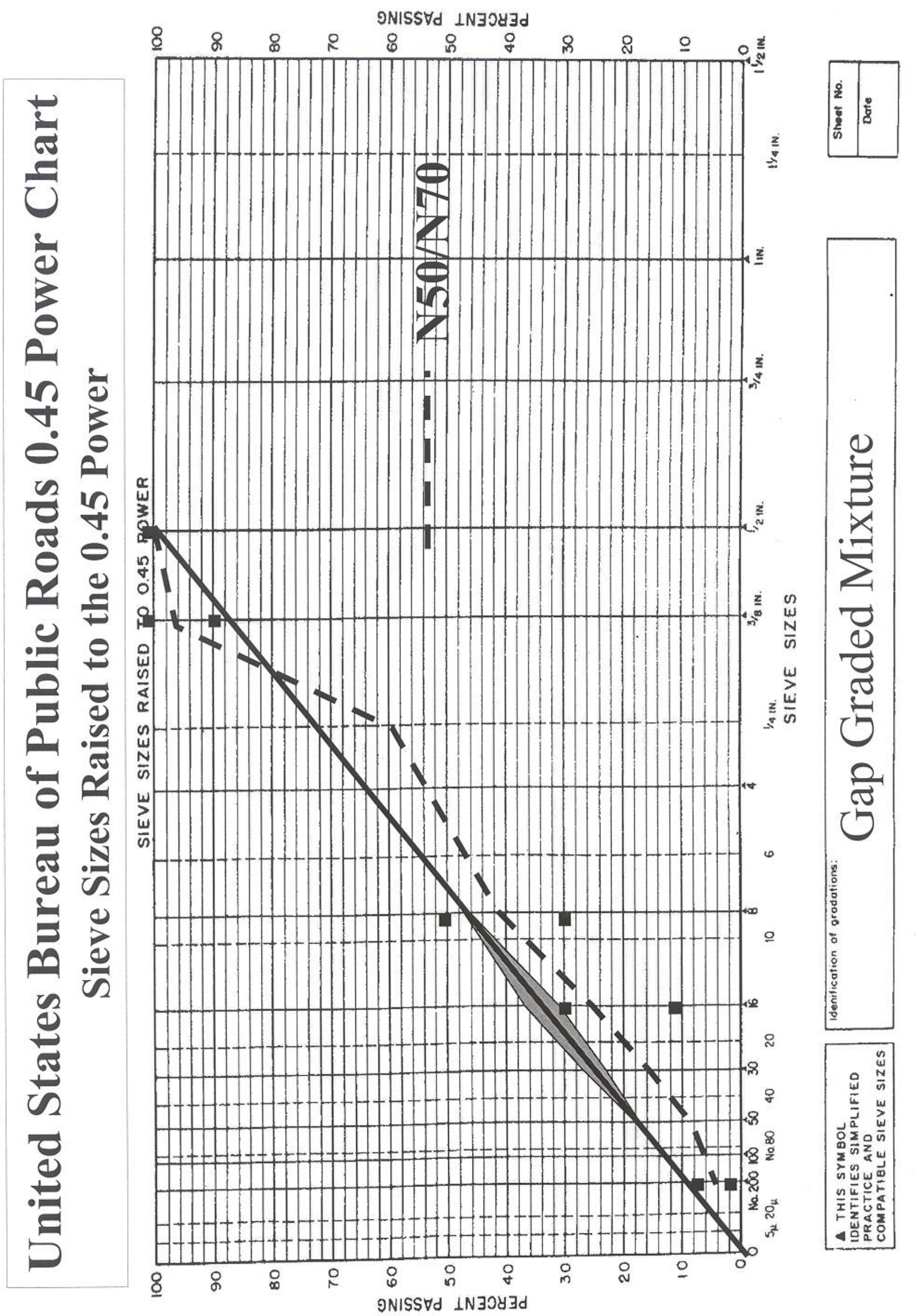


Figure 5-5



Form No. GC-3
THE ASPHALT INSTITUTE

Figure 5-6

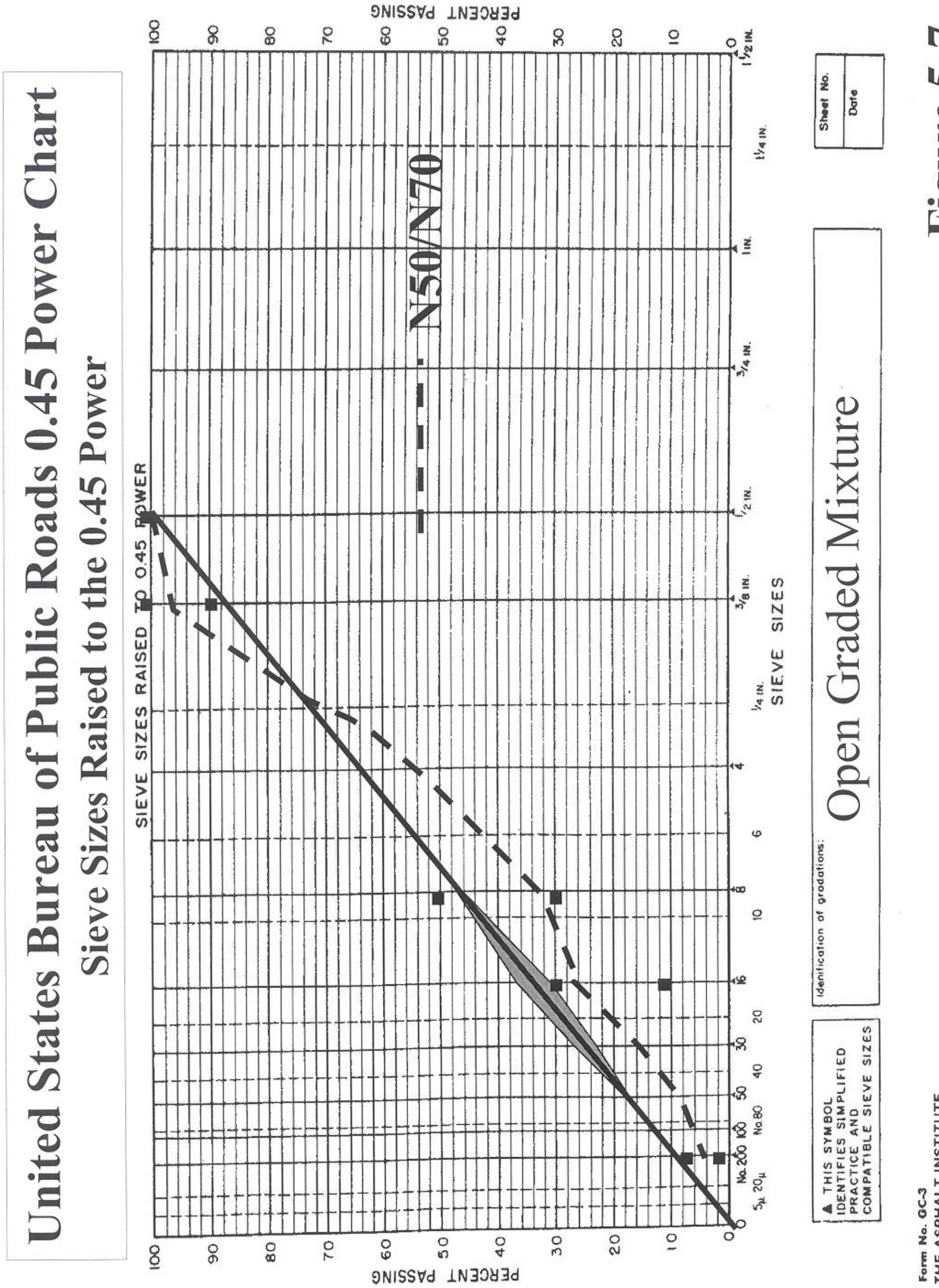
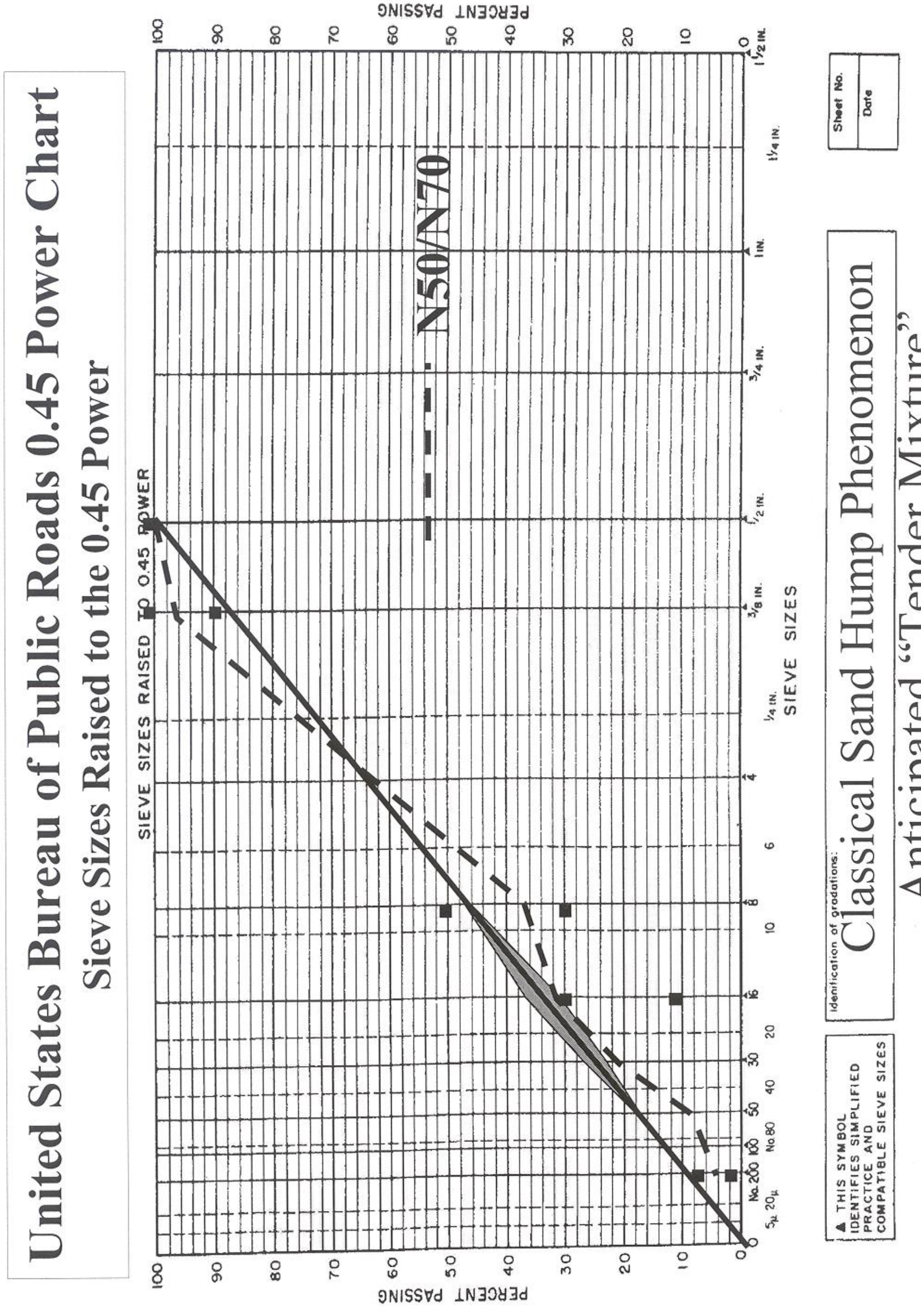
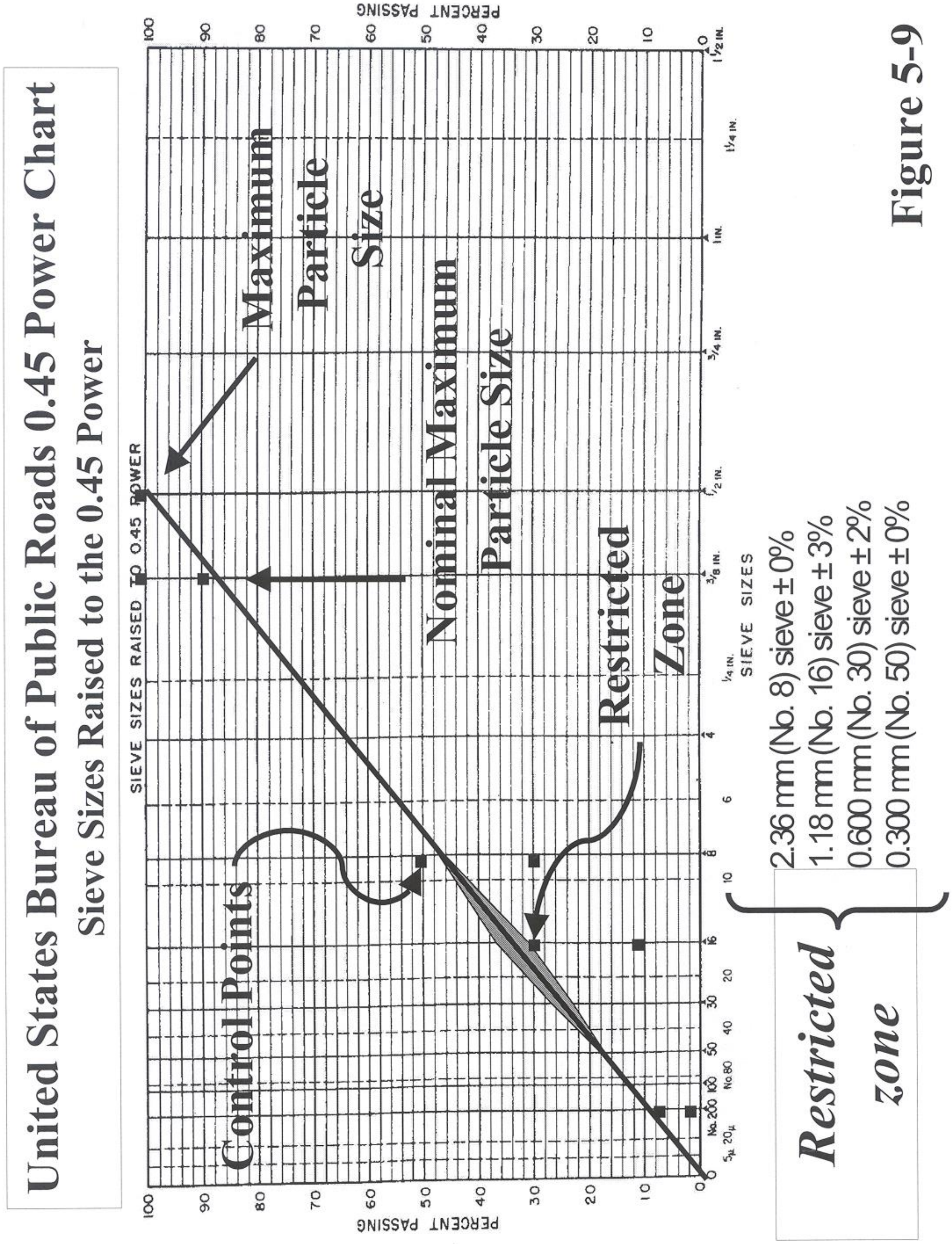

United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
N50/N70
SIEVE SIZES
Identification of gradations:
Open Graded Mixture
THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Sheet No.
Date
Form No. GC-3
THE ASPHALT INSTITUTE

Figure 5-7



United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
SIEVE SIZES
N50/N70
Classical Sand Hump Phenomenon
Anticipated "Tender Mixture"
Identification of gradations:
▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Sheet No.
Date
Form No. QC-3
THE ASPHALT INSTITUTE

Figure 5-8

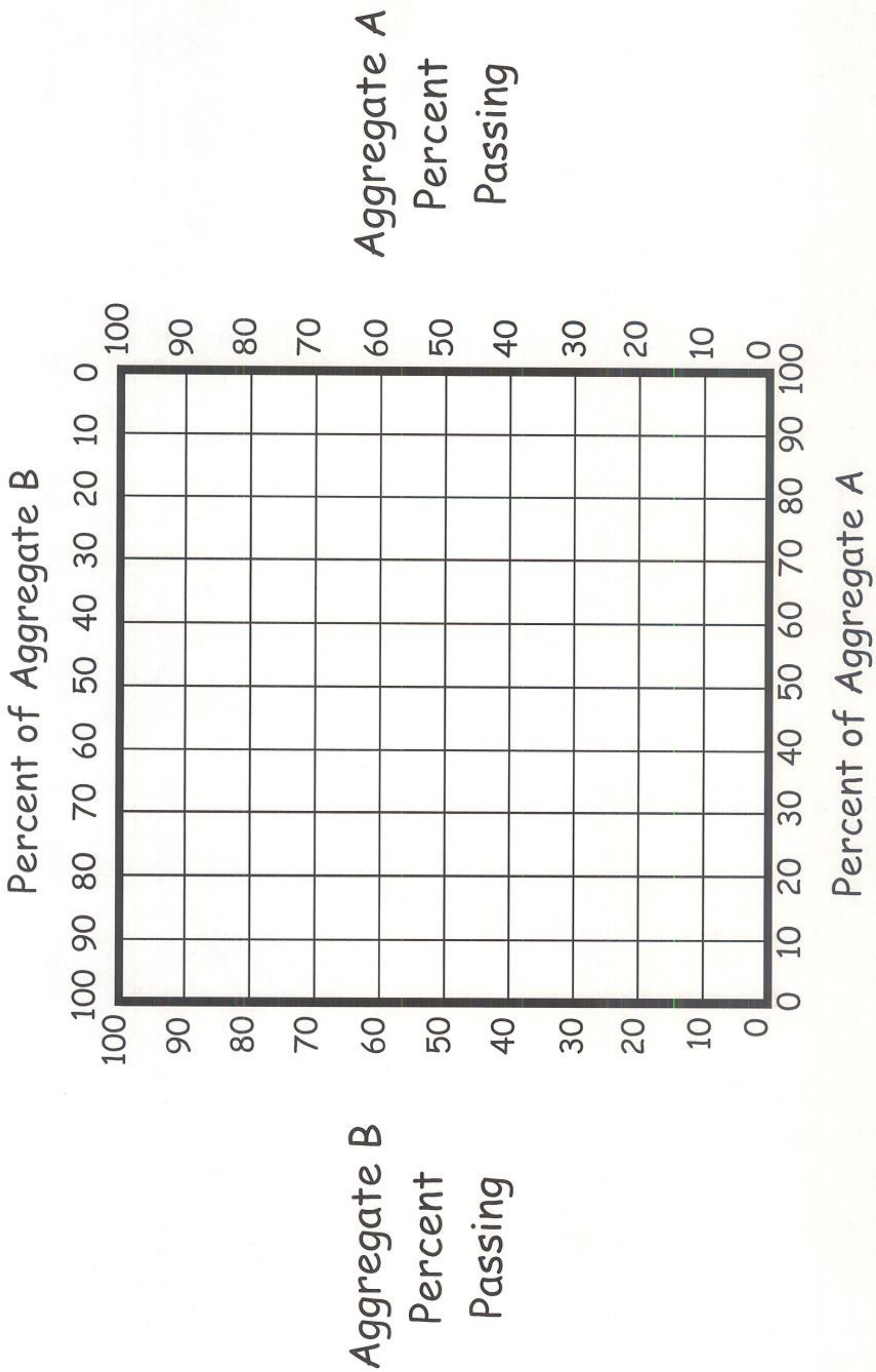


United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
Maximum Particle Size
Nominal Maximum Particle Size
Control Points
Restricted Zone
SIEVE SIZES
2.36 mm (No. 8) sieve ± 0%
1.18 mm (No. 16) sieve ± 3%
0.600 mm (No. 30) sieve ± 2%
0.300 mm (No. 50) sieve ± 0%
Restricted zone

Figure 5-9

Figure 5-10 Surface Design, N50, 9.5mm

Material	CM			FA					
Source									
Percent							Combined	Target	Spec.
Used			%			%	Gradation	Value	Limits
Sieves	Wt. Ret.	% Pass	% For Mix	Wt. Ret.	% Pass	% For Mix	%	%	%
Total									
37.5									
25.0									
19.0									
12.5									
9.5									
4.75									
2.36									
1.18									
600µ									
75µ									
PAN									



Proportioning Two Aggregates

FIGURE 5-11

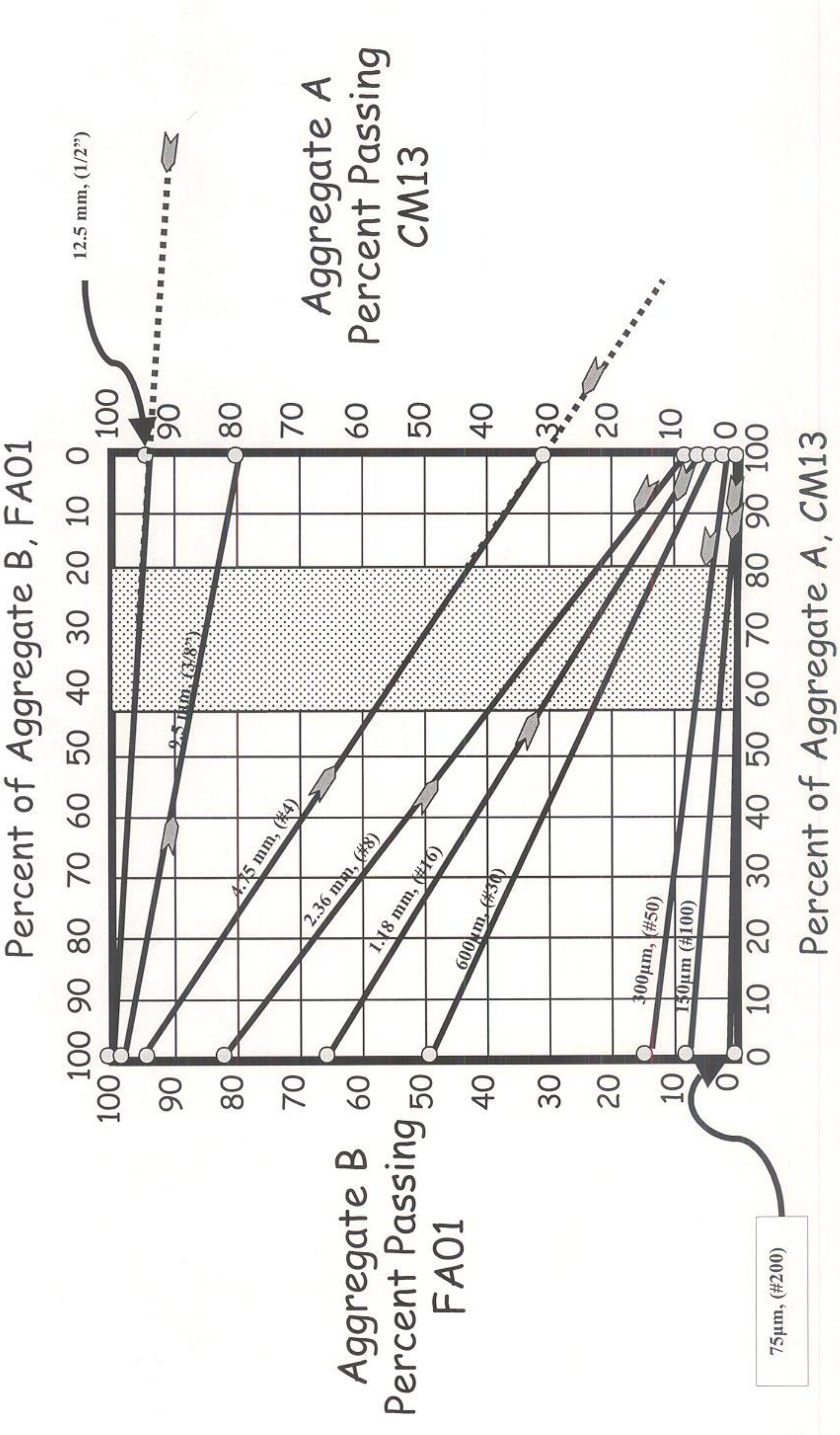


FIGURE 5-12

Proportioning Two Aggregates

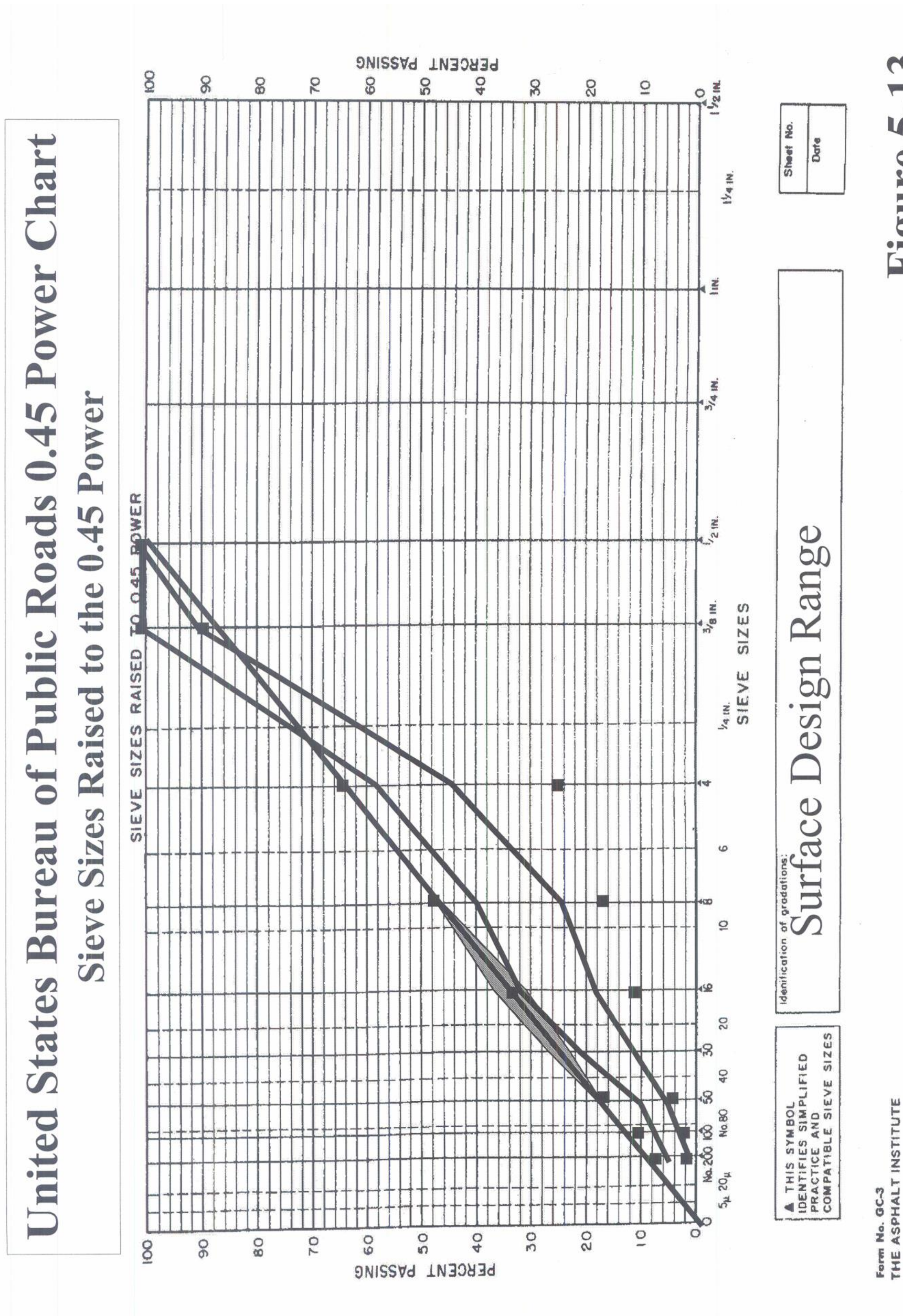

United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
SIEVE SIZES
Identification of gradations:
Surface Design Range
▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Sheet No.
Date
Form No. GC-3
THE ASPHALT INSTITUTE

Figure 5-13

Basic equation for blending aggregates

P = Aa + Bb + Cc + …

Where, P	=	the percentage of the combined aggregate passing a given sieve;
A, B, C,…	=	percentage of material passing a given sieve for the individual aggregates; and
a, b, c,…	=	proportions of individual aggregates used in the combination; where the total equals 1.0

Figure 5-14

Figure 5.14a

BLENDING SEQUENCE

<u>BINDER DESIGN</u>:

1. Select the % passing the 4.75-mm (No. 4) sieve.

2. Determine the material between the 4.75-mm (No. 4) and the 2.36-mm (No. 8) sieves. This determines the target for the % passing the 2.36-mm (No. 8) sieve.

3. Determine the fine aggregate (FA) blend fraction % by adding FA until the % passing is 3% to 4% lower than the target established on the 2.36-mm (No. 8) sieve.

4. The coarse aggregate (CA) fraction equals 100 minus the % FA. Divide the CA fraction into chips and large stone based on the 12.5-mm (1/2-inch) sieve and the already established 4.75-mm (No. 4) sieve.

5. Select the blend % for each sand (if required) to equal the FA fraction based on the 600-µm (No. 30) and the 75-µm (No. 200) sieves.

6. Add in the anticipated degradation quantity based on the increase in minus 75-µm (minus No. 200) material. Use the MF or BHF column.

7. Calculate the % passing for all the sieves based on the blend % and check that the combined gradation is within the master gradation for all the sieves.

8. Plot the combined gradation on the 0.45 power curve and make any adjustments warranted.

Figure 5.14b

BLENDING SEQUENCE

<u>SURFACE DESIGN</u>:

1. Establish a target value on the 2.36-mm (No. 8) sieve.

2. Determine the fine aggregate (FA) blend fraction % by adding FA until the % passing is 3% to 4% lower than the target established on the 2.36-mm (No. 8) sieve.

3. The remaining material is the % of chips or coarse aggregate. This can be material from a single source or multiple sources.

4. Select the blend % for each sand (if required) to equal the FA fraction based on the 600-µm (No. 30) and the 75-µm (No. 200) sieves.

5. Add in the anticipated degradation quantity based on the increase in minus 75-µm (minus No. 200) material. Use the MF or BHF column.

6. Calculate the % passing for all the sieves based on the blend % and check that the combined gradation is within the master gradation for all the sieves.

7. Plot the combined gradation on the 0.45 power curve and make any adjustments warranted.

Surface Design, N70 9.5mm

Material	CM16		FM20		FA01		MF / Breakdown				
Source											
Percent									Combined	Target	Spec.
Used		%		%		%		%	Gradation	Value	Limits
Sieves	% Pass	% For Mix	% Pass	% For Mix	% Pass	% For Mix	% Pass	% For Mix	%	%	%
37.5	100										
25.0	100										
19.0	100										
12.5	100										
9.5	97		100		100		100				
4.75	30		97		97		100				
2.36	7		70		82		100				
1.18	4		50		65		100				
0.600	3		30		50		100				
0.300	3		19		16		100				
0.015	3		10		5		97				
0.075	2.0		4.0		0.4		90.0				
PAN											

Figure 5-15

Binder Design, N90 19.0 mm

Material	CM11		CM16		FM20		FA01		MF / Breakdown				
Source													
Percent											Combined	Target	Spec.
Used		%		%		%		%		%	Gradation	Value	Limits
Sieves	% Pass	% For Mix	% Pass	% For Mix	% Pass	% For Mix	% Pass	% For Mix	% Pass	% For Mix	%	%	%
37.5	100		100										
25.0	100		100										
19.0	92		100										
12.5	45		100										
9.5	10		97		100		100		100				
4.75	6		30		97		97		100				
2.36	5		7		70		82		100				
1.18	4		4		50		65		100				
0.600	3		3		30		50		100				
0.300	3		3		19		16		100				
0.015	2		3		10		5		97				
0.075	2.0		2.0		4.0		0.4		90.0				
PAN													

Figure 5-16

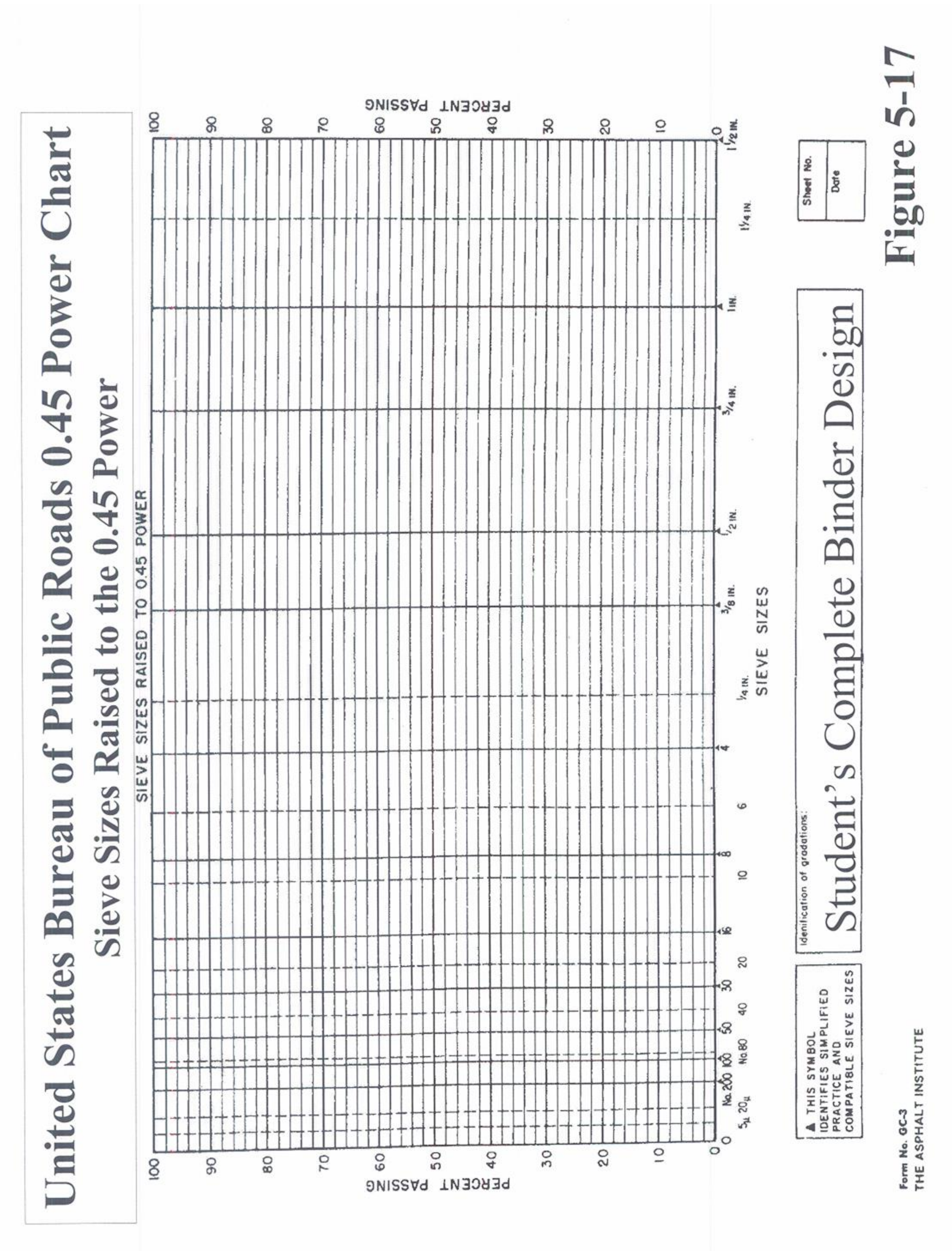

United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
100
90
80
70
60
50
40
30
20
10
0
SIEVE SIZES
5µ 20µ
No. 200 100
No. 80
50
40
30
20
16
10
8
6
4
1/4 IN.
3/8 IN.
1/2 IN.
3/4 IN.
1 IN.
1 1/4 IN.
1 1/2 IN.
▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Identification of gradations:
Student's Complete Binder Design
Sheet No.
Date
Form No. GC-3
THE ASPHALT INSTITUTE

Figure 5-17

Figure 5-18

Binder Design, N90 19.0 mm

Material	CM11		CM16		FM20		FA01		MF / Breakdown				
Source													
Percent											Combined	Target	Spec.
Used		%		%		%		%		%	Gradation	Value	Limits
Sieves	% Pass	% For Mix	% Pass	% For Mix	% Pass	% For Mix	% Pass	% For Mix	% Pass	% For Mix	%	%	%
37.5	100		100										
25.0	100		100										
19.0	92		100										
12.5	45		100										
9.5	10		97		100		100		100				
4.75	6		30		97		97		100				
2.36	5		7		70		82		100				
1.18	4		4		50		65		100				
0.600	3		3		30		50		100				
0.300	3		3		19		16		100				
0.015	2		3		10		5		97				
0.075	2.0		2.0		4.0		0.4		90.0				
PAN													

What about 50 or 70 Gyration Binder Mix?

AGGREGATE BLENDING

Date ______________________

Contract Homework

Mixture HMA Binder, N90

Material	CA11			CA16			FA20			FA01			Breakdown					
Source																		
Percent Used	______%			______%			______%			______%			______%			Combined Gradation %	Target Value	Spec. Limits
Sieves	Frac Wt. Ret	% Pass	% For Mix	Frac Wt. Ret	% Pass	% For Mix	Frac Wt. Ret	% Pass	% For Mix	Frac Wt. Ret	% Pass	% For Mix	Frac Wt. Ret	% Pass	% For Mix		%	%
TOTAL																		
37.5																		
25.0		100			100			100			100			100				
19.0		94			100			100			100			100				
12.5		40			100			100			100			100				
9.5		18			97			100			100			100				
4.75		5			31			98			97			100				
2.36		3			8			66			81			100				
1.18		3			5			37			65			100				
600µ		3			4			20			48			100				
300µ		2			4			12			18			100				
150µ		2			4			8			3			99				
75µ		2			1			4.8			1.5			88				
PAN																		

HOMEWORK #1

AGGREGATE BLENDING

During Lab

Date Tuesday Assignment

Contract Level III Class

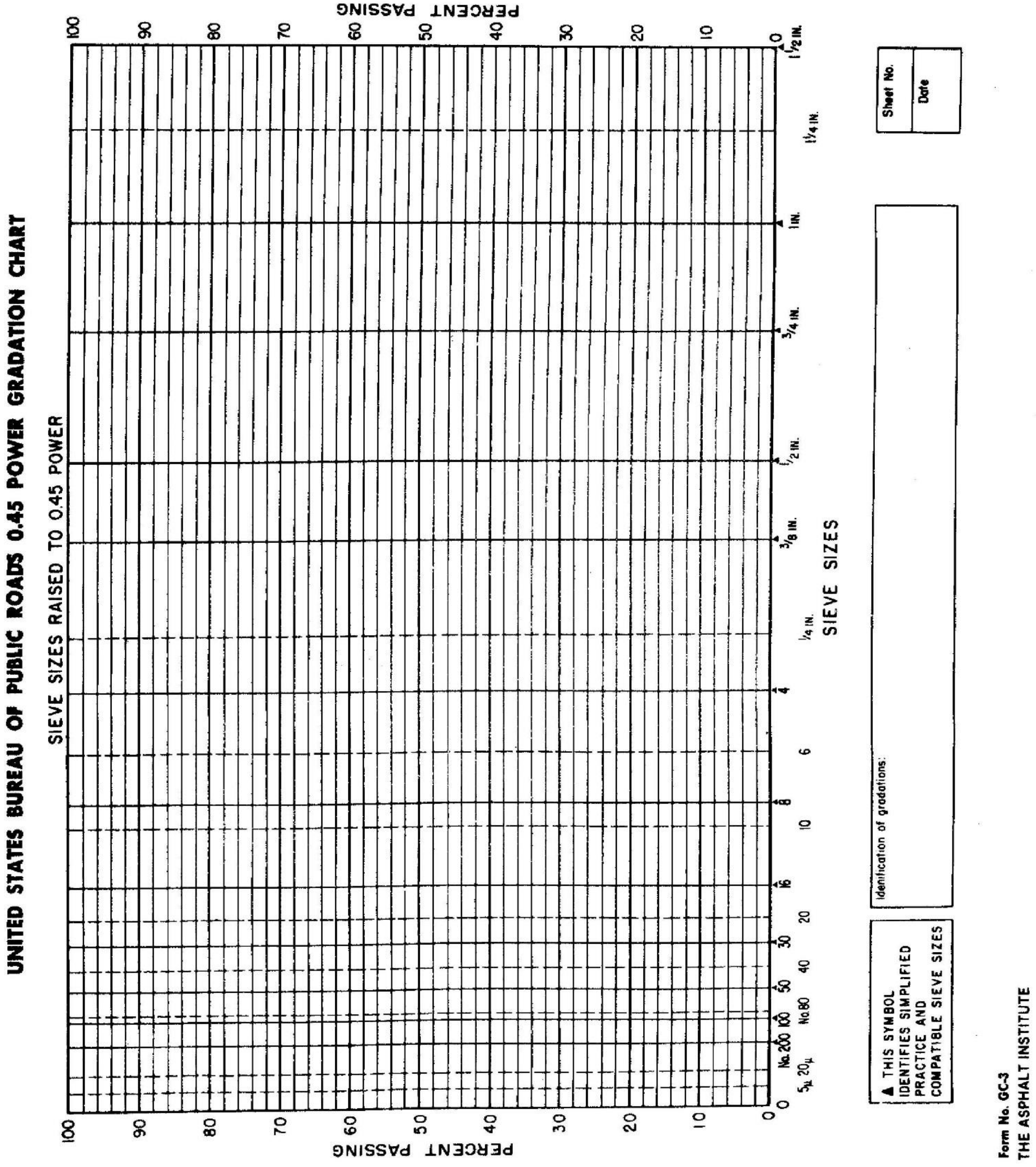
Mixture HMA, Surface, N70

Signed ____________________

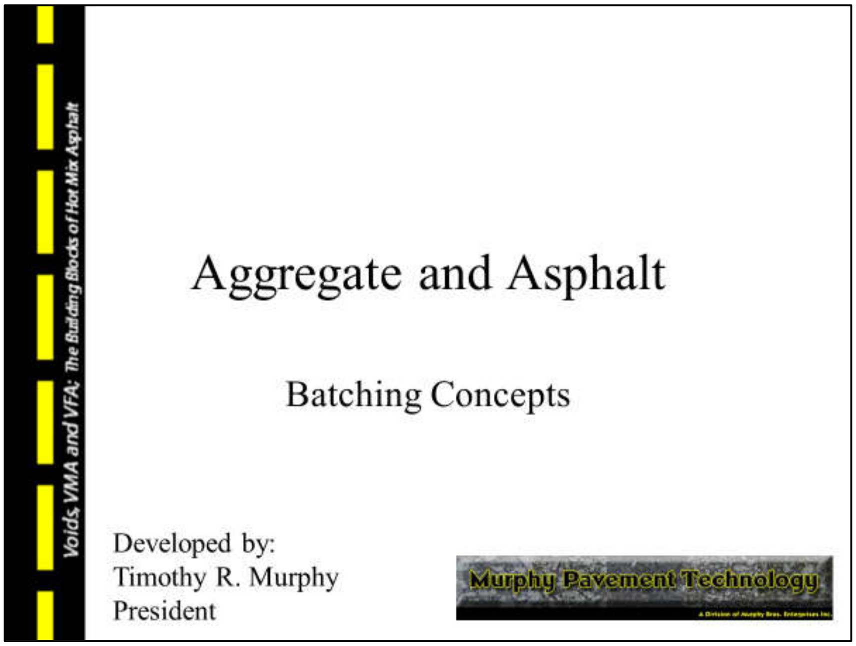
HOMEWORK #2
(Page 1 of 2)

Material	CM16			FM20			FA02			Breakdown								
Source																		
Percent																Combined	Target	Spec.
Used		%			%			%			%			%		Gradation	Value	Limits
Sieves	Frac Wt. Ret	% Pass	% For Mix	Frac Wt. Ret	% Pass	% For Mix	Frac Wt. Ret	% Pass	% For Mix	Frac Wt. Ret	% Pass	% For Mix	Frac Wt. Ret	% Pass	% For Mix	%	%	%
TOTAL																		
37.5																		
25.0																		ry
19.0																		
12.5		100																
9.5		98						100										
4.75		35			100			99										
2.36		5			78			83									42	
1.18		3			45			63										
600µ		2			26			45										
300µ		2			15			16			100							
150µ		2			9			3			94							
75µ		2.0			6.0			1.3			84.0							
PAN																		

HOMEWORK #2
(Page 2 of 2)



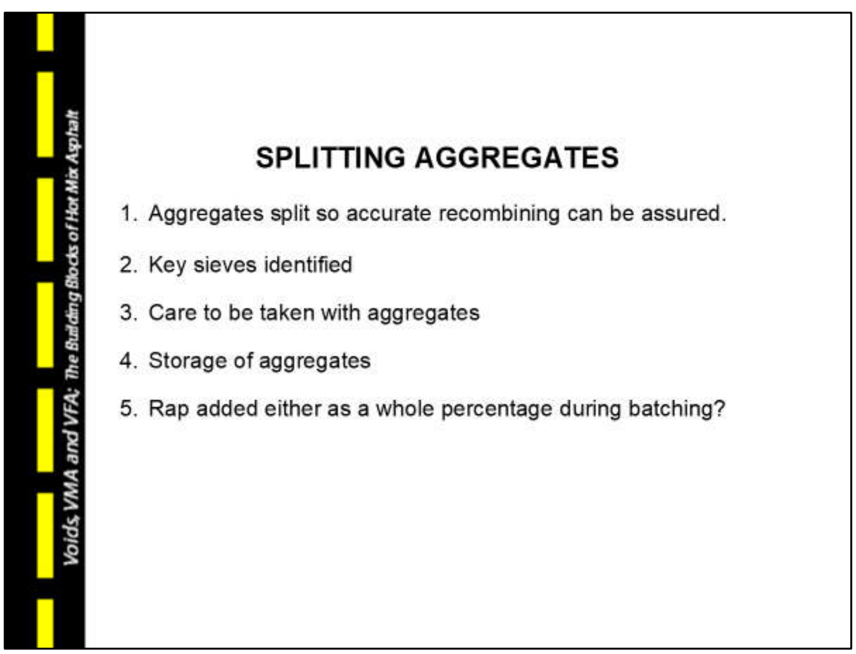
VI. Processing Aggregate for Batching



1. Splitting aggregate samples shall be performed so that accurate recombining of materials in the mix design process can be assured.

2. The key sieves on which the aggregate shall be split are identified.

3. Gradation separation shall be per-formed in such a way so as not to segregate or degrade the materials. It shall be performed in accordance with the procedures taught in the Aggregate Technician Course.



4. Once split, the material shall be placed in a container which can be placed in an oven for drying. This container shall have a large surface area as compared to its height so that sample aggregate can be accurately scooped out.

5. RAP material will be added as a whole percentage during the batching process and will not be split according to the above procedure.

Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

SPLITTING AGGREGATES

Each ingredient material shall be split into the following size fractions and placed in a separate container.

FINE AGGREGATE: FA01 FA02 FA20 FA21

(+) 2.36MM (#8 material)
-2.36 - +600µm (-#8 to +#30 material)
- 600µm (-#30 material)

Figure 5-19FA

Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

SPLITTING AGGREGATES

Each ingredient material shall be split into the following size fractions and placed in a separate container.

COARSE AGGREGATE:

CM07/08	CM11	CM13	CM16
+25			
25 - 19	+19		
19 - 12.5	19 - 12.5	+12.5	
12.5 - 9.5	12.5 - 9.5	12.5 - 9.5	+9.5
9.5 - 4.75	9.5 - 4.75	9.5 - 4.75	9.5 - 4.75
4.75 - 2.36	4.75 - 2.36	4.75 - 2.36	4.75 - 2.36
2.36 - 600µm	2.36 - 600µm	2.36 - 600µm	2.36 - 600µm
- 600µm	- 600µm	- 600µm	- 600µm

Figure 5-19CA

B. Batching Sources

This section deals with calculating batch weights from the blend percent. For mixtures requiring RAP, follow the procedure and example on the next page.

1. (a) Select the batch weight required to produce the desired number of test samples. Multiply the percent of each ingredient material by the batch weight to determine the weight that each ingredient material will contribute to the total batch.

   (b) Calculate the asphalt binder content by the following procedures:

   (1) P_s = 100 - Desired Asphalt Binder Content

   (2) $$\frac{\text{Aggregate Batch Weight}}{P_s} = \text{Total Batch Weight with AC}$$

   (where P_s = % of stone [in decimal form])

   (3) Total Batch Weight with Asphalt Binder – Aggregate Batch Weight = Asphalt Binder Weight (g)

This will be required for each of the various asphalt contents.

[Class performs the binder example]

C. Batching Worksheet

This sheet will be used to determine the weight of each size fraction contributed from each ingredient material.

See Figures 5.20 & 5.21

1. Determine the percentage of each size fraction from the aggregate blending sheet. This is accomplished by subtracting the percent passing the smaller sieve from the percent passing the larger sieve for the size fraction material desired. For example, if the material size is 12.5 mm (1/2") to 9.5 mm (3/8"), subtract the percent passing the 9.5-mm (3/8") sieve from the percent passing the 12.5-mm (1/2") sieve.

2. Multiply the percent of each size fraction (determined in the previous step) by the total weight contributed by that ingredient aggregate. This is performed for each size fraction for each ingredient material.

3. Accumulate the weight as each size fraction of each ingredient material is added to the batch.

4. Calculate the asphalt weight as described earlier in the "Batching Sources" section for each of the trial blends. Notice the aggregate weight stays the same and only the asphalt weight changes. Asphalt is calculated on a percentage-of-total-mix basis.

Remember, RAP material is not broken down into sieve sizes according to the above procedure. Instead, it is added to the batch as a whole percentage.

[Class shall perform calculations on binder mix.]

D. Dust Correction Factor

Adjusted correction factor must be determined for each mix design.

The dust correction factor (DCF) accounts for the additional minus 0.075 mm material present due to the result of batching with separated, unwashed aggregates.

5. Predicting optimum asphalt percent.

   a. Compare to the old design. If the proposed mix is slightly finer, add 0.2% asphalt; if coarser, subtract 0.2% asphalt.

   b. If the designer has no experience with the material, select 3.5% to 5.0% Asphalt Binder for binders and 4.5% to 6.0% Asphalt Binder for surfaces for trial batches. If you are using slag, add 1.0% to 1.5% more Asphalt Binder. Asphalt Binder contents shall be in increments of 0.5% and shall start at 0.0% or 0.5%.

   c. HMA offers a method for calculating the initial trial P_b. See the mix design example in SP-2:

$$P_{bi} = \frac{G_b \, x \left(V_{be} + V_{ba}\right)}{\left(G_b \, x \left[V_{be} + V_{ba}\right]\right) + W_s} x100$$

where:

P_{bi} = Initial Trial Asphalt Binder %

G_b = Specific Gravity of Asphalt Binder (assumed 1.02)

V_{be} = Effective Asphalt Binder = 0.081 - 0.02931 x (Ln S_n) where S_n = nominal max. sieve size of the aggregate blend (in inches)

V_{ba} = Volume of Absorbed Binder, calculated as follows:

$$V_{ba} = \frac{P_s \, x \left(1 - V_a\right)}{\frac{P_b}{G_b} + \frac{P_s}{G_{sb}}} \quad x \quad \left(\frac{1}{G_{sb}} - \frac{1}{G_{se}}\right)$$

where:

V_a = Volume of Air Voids

P_s = % of Aggregate

P_b = % of asphalt binder

d. For state verification/approval, the design shall have a minimum of four points. The optimum asphalt binder content shall be bracketed by at least one asphalt binder content a minimum of 0.5% higher and 0.5% lower. It would be wise to run the design at five trial asphalt binder contents: 1.0% and 0.5% higher than predicted optimum and 1.0% and 0.5% lower.

See Figure 5.22

VII. BATCH WEIGHTS

These batch weights refer to aggregate batch weights. Once asphalt binder is added, the mixture batch weight will be larger depending on the percent of asphalt binder added.

A batch weight of 12,000 grams of aggregate is typically used for all design work. This makes splitting of test samples considerably simpler and reduces the chance for error. This provides approximately 20% excess material to avoid segregation and other potential problems with working with a small amount of material.

It also provides a batch large enough to have one or two extra test specimens in the event one is damaged, as well as saving the time of drying back the "G_{mm}" sample.

SPLITTING AGGREGATES

Each ingredient material shall be split into the following size fractions and placed in a separate container.

FINE AGGREGATE: FA01 FA02 FA20 FA21

(+) 2.36MM (#8 material)
-2.36 - +600µm (-#8 to +#30 material)
- 600µm (-#30 material)

Figure 5-19FA

SPLITTING AGGREGATES

Each ingredient material shall be split into the following size fractions and placed in a separate container.

COARSE AGGREGATE:

CM07/08	CM11	CM13	CM16
+25			
25 - 19	+19		
19 - 12.5	19 - 12.5	+12.5	
12.5 - 9.5	12.5 - 9.5	12.5 - 9.5	+9.5
9.5 - 4.75	9.5 - 4.75	9.5 - 4.75	9.5 - 4.75
4.75 - 2.36	4.75 - 2.36	4.75 - 2.36	4.75 - 2.36
2.36 - 600μm	2.36 - 600μm	2.36 - 600μm	2.36 - 600μm
- 600μm	- 600μm	- 600μm	- 600μm

Figure 5-19CA

Figure 5-20

See Figure 5-15, Chapter 5.2 for information

BATCHING WORKSHEET

BATCH SIZE	**12,000**

% RAP	0
% RAP AC	0
RAP Wt. =	0

Design No.	001 Bit 01	District	91	Date	
Contractor	Jim's Paving HMA Mix Design			Sheet	1 of 1
Mix Type	19524 HMA Surface Course N70 D				

AGG.#1 →		What % →		AGG.#4 →		What % →	
MATERIAL	PERCENT	WEIGHTS	ACCUMLATIVE WEIGHTS	MATERIAL	PERCENT	WEIGHTS	ACCUMLATIVE WEIGHTS
TOTAL				TOTAL			
AGG.#2 →		What % →		AGG.#5 →		What % →	
TOTAL				TOTAL			
AGG.#3 →		What % →		ASPHALT :	**0**	**0**	
				ADDITIVE :			
				GYRATIONS	0	P_b Calculated using batch size of	
				P_b	AC WT.		
				7.0			12000
				6.5			
				6.0			
				5.5			
TOTAL				5.0			

NOTES : **0** **0** **0**

0 **0** **0**

Tested by : ____________________

Reviewed by : ____________________

Figure 5-21

See Figure 5-16 Chapter 5.2 for information

BATCHING WORKSHEET

% RAP	0
% RAP AC	0
RAP Wt. =	0

BATCH SIZE	**12,000**

Design No.	Fig 5-23	District	91	Date	
Contractor	Level III HMA Mix Design			Sheet	1 of 1
Mix Type	19532 HMA Binder Course N90				

AGG.#1 →		What % →		AGG.#4 →		What % →	
MATERIAL	PERCENT	WEIGHTS	ACCUMLATIVE WEIGHTS	MATERIAL	PERCENT	WEIGHTS	ACCUMLATIVE WEIGHTS
TOTAL				TOTAL			
AGG.#2 →		What % →		AGG.#5 →		What % →	
TOTAL				TOTAL			
AGG.#3 →		What % →		ASPHALT :	**0**	**0**	
				ADDITIVE :			
				GYRATIONS	0	P_b Calculated using batch size of	
				P_b	AC WT.		
				7.0			12000
				6.5			
				6.0			
				5.5			
TOTAL				5.0			

NOTES : ____________________

Tested by : ____________________

Figure 5-21a

BATCHING WORKSHEET

% RAP	0
% RAP AC	0
RAP Wt. =	0

BATCH SIZE	**12,000**

Design No. Fig 5-23 District 91 Date

Contractor Level III HMA Mix Design Sheet 1 of 1

Mix Type 19532 HMA Binder Course N90

AGG.#1 →	CM1 1	What % →	48.0	AGG.#4 →	FM 01	What % →	9.0
MATERIAL	PERCENT	WEIGHTS	ACCUMLATIVE WEIGHTS	MATERIAL	PERCENT	WEIGHTS	ACCUMLATIVE WEIGHTS
+19.0	8.0	461	461	+12.5	0.0	0	10680
19.0 - 12.5	47.0	2707	3168	12.5 - 9.5	0.0	0	10680
12.5 - 9.5	35.0	2016	5184	9.5 - 4.75	3.0	32	10712
9.5 - 4.75	4.0	230	5414	4.75 - 2.36	15.0	162	10874
4.75 - 2.36	1.0	58	5472	-2.36 - +60	32.0	346	11220
-2.36 - +60	2.0	115	5587	- 600	50.0	540	11760
- 600	3.0	173	5760				
TOTAL				TOTAL			
AGG.#2 →	CM 16	What % →	26.0	AGG.#5 →	MF01	What % →	2.0
+12.5	0.0	0	5760	+12.5	0	0	11760
12.5 - 9.5	3.0	94	5854	12.5 - 9.5	0	0	11760
9.5 - 4.75	67.0	2090	7944	9.5 - 4.75	0	0	11760
4.75 - 2.36	23.0	718	8662	4.75 - 2.36	0	0	11760
-2.36 - +60	4.0	125	8786	-2.36 - +60	0	0	11760
- 600	3.0	94	8880	- 600	100	240	12000
TOTAL				TOTAL			
AGG.#3 →	FM 20	What % →	15.0	ASPHALT :	0	0	0
+12.5	0.0	0	8880	ADDITIVE :			
12.5 - 9.5	0.0	0	8880	GYRATIONS	0	P_b Calculated using batch size of	
9.5 - 4.75	3.0	54	8934	P_b	AC WT.		
4.75 - 2.36	27.0	486	9420	7.0	903	12903	12000
-2.36 - +60	40.0	720	10140	6.5	834	12834	
- 600	30.0	540	10680	6.0	766	12766	
				5.5	698	12698	
TOTAL				5.0	632	12632	

NOTES :

Tested by :

Reviewed by :

Figure 5-22

Test Data

Trail #1

AC%	Voids	
4.5%	4.4	Select Air Voids at 4.0% AC= 4.7%
5.0%	3.4	
5.5%	2.4	
6.0%	1.4	* Not bracketed on low side *

Trial #2

AC%	
4.0%	* Butter the bowl with the highest AC content.
4.5%	
Possibly 5.0%	* Compare the data for Trial #2 at 4.5% AC to the data at Trial #1 AC content of 4.5%. It should be consistent on voids and G_{se}. Use Trial #1 data to calculate optimum AC%.

Illinois Department of Transportation

Hot-Mix Asphalt Mix Design
Procedure for Dust Correction Factor Determination
Appendix B12

Effective: January 1, 1998
Revised: December 1, 2017

A dust correction factor (DCF) shall be determined and applied to each new mix design using the procedure listed below. This procedure will be used to supplement the Hot-Mix Asphalt Level III Technician Course manual to account for additional minus No. 200 (minus 75-µm) material present as a result of batching with unwashed aggregates.

It is important to note the Adjusted Blend Percentages are temporary percentages used during laboratory batching only. The original Blend Percentages on the "Design Summary Sheet" remain unchanged.

> Note: When adjusting percentages to equal 100, the largest percentage should be adjusted accordingly.

A) Virgin Mix Design

1. Batch a combined aggregate sample matching the job mix formula (JMF). Test sample size shall be determined using Illinois Specification 201 and based on the nominal maximum size of the largest coarse aggregate.
2. Perform a washed test on the combined aggregate sample using Illinois Modified AASHTO T 11.
3. The DCF shall be the difference between the percent passing the No. 200 (75-µm) sieve of the washed test and the JMF.
4. Determine the mineral filler reduction (MFR) by dividing the DCF by the percent (in decimal form) mineral filler gradation passing the No. 200 (75-µm) sieve.
5. Subtract the MFR from the blend percentage of mineral filler.
6. Adjust the remaining blend percentages to sum to 100 by dividing each by the quantity (1 - MFR).

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Revised: December 1, 2017

Example

Bituminous Mixture Design

Design Number:——>	50BITEXPL	
Lab preparing the design?(PP,PL,IL ect.)	IDOT	
Producer Name & Number–>	1111-01 Example Company Inc Somewhere 1, IL	
Material Code Number–>	17552	BITCONC BCS 1 B TONS

Agg No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	032CMM11	032CMM16	038FAM20	037FAM01	004MFM01		10124M
Source (PROD#)	51972-02	51972-02	51230-06	51790-04	51052-04		
(NAME)	MAT SER	MAT SER	MIDWEST	CONICK	LIVINGSTON		2260-01
(LOC)							EMLSCOAT
Aggregate Blend	38.0	35.0	14.5	10.0	2.5	0.0	100.0

Agg No. Sieve Size	#1	#2	#3	#4	#5	#6	Blend
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
3/4	88.0	100.0	100.0	100.0	100.0	100.0	95.4
1/2	45.0	100.0	100.0	100.0	100.0	100.0	79.1
3/8	19.0	97.0	100.0	100.0	100.0	100.0	68.2
#4	6.0	29.0	97.0	97.0	100.0	100.0	38.7
#8	2.0	7.0	80.0	85.0	100.0	100.0	25.8
#16	2.0	4.0	50.0	65.0	100.0	100.0	18.4
#30	1.8	3.0	35.0	43.0	100.0	100.0	13.6
#50	1.7	3.0	19.0	16.0	100.0	100.0	8.6
#100	1.5	3.0	10.0	5.0	90.0	100.0	5.8
#200	1.3	1.3	4.0	2.5	88.0	100.0	4.0

Step 1. **Batch a combined aggregate sample meeting the JMF.** Illinois Specification 201 requires a 5000-gram sample when CM11 is present.

Step 2. **Run a washed test using AASHTO T 11.**

Step 3. **Determine the Dust Correction Factor (DCF).** The DCF is the difference in the percent passing the No. 200 (75-µm) sieve between the washed test and the JMF:

	JMF	Washed Test	DCF
No. 200 (75-µm)	4.0%	5.6%	1.6%

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Step 4. **Determine the Mineral Filler Reduction (MFR)** by dividing the DCF (%) by the percent (in decimal form) mineral filler gradation passing the No. 200 (75-µm) sieve:

MFR (%) = 1.6 / 0.88 = 1.8%

Step 5. **Determine the adjusted mineral filler blend percentage** by subtracting the MFR (%) from the blend percentage of mineral filler:

2.5% - 1.8% = 0.7%

Step 6. **Adjust the remaining blend percentages to sum to 100** by dividing each by the quantity [1 - **MFR** (in decimal form)]:

	Blend Percentage	Adjusted Blend Percentage[1]
032CMM11	38.0	38.7
032CMM16	35.0	35.6
038FAM20	14.5	14.8
037FAM01	10.0	10.2
004MFM01	2.5	0.7
	100.0	100.0

Note 1: It is important to note the Adjusted Blend Percentages are temporary percentages used during laboratory batching only. The original Blend Percentages on the "Design Summary Sheet" remain unchanged.

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Procedure for Dust Correction Factor Determination
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B) RAP Mix Design (Also Applicable to RAP/RAS Mix Designs)

1. Determine the Virgin Aggregate Fraction (VAF). The virgin aggregate fraction is the percentage of virgin aggregate

2. Adjust to the virgin blend percentages by dividing each virgin aggregate by the VAF.

3. Determine the RAP Adjusted JMF (RJMF)

4. Batch the virgin aggregates according to the adjusted blend percentages matching the RJMF. Test sample size shall be determined using Illinois Specification 201 and based on the nominal maximum size of the largest coarse aggregate.

5. Perform a washed test on the combined aggregate sample using Illinois Modified AASHTO T 11.

6. The DCF shall be the difference between the percent passing the No. 200 (75-µm) sieve of the washed test and the RJMF.

7. Determine the mineral filler reduction $(MFR)_{RAP}$ by dividing the DCF by the percent (in decimal form) mineral filler gradation passing the No. 200 (75-µm) sieve.

8. Subtract the MFR_{RAP} from the blend percentage of mineral filler.

9. Adjust the remaining virgin aggregate blend percentages to sum to 100 by dividing each by the quantity $(1 – MFR_{RAP})$.

10. Determine the batching blend percentages with RAP by multiplying the adjusted virgin aggregate blend percentages by the VAF.

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Revised: December 1, 2017

RAP Example

				Design Number:----->	50BITWRAP		
		Lab preparing the design?(PP,PL,IL ect.)			IDOT		
Producer Name & Number>		1111-01 Example Company Inc Somewhere 1, IL					
Material Code Number--->		19512R	BITCONC BC N50 19.0R				
	Required!		FA20/21			RAP in #6	
Agg No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size (e.g. 032CAM16)	042CMM11	042CMM16	FINE AGG	037FMM01	004MF01	017CMM16	PG64-22
Source (PROD#)	50572-01	50572-01		50530-02	51052-04	111-01	5627-02
(NAME)	Prairie Materials	Prairie Materials		Prairie Materials	Livingston	Example Co	BP AMOCO
(LOC)	Ashkum	Ashkum		Paxton	Pontiac	Somewhere	Whitting, Ind
					RAP in Mix:	25	
Aggregate Blend	38.3	23.0		13.0	2.0	23.7	100.0

Agg No. / Sieve Size	#1	#2	#3	#4	#5	#6	Blend
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
3/4	79.0	100.0	100.0	100.0	100.0	100.0	92.0
1/2	34.0	100.0	100.0	100.0	100.0	100.0	74.7
3/8	9.0	99.0	100.0	100.0	100.0	97.8	64.4
#4	1.1	29.0	100.0	98.0	100.0	73.4	39.2
#8	1.1	3.0	100.0	89.0	100.0	49.0	26.3
#16	1.1	2.7	100.0	79.0	100.0	37.0	22.1
#30	1.1	2.5	100.0	63.0	100.0	28.0	17.8
#50	1.1	2.3	100.0	23.0	100.0	18.6	10.3
#100	1.1	1.8	100.0	2.0	90.0	12.6	5.9
#200	1.0	1.7	100.0	1.0	85.0	10.2	5.0

Step 1. **Determine the virgin aggregate fraction (VAF).**

$$VAF = \frac{(100 - RAPAgg\%)}{100} \qquad VAF = \frac{(100 - 23.7)}{100}$$

VAF = 0.763

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Step 2. **Adjust to the virgin aggregate percentages** by dividing each virgin aggregate by the VAF.

	Initial		Virgin agg %	
042CMM11	38.3	(÷ 0.763)	50.3	(added 0.1 sum = 100.0)
042CMM16	23.0	(÷ 0.763)	30.1	
037FMM01	13.0	(÷ 0.763)	17.0	
004MF01	2.0	(÷ 0.763)	2.6	
Sum	100.0		100.0	

Step 3. **Determine the RAP adjusted JMF (RJMF).** Combine gradation using the adjusted virgin aggregate blend percentages.

1	100.0
¾	89.4
½	66.8
3/8	53.9
#4	28.5
#8	19.2
#16	17.4
#30	14.6
#50	7.8
#100	3.8
#200	3.4

Step 4. Batch the virgin aggregates according to the adjusted blend percentages matching the RJMF. Illinois specification 201 requires a 5000-gram sample when CM11 is present.

Step 5. Run a washed test using AASHTO T11.

Step 6. Determine the dust correction factor (DCF). The DCF is the difference between the percent passing the 75µm (No. 200) sieve of the washed test and the RJMF.

	Washed	RJMF	DCF
75µm (No. 200)	4.3	3.4	4.3 - 3.4 = 0.9

DCF = 0.9

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Step 7. Determine the mineral filler reduction $(MFR)_{RAP}$. The $(MFR)_{RAP}$ is determined by dividing the DCF by the percent (in decimal form) mineral filler gradation passing the No. 200 (75-µm) sieve.

$$MFR_{RAP} = \frac{0.9}{0.85} = 1.1\%$$

Step 8. Determine the mineral filler blend percentage by subtracting the MFR_{RAP} from the blend percentage of mineral filler.

2.6 – 1.1 = 1.5%

Step 9. Adjust the remaining blend percentages to sum to 100% by dividing each by the quantity [1-MFR_{RAP} (in decimal form)]:

$1 - MFR_{RAP} = 1 - 0.011 = 0.989$

	Virgin %		Adjusted Virgin Blend%
042CMM11	50.3	(÷ 0.989)	50.9
042CMM16	30.1	(÷ 0.989)	30.4
037FMM01	17.0	(÷ 0.989)	17.2
004MF01	2.6	(from step 8)	1.5
Sum	100.0		100.0

Step 10. Determine the batching blend percentages with RAP by multiplying the adjusted virgin blend % by the VAF.

VAF = 0.763

	Adjusted Virgin %		Batching Blend %	
042CMM11	50.9	(x 0.763)	38.9	(added 0.1 sum = 100.0)
042CMM16	30.4	(x 0.763)	23.2	
037FMM01	17.2	(x 0.763)	13.1	
004MF01	1.5	(x 0.763)	1.1	
		RAPAgg	23.7	
		Sum	100.0	

This Page Is Reserved

Aggregate Blending, Dust Correction Problem

Material	032CMM11			032CMM16			038FMM20			037FAM01			004MFM01			Combined
Source																Gradation
Percent	49.5%			20.6%			16.5%			10.9%			2.5%			%
Sieves	Frac Wt. Ret	% Pass	% for Mix	Frac Wt. Ret	% Pass	% for Mix	Frac Wt. Ret	% Pass	% for Mix	Frac Wt. Ret	% Pass	% for Mix	Frac Wt. Ret	% Pass	% for Mix	
37.5																
25.0		100			100			100			100			100		100
19.0		94			100			100			100			100		97
12.5		40			100			100			100			100		70
9.5		18			97			100			100			100		59
4.75		5			31			98			97			100		38
2.36		3			8			66			81			100		25
1.18		3			5			37			65			100		18
0.600		3			4			20			48			100		13
0.300		3			4			12			19			100		9
0.150		2			4			8			3			99		6
0.075		2.0			3.0			4.8			1.5			88.0		4.8

A washed gradation was conducted on combined aggregate sample meeting this job mix formula.
The percent passing the 0.075 mm sieve in the washed gradation was 5.6 percent.
Determine the dust correction factor and adjust the blend percentages to be used for batching a mix design.

This Page Is Reserved

Date:

Bituminous Mixture Design

Design Number: →	2006BIT01
Lab Preparing the design?(PP,PL,IL,etc.)	MPT
Producer Name & Number->	
Material Code Number->	HMA Surface Course, N90

Agg. No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size		3/8" CA	Man. Sand	Nat. Sand	Breakdown		10112
Source (PROD#)							
(NAME)							
(LOC)							
Aggregate Blend		55.0	22.0	21.0	2.0		100.0

Agg. No. Sieve Size	#1	#2	#3	#4	#5	Blend	Range	Spec
25.4 (1)		100.0	100.0	100.0	100.0			
19.0 (3/4)		100.0	100.0	100.0	100.0			
12.5 (1/2)		100.0	100.0	100.0	100.0			
9.5 (3/8)		98.0	100.0	100.0	100.0			
4.75 (#4)		35.0	100.0	99.0	100.0			
2.36 (#8)		5.0	78.0	83.0	100.0			
1.18 (#16)		3.0	45.0	63.0	100.0			
600µm (#30)		2.0	26.0	45.0	100.0			
300µm (#50)		2.0	15.0	16.0	100.0			
150µm (#100)		2.0	9.0	3.0	94.0			
75µm (#200)		2.0	6.0	1.3	84.0			

Bulk Sp Gr	2.605	2.711	2.602	2.803
Apparent Sp Gr	2.721	2.801	2.654	2.803
Absorption, %	1.3	1.0	0.7	0.0

AC Specific Gravity 1.030

Date:

Bituminous Mixture Design

Design Number: →	2006BIT02
Lab Preparing the design?(PP,PL,IL,etc.)	MPT
Producer Name & Number->	
Material Code Number->	HMA Surface Course, N90

Agg. No.	#1	#2	#3	#4	#5		ASPHALT
Size		3/8” CA	Man. Sand	Nat. Sand	Breakdown		10112
Source (PROD#)							
(NAME)							
(LOC)							
Aggregate Blend		55.0	30.0	13.0	2.0		100.0

Agg. No. Sieve Size	#1	#2	#3	#4	#5	Blend	Range	Spec
25.4 (1)		100.0	100.0	100.0	100.0			
19.0 (3/4)		100.0	100.0	100.0	100.0			
12.5 (1/2)		100.0	100.0	100.0	100.0			
9.5 (3/8)		98.0	100.0	100.0	100.0			
4.75 (#4)		35.0	100.0	99.0	100.0			
2.36 (#8)		5.0	78.0	83.0	100.0			
1.18 (#16)		3.0	45.0	63.0	100.0			
600μm (#30)		2.0	26.0	45.0	100.0			
300μm (#50)		2.0	15.0	16.0	100.0			
150μm (#100)		2.0	9.0	3.0	94.0			
75μm (#200)		2.0	6.0	1.3	84.0			

Bulk Sp Gr		2.605	2.711	2.602	2.803
Apparent Sp Gr		2.721	2.801	2.654	2.803
Absorption, %		1.3	1.0	0.7	0.0

AC Specific Gravity 1.030

BATCHING WORKSHEET

Batch Size	12,000

Design No. 2006MPT Dist________ Date ________

Contractor Murphy Pavement Technology Sheet 1 of 1

Mix Type HMA Bituminous Concrete Surface Course, N90

AGG. #1->		What %->		AGG. #4->		What %->	
MATERIAL	PERCENT	WEIGHTS	ACCUMULATIVE WEIGHTS	MATERIAL	PERCENT	WEIGHTS	ACCUMULATIVE WEIGHTS
				+2.36			
				-2.36 - +600			
				-600			
TOTAL				TOTAL			
AGG. #2->		What %->		AGG. #5->		What %->	
+9.5				-2.36			
9.5 – 4.75							
4.75 – 2.36							
2.36 – 600							
-600							
TOTAL				TOTAL			
AGG. #3->		What %->		ASPHALT:			
+2.36				ADDITIVE:			
-2.36 - +600				P_b	AC WT.		
-600							
TOTAL							

NOTES:____________________

SUMMARY OF TEST DATA – 2006BIT01

	AC % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (V_a -or- P_a)	VMA VMA	VOIDS FILLED VFA	EFFECTIVE AC, VOL V_{be}	EFFECTIVE AC, % WT P_{be}	ABSORPTION G_{se} G_{se}	ABSORPTION AC, % WT P_{ba}
	4.5	2.341	2.525							
	5.0	2.373	2.505							
	5.5	2.388	2.488							
	6.0	2.395	2.470							

	P_b	d (G_{mb})	D (G_{mm})	% VOIDS (P_a)	VMA	VFA	G_{se}	G_{sb}
Asphalt determined at 4.0% voids: - OPTIMUM DESIGN DATA:---								

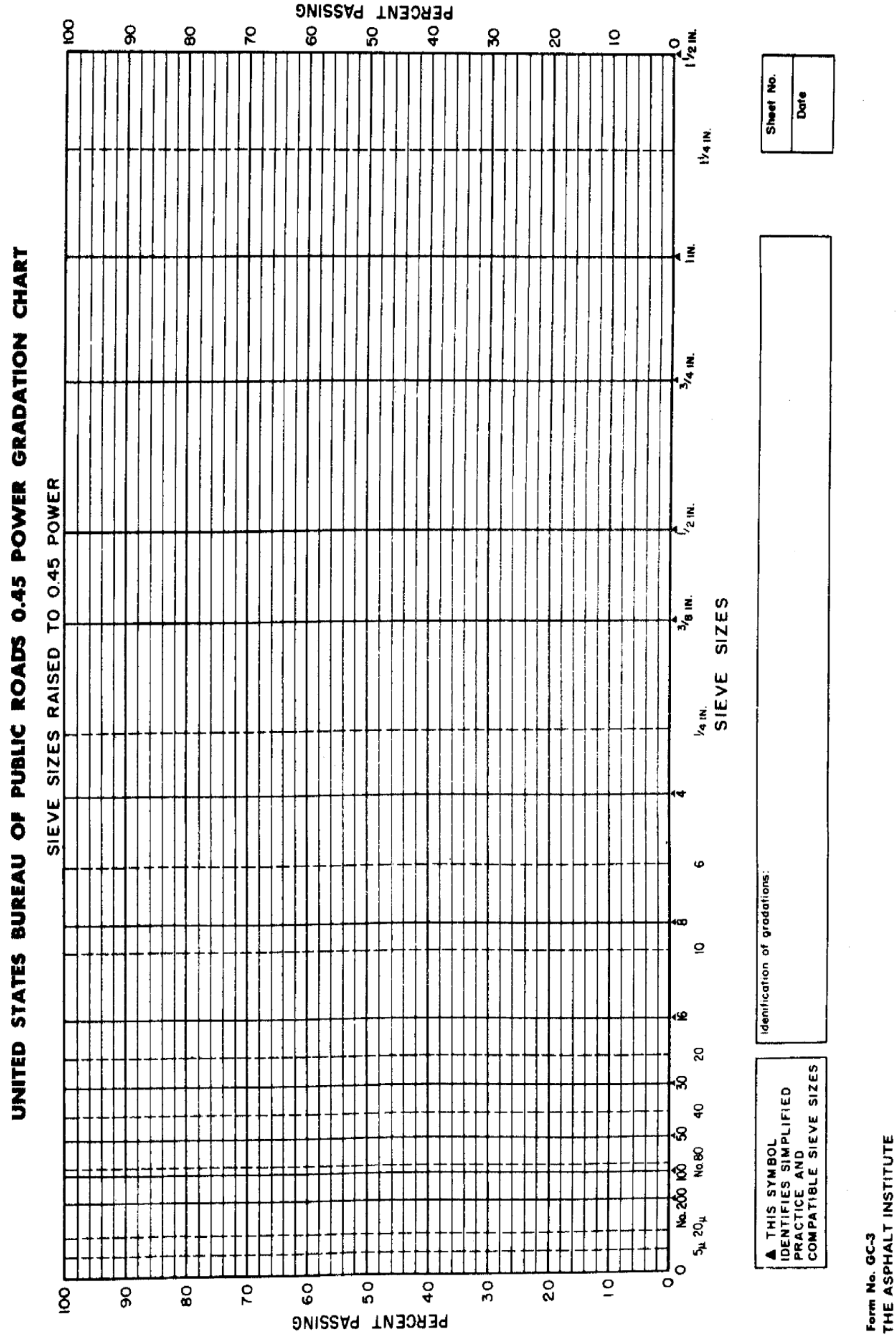
REMARKS:

SUMMARY OF TEST DATA – 2006BIT02

	AC % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (V_a -or- P_a)	VMA VMA	VOIDS FILLED VFA	EFFECTIVE AC, VOL V_{be}	EFFECTIVE AC, % WT P_{be}	ABSORPTION G_{se} G_{se}	ABSORPTION AC, % WT P_{ba}
	4.5	2.333	2.522							
	5.0	2.353	2.504							
	5.5	2.362	2.486							
	6.0	2.379	2.469							

	P_b	d (G_{mb})	D (G_{mm})	% VOIDS (P_a)	VMA	VFA	G_{se}	G_{sb}
Asphalt determined at 4.0% voids: - OPTIMUM DESIGN DATA:---								

REMARKS:


UNITED STATES BUREAU OF PUBLIC ROADS 0.45 POWER GRADATION CHART
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
100 90 80 70 60 50 40 30 20 10 0
SIEVE SIZES
5μ 20μ No.200 No.80 100 50 40 30 20 16 10 8 6 4 1/4 IN. 3/8 IN. 1/2 IN. 3/4 IN. 1 IN. 1 1/4 IN. 1 1/2 IN.
▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Identification of gradations:
Sheet No.
Date
Form No. GC-3
THE ASPHALT INSTITUTE

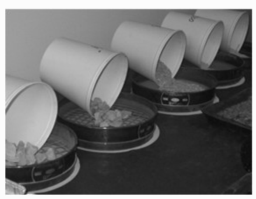
Laboratory Requirements

- Safety,
- Cooperation,
- Teamwork
- Care, Accuracy, Precision,
- Complete all paperwork,
- Class work during day.

Timothy R. Murphy, P.E.
President
Murphy Pavement Technology

Separate Aggregates

- Various sizes per splitting requirements,
- Coarse aggregate through fine aggregate with RAP between,
- Dust correction factor.



Equipment & Materials

- Heat all metal parts and ingredients to mimic asphalt production,
- Requires extra ovens for design labs.

Batching Bucket

- Separator pan to protect scale,
- Scale capable of handling 15,000 g.

Batching Bucket from Above

- Batching is Coarse aggregate thru fine aggregate so CA ends up on top,
- Thoroughly mix aggregate.

Checking Prior to Adding Asphalt Binder

- Thoroughly mix aggregate,
- Check aggregate mass,
- Adjust asphalt mass.

Asphalt Binder

- Check contract documents,
- Introduce proper mass of Asphalt Binder for each asphalt content and aggregate mass,
- Work FAST!!!

Mixing

- Begin mixing aggregate and asphalt mass,
- Mix until homogenous coating has occurred.

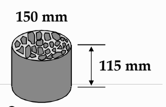
Empty 5-gallon Bucket

- Discharge quickly,
- Thoroughly clean walls,
- Split evenly for test specimens according to agency specifications.

HMA Splitter

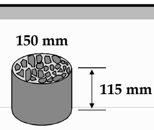
- Remix,
- Split,
- Watch "Rice" sample size.

Specimen Preparation



- Specimen Height & Mass for Volumetrics
  - 115 mm ± 5 mm
  - Approximately 4850 g of mix required (4600 g of natural aggregate),
  - 5150 g for 50/50 mass of steel slag,
  - 4750 g for 50/50 mass of ACBF slag.

Specimen Preparation



- Specimen Height & Mass for Performance Tests
  - TSR's – AASHTO T-283
    - 95 mm ± 5 mm (7 ± 1.0%)
    - Approximately 3,500 - 4,000 grams
  - Hamburg – AASHTO T-324
  - I-Fit – AASHTO T-324
    - 160 mm ± 1 mm
    - Approximately 6-7000 grams

Conditioning in oven

- Place samples in oven at compaction temperature for specified time,

Illinois Modified Test Procedure
Effective Date: June 1, 2012
Revised Date: December 1, 2022

Standard Practice
for
Laboratory **Conditioning of Asphalt** Mixtures

Reference AASHTO R 30-22

AASHTO Section	*Illinois Modification*
7.1.1	Replace the first two sentences with the following: The mixture conditioning for the volumetric mixture design procedure, for short-term conditioning of Hamburg Wheel test and I-FIT specimens, and for specimens for strength and TSR testing applies to laboratory-prepared, loose mixture only. Mixture conditioning is only required when conducting quality control or quality assurance testing on plant-produced mixture for I-FIT long-term aging specimens and as specified for warm mix asphalt (WMA) mixtures.
7.1.1 Note 2	Delete
7.1.2	Replace with the following: Place the mixture in a pan and spread the mixture to an even thickness ranging between 1 in. (25 mm) and 2 in. (50 mm). The aging may take place either: a. Immediately after mixing but before compaction (without being cooled down), or b. After the mixture has been cooled down to room temperature. The mixture shall be placed in the oven, which has been pre-heated to compaction temperature, for the appropriate time specified below. For testing of all mixtures with low-absorptive aggregate, place the mixture and pan in the conditioning oven pre-heated to the mixture's specified compaction temperature ± 5 °F (± 3 °C) for 1 hr. ± 5 min. prior to compaction. (1 hr. of oven time, not the time the mixture was held at compaction temperature, is used.) For testing of all mixtures with high-absorptive aggregate, place the mixture and pan in the conditioning oven pre-heated to the mixture's specified compaction temperature ± 5 °F (± 3 °C) for 2 hrs. ± 5 min. prior to compaction. (2 hrs. of oven time, not the time the mixture was held at compaction temperature, is used.)
7.1.2 Note 3	Replace with the following: Note 3 – When SB/SBS/SBR polymer and GTR modified asphalt is used, the required compaction temperature is 305 ± 5 °F (152 ± 3 °C).

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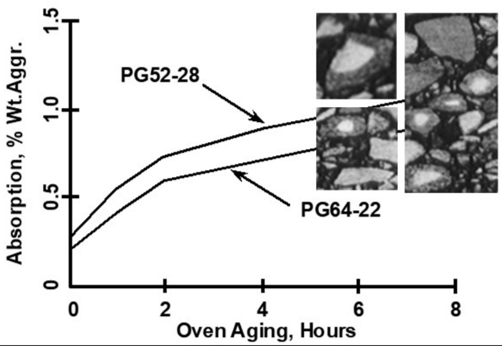
7.1.2	Replace with the following: Place the mixture in a pan and spread the mixture to an even thickness ranging between 1 in. (25 mm) and 2 in. (50 mm). The aging may take place either: a. Immediately after mixing but before compaction (without being cooled down), or b. After the mixture has been cooled down to room temperature. The mixture shall be placed in the oven, which has been pre-heated to compaction temperature, for the appropriate time specified below. For testing of all mixtures with low-absorptive aggregate, place the mixture and pan in the conditioning oven pre-heated to the mixture's specified compaction temperature ± 5 °F (± 3 °C) for 1 hr. ± 5 min. prior to compaction. (1 hr. of oven time, not the time the mixture was held at compaction temperature, is used.) For testing of all mixtures with high-absorptive aggregate, place the mixture and pan in the conditioning oven pre-heated to the mixture's specified compaction temperature ± 5 °F (± 3 °C) for 2 hrs. ± 5 min. prior to compaction. (2 hrs. of oven time, not the time the mixture was held at compaction temperature, is used.)
7.1.2.1 New Table	Add the following: Table 1

Short Term Conditioning (hours) [1/]

	Lab-Produced Mix			Plant-Produced Mix		
	Volumetrics	T-283	Hamburg/I-FIT	Volumetrics	T-283	Hamburg/I-FIT
HMA	1 or 2	1 or 2	1 or 2	0	0	0
WMA	1 or 2	1 or 2	3 or 4	0	0	2

1/ When two different values are present within a single cell, the correct value is based on whether low or high absorptive aggregates are used.

Effect of Absorption, I



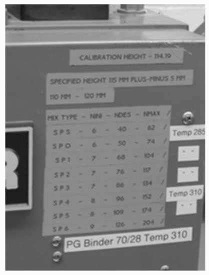
Gyratory Compactors

Goals of HMA Compaction Method

- Simulate field densification
  - traffic
  - climate
- Accommodate large aggregates
- Measure mix compactability
- Equipment conducive to QC

Prepare the SGC

- Perform regular calibrations,
- Review compaction temperature requirement,
- Set N_{design} or N_{max} depending on your specification.

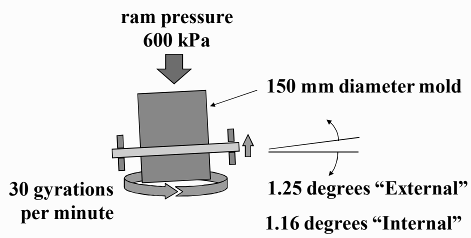


7.1.2 Note 3	Replace with the following: Note 3 – When SB/SBS/SBR polymer and GTR modified asphalt is used, the required compaction temperature is 305 ± 5 °F (152 ± 3 °C).
7.1.2 New Note	Note 3A – High-absorptive aggregate mixture is defined as aggregate with a combined absorption greater than 2.5% and all slags.
7.1.2 New Note	Note 3B – The compaction temperature for non-SB/SBS/SBR polymer and non-GTR modified asphalt is 295 ± 5 °F (146 ± 3 °C).
7.1.2 New Note	Note 3C – Short-term conditioning is not permitted for testing plant-produced mixture, except as specified for WMA mixtures.
7.1.2 New Note	Note 3D – Condition Hamburg Wheel specimens from WMA mixtures from both lab-produced mix and plant-produced mix for two hours in addition to the requirements for HMA.

Compaction process

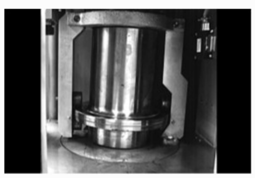
- Charge mold with properly cured and heated HMA,
- Insert paper disks on top and bottom,
- Engage compactor, push button, and wait.

Details…



SGC in Action

- 30-gyrations per minute,
- 600 kPa force,
- 1.25 degrees external angle.
- 1.16 degrees internal angle.



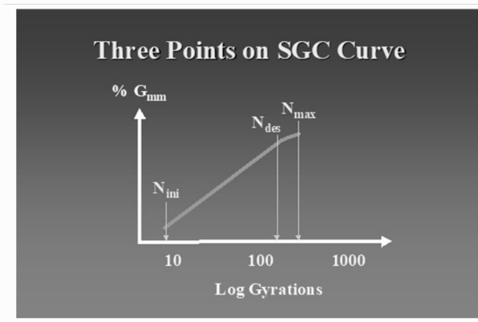
Extrude specimen

- Fairly quickly for coarse graded mixtures,
- After a little cooling for fine graded mixtures to avoid deformation.

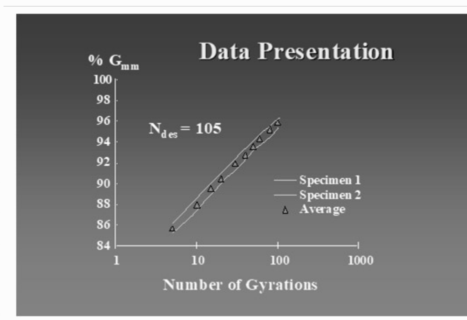
Identify specimens

- Asphalt Binder content,
- Test specimen number,
- Design number, etc.

Compaction Data



Compaction of 2-Specimens



Bulking Specimens

- Bulk specific gravity (G_{mb}) specimens
  - Low-absorptive aggregates conditioned for 1 hr. ± 5 min @ compaction temperature ± 5º F (± 3º C)
  - Highly absorptive aggregates conditioned for 2 hrs. ± 5 min @ compaction temperature ± 5º F (± 3º C)
  - No conditioning for plant mix specimens.

Bulking Specimens

BRICK NO.		4.0A	4.0B
DRY WEIGHT	A		
SATURATED SURFACE DRY WEIGHT	B		
SUBMERGED WEIGHT	C		
BULK SPECIFIC GRAVITY G_{mb} [A/(B-C)]			

(Average & Report to 3-places, [2.XXX])

"Rice" Gravity

- Maximum theoretical gravity (G_{mm}) specimens
  - Low-absorptive aggregates conditioned for 1 hr. ± 5 min @ compaction temperature ± 5º F (± 3º C)
  - Highly absorptive aggregates conditioned for 2 hrs. ± 5 min @ compaction temperature ± 5º F (± 3º C)
  - No conditioning for plant mix specimens.

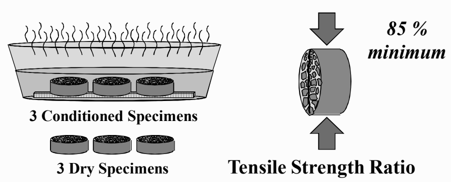
"Rice" Gravity

1. Dry Sample Weight (A) ______
2. Averaged calibrated Pycnometer weight (C) ______
   (Pycnometer suspended in water bath)
3. Vacuumed sample weight (B) ______
   (Pycnometer + sample suspended in water bath)
4. Maximum Specific Gravity, [A/(A-(B-C)] ______

   (report to 3 places, [2.xxx])

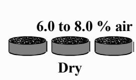
Moisture Sensitivity; Modified AASHTO T283-22

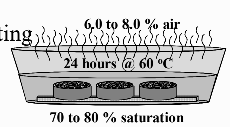
- Measured on Proposed Aggregate Blend and Asphalt Binder Content



AASHTO T283-22 Modified

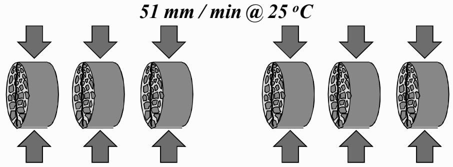
- Two subsets with equal voids
  - one - "dry"
  - one - saturated
- One set conditioned
  - 24 hrs @ 60ºC
  - 2 hrs @ 25ºC before testing





AASHTO T283-22
Test Procedure

51 mm / min @ 25 °C

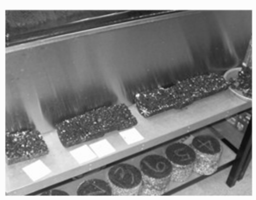


Avg Dry Tensile Strength **Avg Wet Tensile Strength**

$$TSR = \frac{Wet}{Dry} \geq 85\ \%$$

Stripping Pass/Fail

- Test Data,
- Specification Requirements,
- Cracked rock vs. stripped rock.
- Visual Ratings.



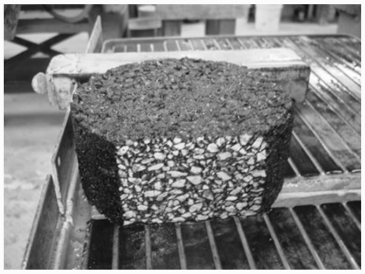
Hamburg AASHTO T 324-22

2022 Standard Specifications
Art. 1030.05(d)(3)

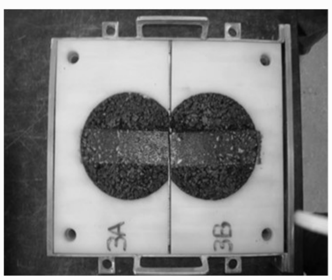
(3) Hamburg Wheel Test. The maximum allowable rut depth shall be 0.5 in. (12.5 mm). The minimum number of wheel passes at the 0.5 in. (12.5 mm) rut depth is based on the high temperature binder grade of the mix as specified in the mix requirements table on the plans and shall be according to the following.

Illinois Modified AASHTO T 324 Requirements 1/	
PG Grade	Minimum Number of Wheel Passes
PG 58-xx (or lower)	5,000
PG 64-xx	7,500
PG 70-xx	15,000 2/
PG 76-xx (or higher)	20,000 2/

Hamburg AASHTO T 324-22



Hamburg AASHTO T 324-22



Hamburg AASHTO T 324-22

I-Fit AASHTO T 393-22

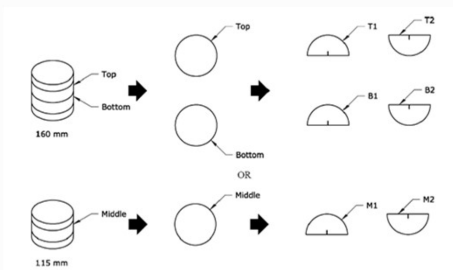
2022 Standard Specifications
Art. 1030.05(d)(4)

(4) I-FIT. The minimum flexibility index (FI) shall be as follows.

Illinois Modified AASHTO T 393		
Mixture	Short Term Aging, Minimum FI	Long Term Aging, Minimum FI [2/]
HMA [1/]	8.0	5.0 [3/]
SMA	16.0	10.0
IL-4.75	12.0	-

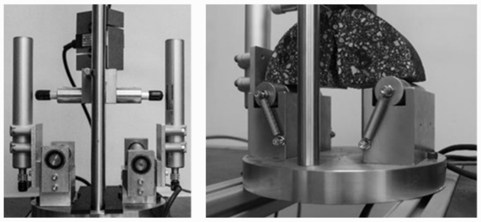
1/ All mix designs, except for SMA and IL-4.75 mixtures.

I-Fit AASHTO T 393-22



I-Fit AASHTO T 393-22

I-Fit AASHTO T 393-22

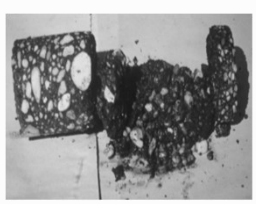


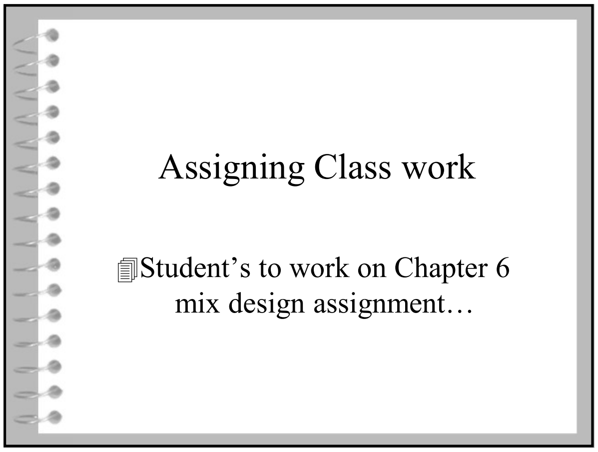
Laboratory Requirements

- Safety,
- Cooperation,
- Teamwork
- Care, Accuracy, Precision,
- Complete all paperwork,
- Class work during day.

End of Day

- Review of work done in laboratory,
- Assignment of homework,
- Solve this problem>>>>>>>




Assigning Class work
Student's to work on Chapter 6 mix design assignment…

I. OVERVIEW

- Slide show and calculation examples

II. MIXING

- Start with aggregate in oven to be batched to finish mixing.

III. TESTING PROCEDURES

A. Splitting

B. Stabilizing Mixture

C. Compaction

D. Bulk Specific Gravity (G_{mb}) - AASHTO T 166-22, Modified

E. Maximum Theoretical Specific Gravity (G_{mm}) - AASHTO T 209-22, Modified

F. Tensile Strength Ratio (TSR) - AASHTO T 283-22, Modified
Hamburg Wheel Tester – AASHTO T 324-22, Modified
Potential of Asphalt Mixtures Using the Illinois Flexibility Index Test (I-FIT) – AASHTO 393-22, Modified

G. Trial Gradations

H. HMA Mixture Requirements

IV. SUMMARY

Chapter 7

Mix and Compaction Temperatures

This table summarizes the correct mixing and compaction temperatures for IDOT HMA mixtures.

You should use this table for this class.

In practice, these may be overridden by a project special provision or test procedure in the Manual of Test Procedures for Materials.

	G_{MB}		G_{MM}		TEST Procedure
	Neat P_b	Modified P_b	Neat P_b	Modified P_b	
Mixing Temperature	295±5°F	325±5°F	295±5°F	325±5°F	T-312
Compaction Temperature	295±5°F	305±5°F	N/A	N/A	T-312
Aging Temperature	295±5°F	305±5°F	295±5°F	305±5°F	PP-2

I. OVERVIEW

HMA is the product of a national research effort for the development of a new method of asphalt mix design. It bases materials selection and level of laboratory compaction specifically on temperature and traffic. By basing materials selection on performance, HMA provides the agency with better selection and control of asphalt binder and aggregates.

There are four steps in the HMA mix design process: materials selection, design aggregate structure, design binder content, and performance test (TSR, Hamburg, I-Fit). During the materials selection, aggregates are tested for suitability.

Aggregate suitability is determined by testing for compliance with specification requirements for wear or abrasion resistance, detrimental fines, crushed pieces, or other qualities. Specific procedures for these tests are found in IDOT Standard Specifications and test procedure manuals.

The specific gravity of each aggregate is then obtained from the current IDOT aggregate specific gravity/absorption listing. Specific gravity of baghouse fines (BHF) for the asphalt and any mineral filler to be used in the mixture may also be obtained from IDOT. This information is later used to calculate the voids properties of test specimens.

Next, each aggregate has a washed sieve analysis conducted on it to determine its gradation. When RAP mixtures are being designed, the RAP gradations must be determined from washed extractions.

The individual aggregates are dry-sieved into fractions. The sizes shown are recommended. The results are used to calculate an aggregate blend that will produce the desired mix gradation. For preliminary mix design, initial trial mixes are usually made using an aggregate grading that approaches the median of the specification limits. When designing RAP mixtures, only the blended virgin aggregates are dry-sieved into fractions. The RAP is introduced into the batch as a whole percentage.

The next step is to compute the weights of the sized aggregates, mineral filler (if used), and asphalt required to prepare a compacted specimen of mixture 115mm ± 5mm in height for volumetrics. HMA uses the Superpave Gyratory Compactor (SGC) in the laboratory to simulate field densification.

The required number of batches of aggregate needed to produce the desired number of trial mixes through a range of asphalt binder contents are then prepared. This usually involves 8 to 10 batches.

Trial mixes are made by first heating the aggregate in a 161° C (322° F) (AASHTO R 35-17) oven to a temperature at approximately the mixing temperature of 146° ± 3° C (295° ± 5° F) (AASHTO R 30-02(2019)). RAP mixtures require that the RAP be “sandwiched” between the virgin aggregate prior to bringing it to mixing temperature.

Meanwhile, the asphalt binder is heated to the mixing temperature of 146° ± 3° C (295° ± 5° F). All mixtures requiring RAP should be designed using based on double bumping of the asphalt grade, (PG64-22 will be a PG58-28). The Engineer will reserve the right to change the grade of Asphalt Binder during field production if required by job specific information.

When the aggregate and asphalt binder are at the proper temperature, a heated mixing bowl is placed on a balance and its tare weight determined.

A previously prepared batch of heated aggregate is weighed into the bowl and a crater formed in its center.

The amount of asphalt binder required for each asphalt binder content mix is added to the aggregate mixture according to the previously calculated batch weights.

The aggregates and asphalt binder are thoroughly mixed with a mechanical mixer until all aggregate particles are uniformly coated.

The individual test specimens are then split according to the procedure described in the Level I course. The bulk specific gravity (G_{mb}) samples and the two maximum theoretical specific gravities (G_{mm}) (covered) are placed in the oven at 154° C (310° F) for a minimum of 1 hour. If coarse aggregate having an absorption greater than 2.5%, or slag aggregate, is used in a mixture design, both, the bulk specific gravity (G_{mb}) samples and the maximum theoretical specific gravity (G_{mm}) samples are placed in the oven at 154° C (310° F) for a minimum of 2 hours. After the 2 hours, the maximum theoretical specific gravity (G_{mm}) is removed and allowed to cool. NOTE: The 2-hour time requirement may be adjusted by the Engineer if required by job-specific information.

Meanwhile, a compaction mold and base plate are placed in a forced draft oven at 310 ± 5º F (154 ± 3º C) 30 minutes prior to compaction, and the SGC is set to the proper gyrations. The N_{design} table defines the gyration levels based on traffic loading, according to ESALs. This information is provided by the state in the General Notes table of the project plans.

A paper disk is placed in the bottom of the mold to prevent the paving mixture from sticking to the base.

Before compaction, the mix temperature is checked to be certain it is within the limits specified, i.e., 146° ± 3° C (295° ± 5° F).

Test specimens are transferred into the heated mold, leveled off, and a paper disk is placed on top of the material.

Compaction is done with the SGC according to Illinois Modified AASHTO T 312-19.

The specimen mold is then loaded into the compactor and centered under the loading ram. The ram is then lowered until the pressure on the specimen reaches 600kPa ± 18kPa.

An internal angle 1.16 ± 0.02° (20.2 ± 0.35 mrad) is applied to the mold assembly prior to engaging the SGC.

After the SGC shuts off, the angle from the mold assembly is removed, the ram is raised, and the mold is removed. The specimen is extruded from the mold.

The paper disks then removed, and each specimen is allowed to cool sufficiently so that it will not distort when removed from its mold.

After cooling, the specimens are removed from their molds. The end result is a series of specimens in duplicate, each containing a slightly different percentage of asphalt binder. The results derived from testing these specimens will be used to determine an optimum percentage of asphalt binder for the actual paving mixture.

In addition to batching enough to prepare the compacted specimens, there should be adequate material that the Maximum Theoretical Specific Gravity Test (G_{mm}) can be performed at each of the various asphalt binder contents. Along with specific gravity data for the aggregate, the data from this test is used to calculate volumetric properties of the compacted specimens.

The density and voids analysis is done by weighing each sample in both air and water to determine its bulk specific gravity. Bulk specific gravity is then used to calculate the specimen's density, percentage of air voids, and VMA (voids in the mineral aggregate).

The percentage of air voids, percentages of VMA, and percentages of VFA of all specimens tested are plotted on separate graphs. Here are the results of testing several mixtures, each containing a slightly different amount of asphalt cement. The data on these graphs will be used later to determine optimum asphalt content.

Once HMA testing is completed, there remains the job of determining from the test results which asphalt binder content is best for the final paving mixture and if at that asphalt binder content the various test properties satisfy the design criteria. IDOT requires the optimum asphalt binder content be established at the percentage corresponding to the design air voids selected.

The additional HMA design criteria, as plotted on the graphs, should be checked for specification compliance at the optimum asphalt binder content selected based on the design voids. These criteria include VMA and VFA.

All performance tests shall also be completed and reviewed for compliance with the current design requirements.

II. MIXING

This process involves coating heated aggregate with hot asphalt binder within certain temperature constraints in a manner similar to how field production should occur. Once the mixture has been produced in the lab, various field/lab tests can be performed to predict the expected performance in the field.

Note: The mixing and compaction temperatures used are a function of the type of asphalt binder used and are determined by temperature-viscosity curves. For unmodified Performance Graded (PG) binders, the mixing and compaction temperature is specified at 295° ± 5° F (146° ± 3° C).

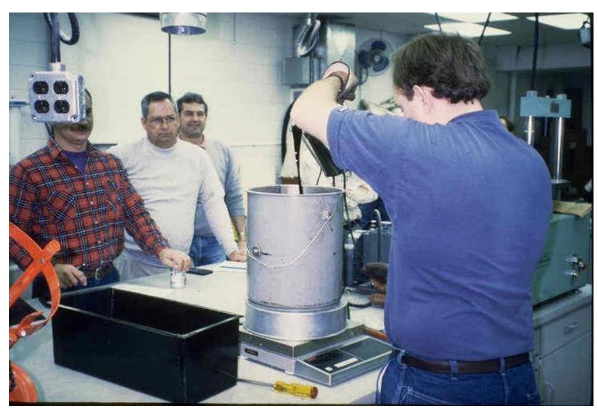
A. At this point, the batched aggregate should be in the oven, dried, and heated to no more than the mixing temperature. The asphalt binder should be at the mixing temperature of 295° ± 5° F (146° ± 3° C).

B. Create a dead space on the surface of the scale to prevent warping of the surface. Place the clean heated mixing bowl on the scale and tare the weight to zero. The mixing bowl should be clean prior to a new design or single point being mixed unless two mixes are to be performed in the same day using the same grade and supplier of asphalt binder.

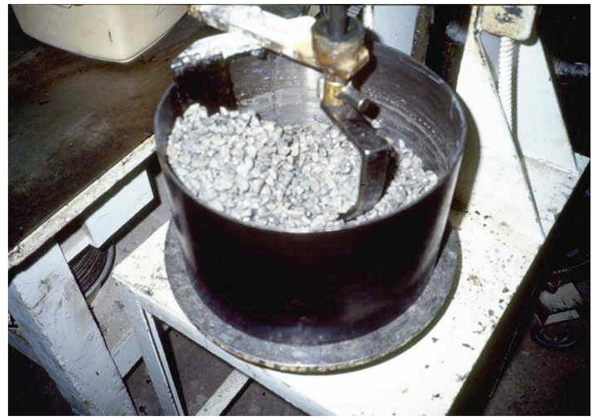
C. Introduce the heated aggregate into the mixing bowl. Check the batch weight of aggregate. Dry-mix the aggregate thoroughly.

D. In the center of the aggregate, form a crater into which the asphalt binder will be poured. At this point the aggregate should be at mixing temperature.

E. Slowly pour the calculated weight of asphalt binder into the center of the crater. This allows a minor adjustment to be made in the event too much asphalt binder is added accidentally.



F. Begin mixing immediately. Mix until a uniform distribution of asphalt is on all particles. There is no standard time on this process, but it should be done quickly to maintain the materials at the proper mixing temperature.

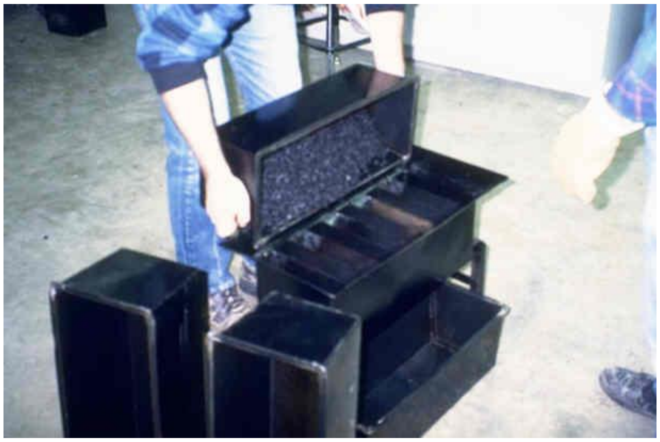


G. Remove the mix from the mixing bowl. Thoroughly clean the inside of the bowl and all the utensils used during this process. It should be noted to start with the batch containing the highest percent asphalt in an effort to butter the bowl. Repeat this mixing process for the remainder of the batches. Once the mixture is removed from the bowl, splitting of the material should occur as described in the following section.

III. TESTING PROCEDURES

A. Splitting

After the mixture has been uniformly mixed, the batch should be subdivided by splitting into test-sized samples using the procedure taught in Level I. It is best to do this while the mixture is still hot.



It may be necessary to use a scoop to add or subtract material from each final split to attain the proper sample test weight. Care must be taken to remove or add material to the sample uniformly. The sample weight for the maximum theoretical specific gravity (G_{mm}) should not be adjusted from an even split.

B. Stabilizing Mixture

This laboratory procedure allows the hot fluid asphalt binder to absorb into the aggregate particles while the mixture is being held in an oven for an extended period of time. This simulates the actual field operation where the mix is produced, sits in a silo, is hauled by a truck, and is placed in the roadway.

1. After the mixture is split into specimen-sized samples, the loose mixture is placed in a baking pan at an even thickness of 1 to 2 inches. (G_{mm}) samples shall be covered.

2. The samples shall remain in the oven a minimum of one hour. For aggregates with water absorption greater than 2.5% and for slag aggregates, the cure time for the bulk specific gravity (G_{mb}) specimens, as well as the maximum theoretical specific gravity (G_{mm}) sample, shall be extended to 2 hours.

   If the mixture is being conditioned for 2 hours, stir the mixture after 1 hour to maintain uniform conditioning. Illinois Modified AASHTO R30 covers mixture conditioning.

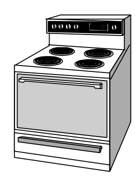
   Conditioning temperatures are as follows:

   - 295±5 °F for unmodified asphalt
   - 305±5 °F for modified asphalt

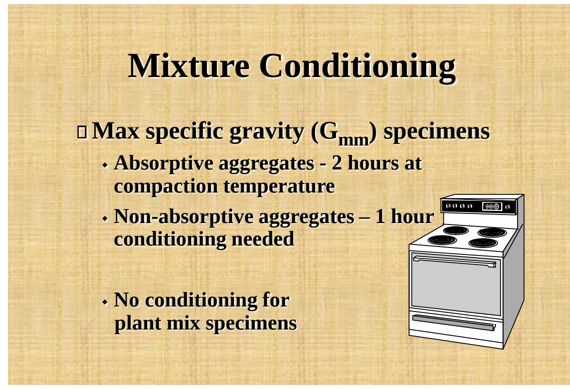
See Figure7.1

Mixture Conditioning

- **Bulk specific gravity (G_{mb}) specimens**
  - **Absorptive aggregates - 2 hours at compaction temperature**
  - **Non-absorptive - 1 hour at compaction temperature**
  - **No conditioning for plant mix specimens**



3. Once the bulk specific gravity (G_{mb}) specimens are at their compaction temperature anytime after this initial cure, they shall be compacted. The maximum theoretical specific gravity (G_{mm}) sample is allowed to cool after the cure time is reached. Once cooled, this test procedure can continue.



C. Compaction

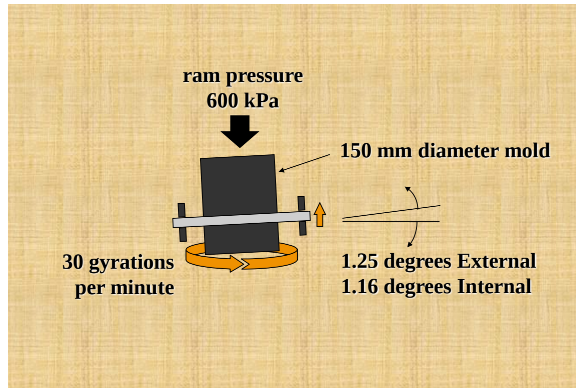
The goals of the HMA Compaction Method are as follows:

- Simulate field densification
  - Traffic
  - Climate
- Accommodate large aggregates
- Measure mix compactability
- Equipment conducive to QC

In achieving such goals, the Superpave gyratory compactor (SGC) was developed.

The first two SGC manufacturers were Pine and Troxler, however, many styles from several manufacturers now exist.

The diagram to the right shows the characteristics of the Superpave gyratory compactor.



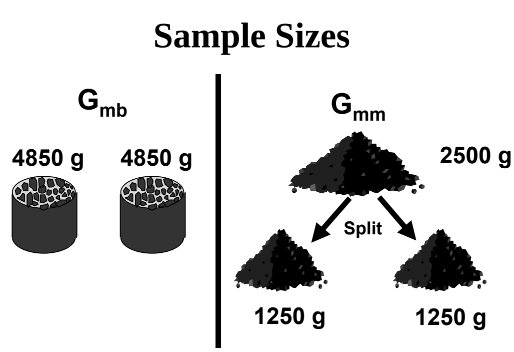
- The 150mm mold allows for up to 37.5mm (1.5 inch) maximum aggregate size.
- Recording of the height of the mixture in the mold during the compaction process is an important feature.

Compaction in the laboratory attempts to simulate the compactive forces of the construction equipment and traffic. It is also used to produce samples of compacted mixture in order to test various strength, volumetric, and performance characteristics. The procedure is as follows:

1. Heat the individual sized test specimens to the desired temperature in an oven. The approximate HMA sample sizes are as follows:

   - No Slag - - - - - - - - 4850g
   - 50/50 Steel Slag - - 5150g
   - 50/50 ACBF Slag - - 4650g

   Specimen preparation is conducted using the Illinois Modified AASHTO TP4 procedure. A table listing G_{mm} vs. HMA sample size is given at the end of this chapter.



2. Place a thermometer in the heart of the sample to assure an accurate temperature.

3. Set the SGC to the proper gyrations.

   Note: Dwell gyrations must be set to zero.

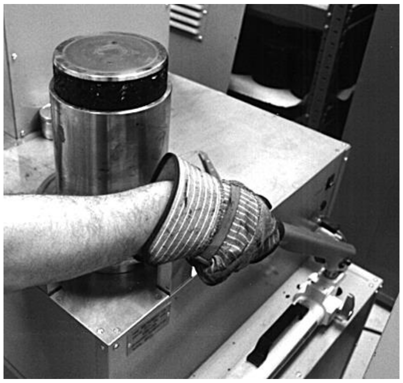
4. Place a paper disk in the bottom of the mold.

5. The sample is loaded into the mold in one smooth, continuous motion.

6. Place the mold into the SGC.

7. Activate the SGC for the given number of gyrations.

8. After the compaction is complete, allow the mix to cool and remove the sample from the mold.

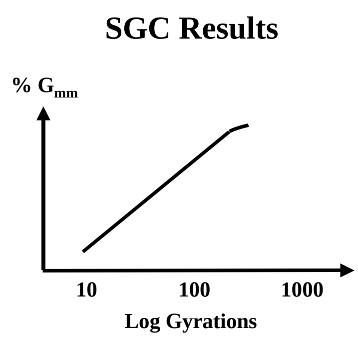


9. Remove the paper disks.

10. Mark the sample with its identification.

The height during compaction is converted to percent of maximum theoretical density, and plotted versus number of gyrations.

This plot is typically a straight line, with maybe a slight downturn at the end of the compaction cycle.

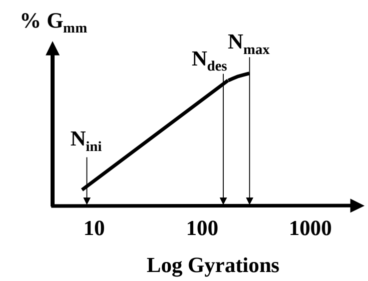


Previously, compaction was carried out to N_{max}, and the density of the mix was determined at N_{max}, N_{des}, and N_{ini}.

Compaction is now stopped at N_{des}, not at N_{max}, except as a final check.

Illinois Modified AASHTO PP28 covers HMA mix design, however, Illinois has not yet addressed the measurement and specification of density values at N_{max} and N_{ini} for the Illinois compaction levels.

Three Points on SGC Curve



Illinois has, however, developed the N_{design} table for compactive effort. The ESALs are determined using a design life of 20 years, even if the road design life isn't going to be 20 years.

Table 1 – N_{design} Table

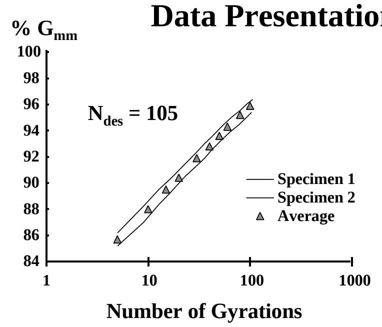
Design ESALs (millions) Based on 20-year design	N_{des}	Typical Roadway Application
< 0.3	30	Roadway with very light traffic volume such as local roads, county roads, and city streets where truck traffic is prohibited or at a very minimal level (considered local in nature; not regional, intrastate, or interstate). Special purpose roadways serving recreational sites or areas may also be applicable.
0.3 to 3	50	Includes many collector roads or access streets. Medium-trafficked city streets and the majority of county roadways.
3 to 10	70	Includes many two-lane, multi-lane, divided, and partially or completely controlled access roadways. Among these are medium-to-highly trafficked streets, many state routes, U.S. highways, and some rural interstates.
≥ 10	90	May include the previous class of roadways which have a high amount of truck traffic. Includes U.S. Interstates, both urban and rural in nature. Special applications such as truck-weighing stations or truck-climbing lanes on two-lane roadways may also be applicable to this level.

Using both specimens, the compaction data is averaged.

Nationally, compaction is carried out to N_{max} only as a final check of the design mixture.

Compaction may be carried out to 125 gyrations with 2 specimens mixed at optimum asphalt binder content to capture locking point data and further characterize IDOT HMA mixes.

Data Presentation



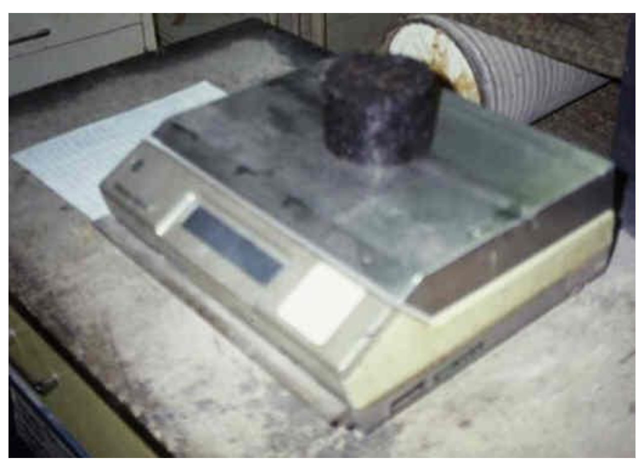
D. Bulk Specific Gravity (G_{mb}) - AASHTO T 166-22, Illinois Modified

This step of the process involves determining the specific gravity of the compacted specimen to be used when calculating various volumetric properties of the mixture.

1. Once cooled, brush the Marshall brick to remove any loose particles from the sample.

2. Measure the height of the specimen in three locations and record the average to the nearest 1.0 mm (1/16 inch).

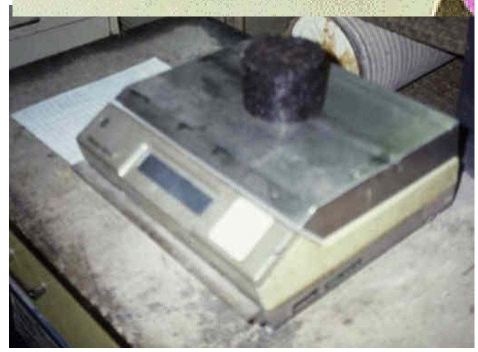
3. Determine the specimen's original dry weight to the nearest 0.1 gram.



4. Place the specimen(s) in a tub of 77° ± 1.8° F (25° ± 1° C) water on their curved side completely submerged for 4 ± 1 minutes. Gently tap the sides of the tub to assure the voids in the specimen are filled with water.

5. Place the specimen on its curved side in the hanging basket and record the sub-merged weight to the nearest 0.1 gram.

6. Remove the specimen and lightly pat the surface dry with a damp towel and record its weight to the nearest 0.1 gram.



7. Calculate the specific gravity by the following equation:

$$G_{mb} = \frac{\text{Original Dry Weight}}{(\text{Saturated Surface Dry Weight} - \text{Submerged Weight})}$$

8. Convert the G_{mb} to a unit weight by multiplying by 1,000 kg/m^3 (62.4 lbs/ft^3).

QC/QA WORK SHEET FOR HMA TEST

NAME____________________COMPANY___________________SAMPLE#__________

BRICK NO.	________	________	________
DRY WEIGHT	________	________	________
SATURATED SURFACE DRY WEIGHT	________	________	________
SUBMERGED WEIGHT	________	________	________
BULK SPECIFIC GRAVITY G_{mb} (d)	________	________	________
%VOIDS	________	________	________
G_{mm}(D)	________	________	________
HEIGHT	________	________	________

BRICK NO.	________	________	________
DRY WEIGHT	________	________	________
SATURATED SURFACE DRY WEIGHT	________	________	________
SUBMERGED WEIGHT	________	________	________
BULK SPECIFIC GRAVITY G_{mb} (d)	________	________	________
%VOIDS	________	________	________
G_{mm}(D)	________	________	________
HEIGHT	________	________	________

This Page Is Reserved

E. Maximum Theoretical Specific Gravity (G_{mm}) - AASHTO T 209-22, Illinois Modified

This procedure determines the maximum specific gravity a paving mix can obtain. This would be considered a voidless mix. It is used in calculating various volumetric properties of the mixture.

1. Calibrate the pycnometer. The pycnometer pot should be calibrated periodically and anytime questionable results are obtained. This should be documented.

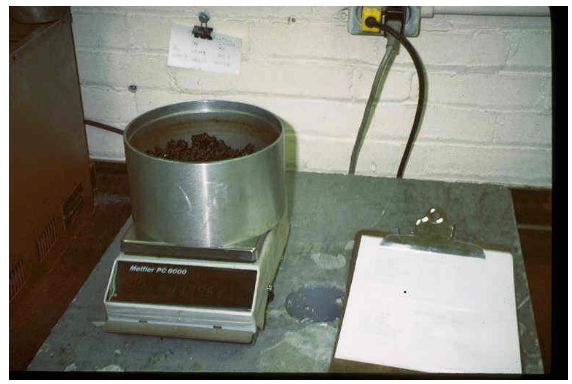
   (a) Place the pycnometer and lid in 77° ± 1.8 F (25° ± 1° C) bath for 10 minutes.

   (b) Place the lid on the pycnometer; seat firmly, pressing out excess water and entrapped air.

   (c) Weigh the lid, pycnometer, and water. Repeat two more times and average all three weights. This is the average pycnometer calibration weight and should be recorded as letter (D) on your worksheet.

2. Cool the sample and split to test weight. Separate the particles by hand to minus 6mm (1/4-inch) size.

3. Weigh the sample at dry weight to the nearest 0.1 gram and record as (A).
4. Place the sample in the pycnometer and cover with water.



5. Remove entrapped air by subjecting the sample to a partial vacuum of 730 mm (28.7 inches) Hg or greater vacuum gauge pressure for 15 ± 2 minutes.

6. Submerge the pycnometer and the sample in 77° ± 1.8° F (25° ± 1° C) bath for 10 minutes.
7. Cover with lid; seat it firmly, thus forcing out water and entrapped air

8. Weigh pycnometer, lid, sample, and water to nearest 0.1 gram and record as (E).

9. Calculate the maximum theoretical specific gravity (G_{mm}) by the following equation:

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

10. Convert the G_{mm} to a density by multiplying it by 1,000 kg/m^3 (62.4 lbs/ft^3).

Maximum Specific Gravity (G_{mm}) Worksheet (Weighing-In-Water Method)

Name______________________________

		Sample 1	2	3	4
1. Dry sample Weight	(A)	________	________	________	________
2. Averaged calibrated Pycnometer weight (Pycnometer suspended in water bath)	(C)	________	________	________	________
3. Vacuumed sample weight (Pycnometer + sampled suspended In water bath)	(B)	________	________	________	________
4. Maximum Specific Gravity (report to 3 places, **[2.xxx])**		________	________	________	________

$$\frac{A}{A - (B-C)}$$

Average G_{mm}(D) ________ (2.xxx)

Pyc. Calibration Weights

1. __________
2. __________
3. __________

A = Dry sample weight

C = Calibrated Pycnometer weight

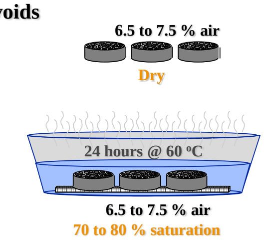
B = Vacuumed sample + Pycnometer suspended in water bath

F. Tensile Strength Ratio (TSR) - AASHTO T 283-22, Illinois Modified

This will be reviewed in Chapter 13

IL Modified AASHTO T 283-22 Conditioning

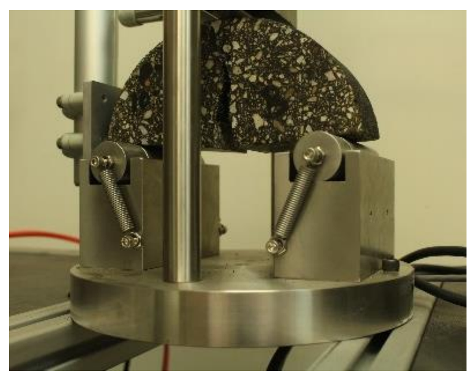
- two subsets with equal voids
  - one - "dry"
  - one - saturated
- One set conditioned
  - 24 hrs @ 60˚C
  - 2 hrs @ 25˚C before testing



Moisture Sensitivity.

Hamburgs

IFit



HMA Example

Class example.

Location(s):	Interstate
Mixture Use(s):	Surface
AC/PG:	SBS PG 70-22
Design Air Voids:	0
Mixture Composition:	4.0 @ N_{des} = 90
(Gradation Mixture)	IL-12.5mm
Friction Aggregate:	Mixture D

IV.SUMMARY

A. Materials Selection and Evaluation

1. Select asphalt binder content specification and HMA criteria for project conditions.
2. Select materials.
   (a) asphalt binder
   (b) coarse aggregate
   (c) fine aggregate
3. Verify that materials meet required specifications.

B. Trial Mix Preparation and Testing

1. Obtain temperature/viscosity relationship of asphalt binder.
2. Determine gradation of aggregates.
3. Obtain specific gravity and absorption of aggregates.
4. Perform aggregate blend calculations.
5. Prepare aggregate portion of trial mix specimens.
6. Mix and compact trial mix specimens.
7. Measure maximum theoretical specific gravity of trial mixes.
8. Test trial mix specimens.
9. Calculate volumetric properties of trial mix specimens.
   (a) air voids
   (b) voids in the mineral aggregate
   (c) voids filled with asphalt binder

C. Analysis of Results

1. Plot trial mix data, i.e., asphalt binder content versus:
   (a) air voids
   (b) voids in the mineral aggregate (VMA)
   (c) voids filled with asphalt (VFA)
   (d) specific gravities G_{mb} G_{mm}
2. Select optimum asphalt binder content for desired mix behavior.
3. Perform moisture susceptibility test (TSR) to determine if an anti-strip agent is required or is effective.
4. Perform Hamburg Wheel-Track Test to determine compliance with specification.
5. Perform and Determine the Fracture Potential of Asphalt Mixtures Using the Illinois Flexibility Index Test (I-Fit) to determine the compliance with the specifications.

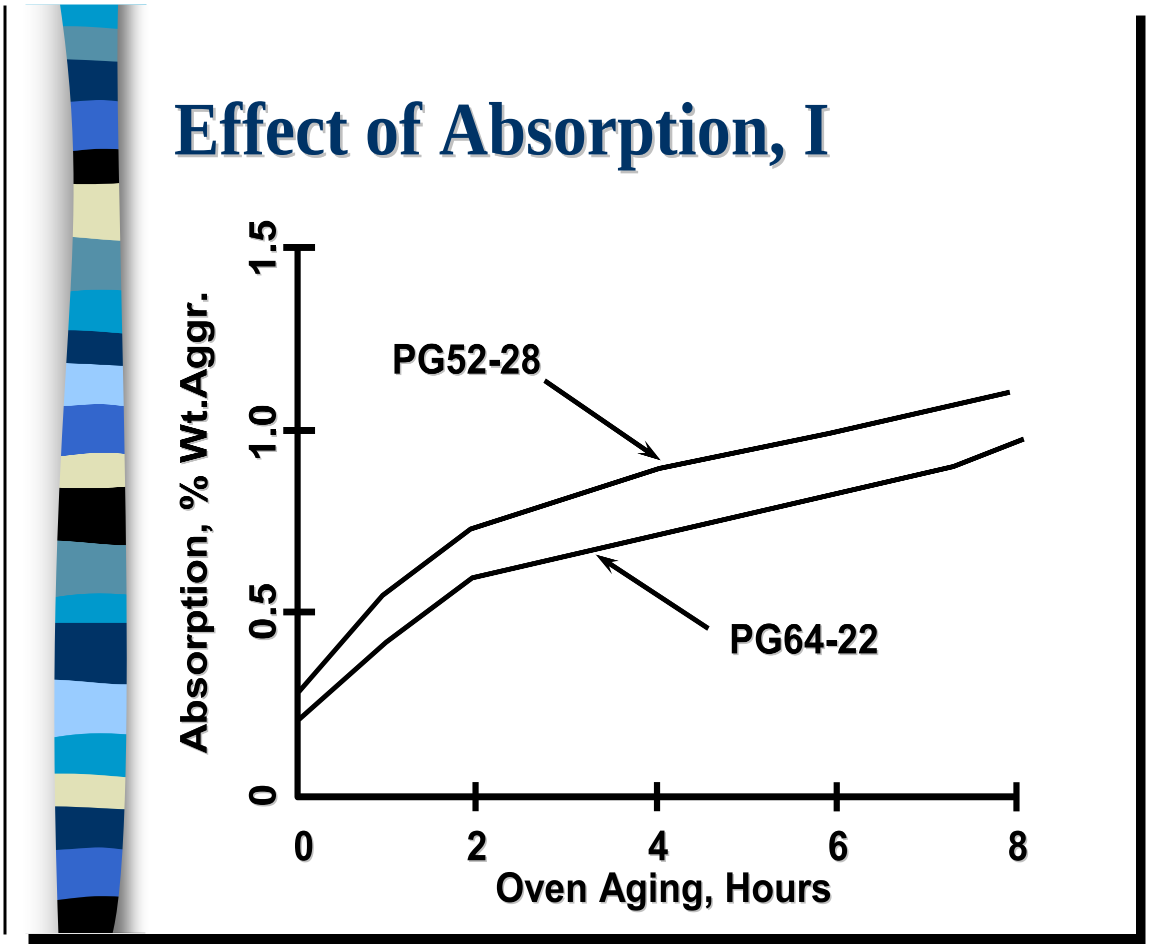

Effect of Absorption, I
Absorption, % Wt.Aggr.
0
0.5
1.0
1.5
PG52-28
PG64-22
0
2
4
6
8
Oven Aging, Hours

Figure 7.1

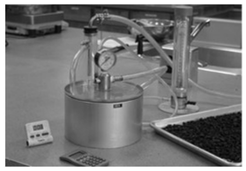
Superpave Gyratory Sample Masses for Varying Gmm

(includes asphalt and aggregate)

DESIRED VOIDS 4
1
DESIRED HEIGHT(mm) 115

Gmm	MASS, g	Gmm	MASS, g
2.30	**4487**	**2.56**	**4994**
2.31	**4507**	**2.57**	**5014**
2.32	**4526**	**2.58**	**5033**
2.33	**4546**	**2.59**	**5053**
2.34	**4565**	**2.60**	**5072**
2.35	**4585**	**2.61**	**5092**
2.36	**4604**	**2.62**	**5111**
2.37	**4624**	**2.63**	**5131**
2.38	**4643**	**2.64**	**5150**
2.39	**4663**	**2.65**	**5170**
2.40	**4682**	**2.66**	**5189**
2.41	**4702**	**2.67**	**5209**
2.42	**4721**	**2.68**	**5229**
2.43	**4741**	**2.69**	**5248**
2.44	**4760**	**2.70**	**5268**
2.45	**4780**	**2.71**	**5287**
2.46	**4799**	**2.72**	**5307**
2.47	**4819**	**2.73**	**5326**
2.48	**4838**	**2.74**	**5346**
2.49	**4858**	**2.75**	**5365**
2.50	**4877**	**2.76**	**5385**
2.51	**4897**	**2.77**	**5404**
2.52	**4916**	**2.78**	**5424**
2.53	**4936**	**2.79**	**5443**
2.54	**4955**	**2.80**	**5463**
2.55	**4975**	**2.81**	**5482**

Asphalt Mixture Volumetrics

Timothy R. Murphy, P.E.
President
Murphy Pavement Technology

Asphalt Mixture Volumetrics

- **Section Objectives**
  - **Review the component relationships of an asphalt mixture**
  - **Step through example mass/volume calculations**
  - **Review the volumetric requirements of HMA**

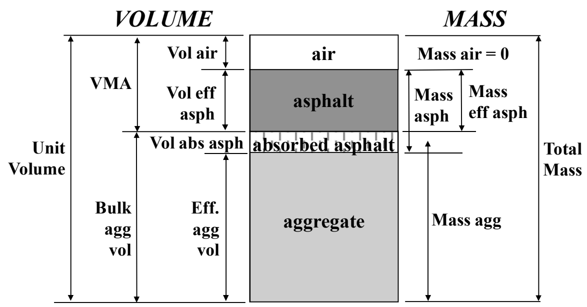
Final Result

Participant will understand the basis of the volumetric mix design determinations.

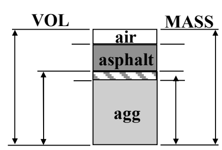
Volumetric Nomenclature

Percentage, "P" **Gravity, "G"**

Reference Handout



Specific Gravity



- {mix, agg, and binder}
- Bridge between Mass and Volume

$$G = \frac{\left(\frac{M_x}{V_x}\right)}{\left(\frac{M_w}{V_w}\right)}$$

$\left(\frac{M_w}{V_w}\right)$ = 1.000 g/cm^3 — approx. density of water at 25° C

Specific Gravity

- Relates Density

$$D = G \times 1.000$$

- D: Density in g/cm^3
- G: specific gravity of object
- 1.000: density of water

Specific Gravity

- **Relates Volume**

$$V = \frac{M}{G \times 1.000}$$

mass of object (M)
volume of object (V)
specific gravity of object (G)
density of water (1.000)

Specific Gravity

- **Relates Mass**

$$M = V \times G \times 1.000$$

volume of object (V)
mass of object (M)
specific gravity of object (G)
density of water (1.000)

Aggregate Specific Gravity (Three Types Exist for HMA)

- **Bulk (G_{sb}) Volume**
  - **SSD condition**
- **Effective (G_{se}) Volume**
  - **excludes absorbed asphalt volume**
- **Apparent (G_{sa}) Volume**
  - **excludes absorbed water volume**

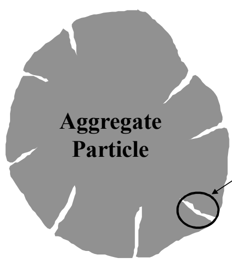
Same Mass

Different Volumes

Aggregate Bulk Specific Gravity

"SSD" Level

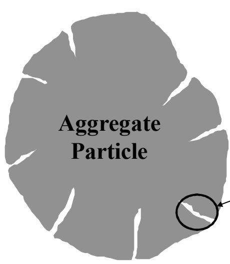
$$G_{sb} = \frac{\text{Dry Mass}}{\text{Bulk Vol}} \Big/ 1.000\ \text{g/cm}^3$$



Bulk Volume = solid volume + water permeable pore volume

Aggregate Apparent Specific Gravity

$$G_{sa} = \frac{\text{Dry Mass}}{\text{App Vol}} \Big/ 1.000\ \text{g/cm}^3$$

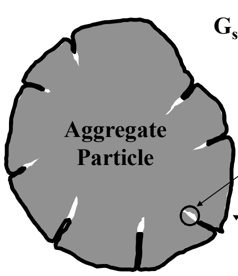


Apparent Volume = volume of solid aggregate particle only

Pores not included

Aggregate Effective Specific Gravity

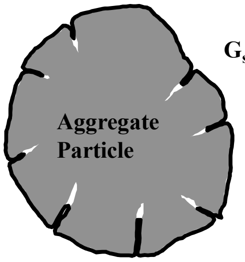
$$G_{se} = \frac{\text{Dry Mass}}{\text{Eff Vol}} \Big/ 1.000\ \text{g/cm}^3$$



Effective Volume = solid volume + volume of water permeable pores not filled with asphalt

asphalt coating

Aggregate Effective Specific Gravity



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

G_{mm}: measured "Rice" gravity

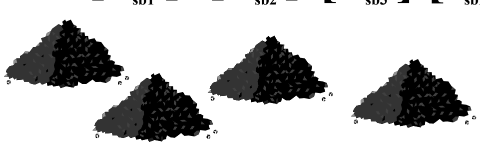
G_b: measured

Aggregate Specific Gravities

- G_{sb} - largest volume, lowest value
- G_{se} - in-between volume, middle value
- G_{sa} - smallest volume, highest value

Combined Aggregate Bulk Specific Gravity

$$G_{sb}\text{ (combined)} = \frac{100}{\left[\frac{P_1\%}{G_{sb1}}\right] + \left[\frac{P_2\%}{G_{sb2}}\right] + \left[\frac{P_3\%}{G_{sb3}}\right] + \left[\frac{P_{RAP}\%}{G_{sbRAP}}\right]}$$



Bulk Specific Gravity - Mix

- **Definition**
  - **mass of a unit volume of mix compared to unit volume of water**
  - **Use G_{mb}**
- **"Bulk Density"**
  - **contains several materials**

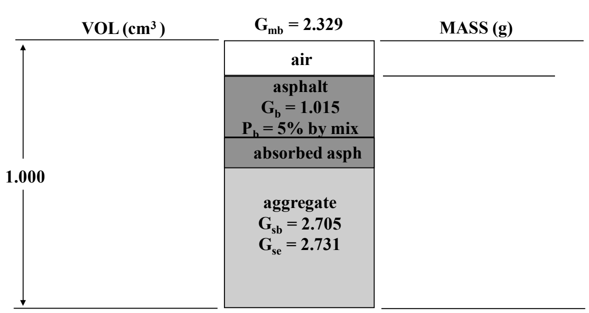
$$G_{mb} = \frac{\text{Dry Mass}}{\text{Bulk Volume}}$$

Bulk Volume = SSD Mass-Weight In Water

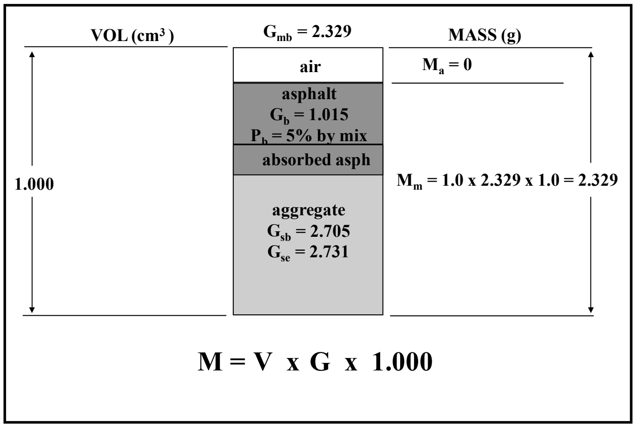
Maximum Theoretical Specific Gravity - Mix

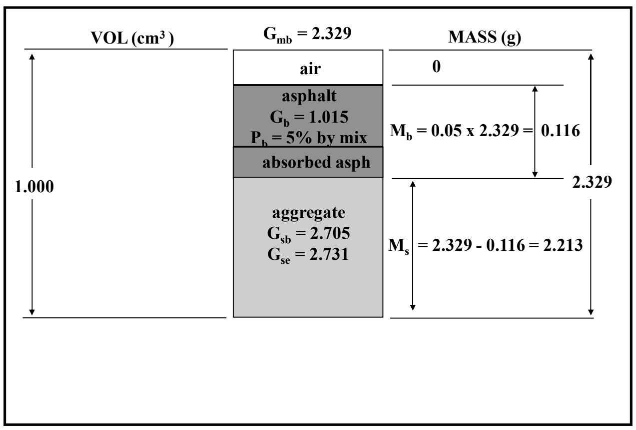
- **Definition**
  - **mass per volume of material containing no air voids, compared to unit volume of water**
- **Use G_{mm}**

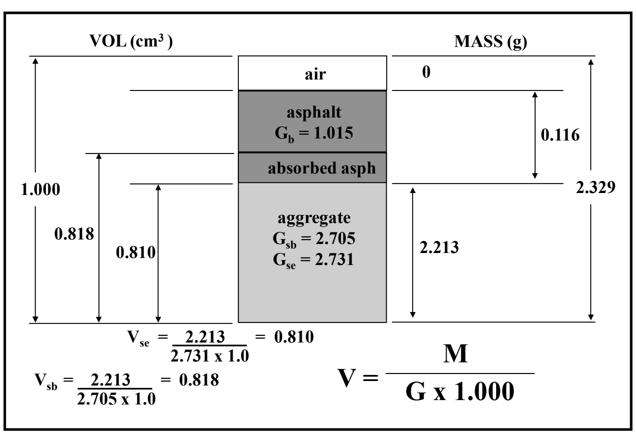
$$G_{mm} = \frac{\text{Dry Mass}}{\text{Voidless Volume}}$$

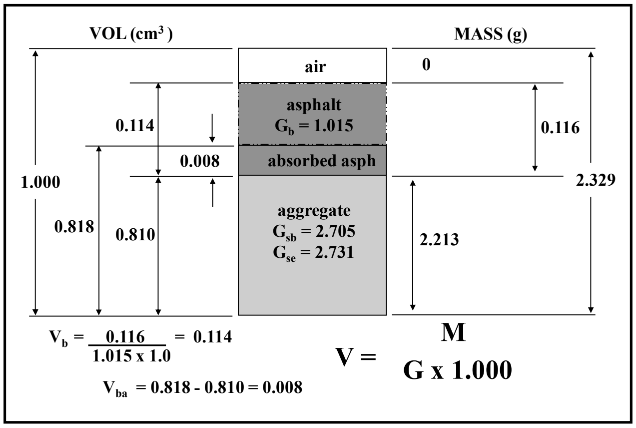


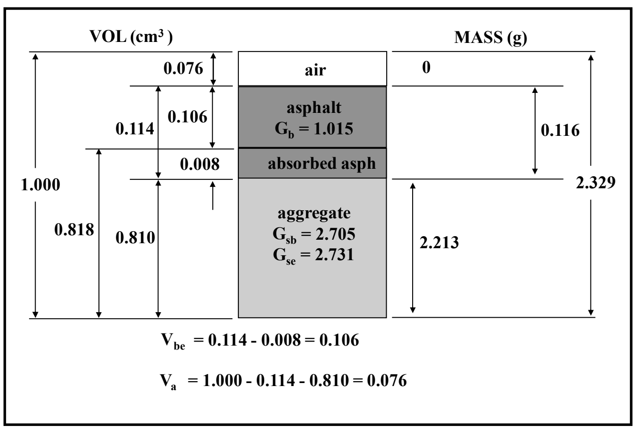
$$G = [\, M / V \,] / \gamma_{H2O}$$

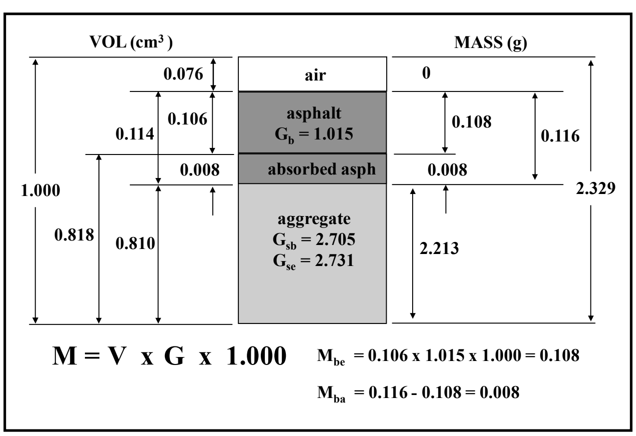

VOL (cm³)
Gmb = 2.329
MASS (g)
air
Ma = 0
asphalt
Gb = 1.015
Pb = 5% by mix
absorbed asph
1.000
Mm = 1.0 x 2.329 x 1.0 = 2.329
aggregate
Gsb = 2.705
Gse = 2.731
M = V x G x 1.000

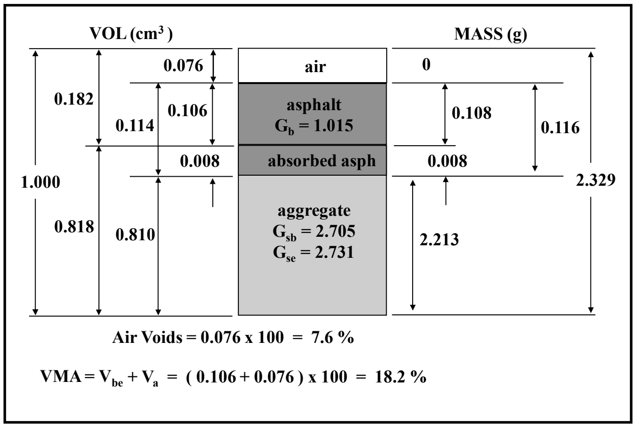

VOL (cm³)
Gmb = 2.329
MASS (g)
air
0
asphalt
Gb = 1.015
Pb = 5% by mix
Mb = 0.05 x 2.329 = 0.116
absorbed asph
1.000
2.329
aggregate
Gsb = 2.705
Gse = 2.731
Ms = 2.329 - 0.116 = 2.213

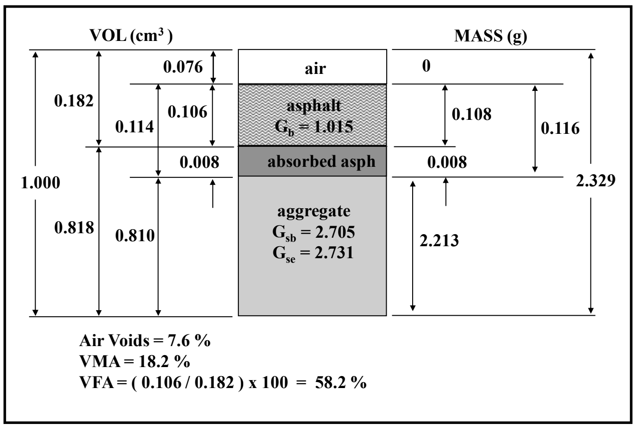

VOL (cm³)
MASS (g)
air
0
asphalt
Gb = 1.015
0.116
absorbed asph
1.000
2.329
aggregate
Gsb = 2.705
Gse = 2.731
0.818
0.810
2.213
Vse = 2.213 / 2.731 x 1.0 = 0.810
Vsb = 2.213 / 2.705 x 1.0 = 0.818
V = M / G x 1.000

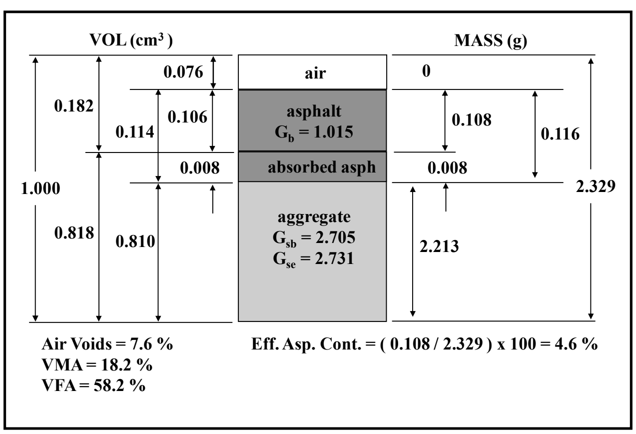

VOL (cm³)
MASS (g)
air
0
asphalt
Gb = 1.015
0.114
0.116
0.008
absorbed asph
1.000
2.329
aggregate
Gsb = 2.705
Gse = 2.731
0.818
0.810
2.213
Vb = 0.116 / 1.015 x 1.0 = 0.114
V = M / G x 1.000
Vba = 0.818 - 0.810 = 0.008

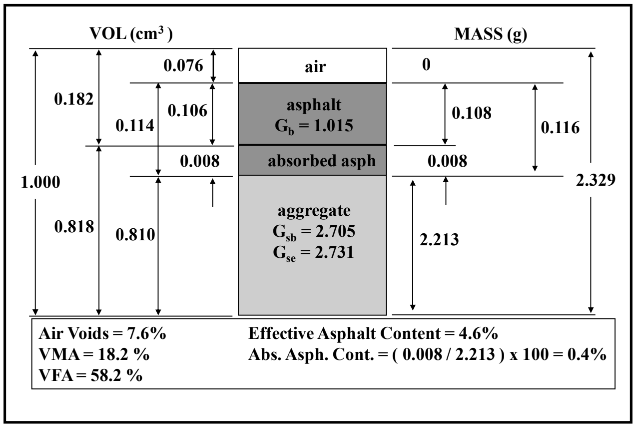

VOL (cm³)
MASS (g)
0.076
air
0
0.106
asphalt
Gb = 1.015
0.114
0.116
0.008
absorbed asph
1.000
2.329
aggregate
Gsb = 2.705
Gse = 2.731
0.818
0.810
2.213
Vbe = 0.114 - 0.008 = 0.106
Va = 1.000 - 0.114 - 0.810 = 0.076

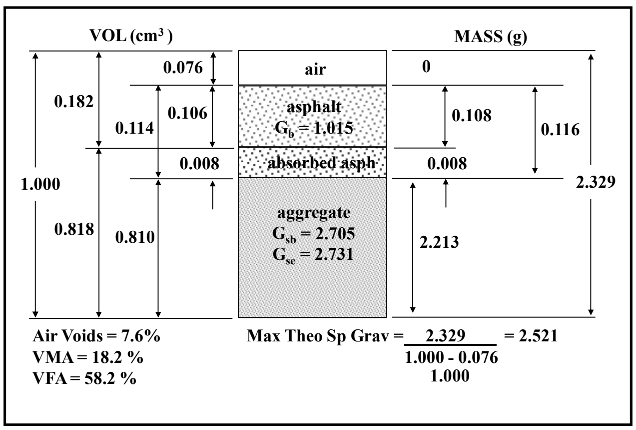

VOL (cm³)
MASS (g)
0.076
air
0
0.106
asphalt
Gb = 1.015
0.108
0.114
0.116
0.008
absorbed asph
0.008
1.000
2.329
aggregate
Gsb = 2.705
Gse = 2.731
0.818
0.810
2.213
M = V x G x 1.000
Mbe = 0.106 x 1.015 x 1.000 = 0.108
Mba = 0.116 - 0.108 = 0.008

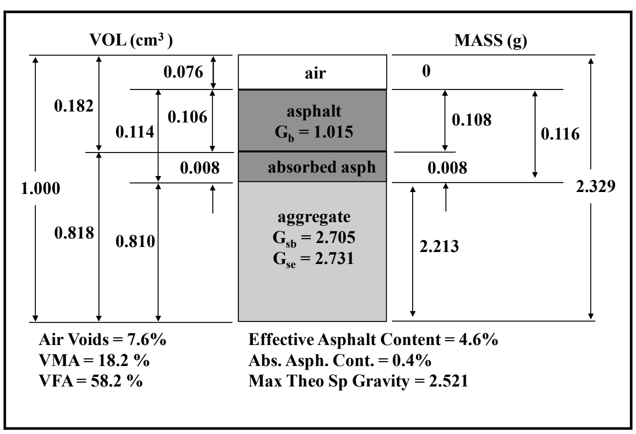

VOL (cm³)
MASS (g)
0.076
air
0
0.182
0.114
0.106
asphalt
G_b = 1.015
0.108
0.116
0.008
absorbed asph
0.008
1.000
2.329
0.818
0.810
aggregate
G_sb = 2.705
G_se = 2.731
2.213
Air Voids = 0.076 x 100 = 7.6 %
VMA = V_be + V_a = (0.106 + 0.076) x 100 = 18.2 %


VOL (cm³)
MASS (g)
0.076
air
0
0.182
0.114
0.106
asphalt
G_b = 1.015
0.108
0.116
0.008
absorbed asph
0.008
1.000
2.329
0.818
0.810
aggregate
G_sb = 2.705
G_se = 2.731
2.213
Air Voids = 7.6 %
VMA = 18.2 %
VFA = (0.106 / 0.182) x 100 = 58.2 %


VOL (cm³)
MASS (g)
0.076
air
0
0.182
0.114
0.106
asphalt
G_b = 1.015
0.108
0.116
0.008
absorbed asph
0.008
1.000
2.329
0.818
0.810
aggregate
G_sb = 2.705
G_se = 2.731
2.213
Air Voids = 7.6 %
VMA = 18.2 %
VFA = 58.2 %
Eff. Asp. Cont. = (0.108 / 2.329) x 100 = 4.6 %


VOL (cm³)
MASS (g)
air
asphalt
Gb = 1.015
absorbed asph
aggregate
Gsb = 2.705
Gse = 2.731
0.076
0.182
0.114
0.106
0.008
1.000
0.818
0.810
0
0.108
0.116
0.008
2.329
2.213
Air Voids = 7.6%
VMA = 18.2 %
VFA = 58.2 %
Effective Asphalt Content = 4.6%
Abs. Asph. Cont. = (0.008 / 2.213) x 100 = 0.4%


VOL (cm³)
MASS (g)
air
asphalt
Gb = 1.015
absorbed asph
aggregate
Gsb = 2.705
Gse = 2.731
0.076
0.182
0.114
0.106
0.008
1.000
0.818
0.810
0
0.108
0.116
0.008
2.329
2.213
Air Voids = 7.6%
VMA = 18.2 %
VFA = 58.2 %
Max Theo Sp Grav = 2.329 / (1.000 - 0.076 / 1.000) = 2.521


VOL (cm³)
MASS (g)
air
asphalt
Gb = 1.015
absorbed asph
aggregate
Gsb = 2.705
Gse = 2.731
0.076
0.182
0.114
0.106
0.008
1.000
0.818
0.810
0
0.108
0.116
0.008
2.329
2.213
Air Voids = 7.6%
VMA = 18.2 %
VFA = 58.2 %
Effective Asphalt Content = 4.6%
Abs. Asph. Cont. = 0.4%
Max Theo Sp Gravity = 2.521

Presentation of Equations

Reference MS-2

$$G_{mm} = \frac{100}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

$$V_a = \left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right) \times 100$$

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

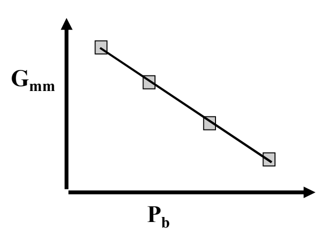
$$VMA = 100 - \frac{G_{mb} \times P_s}{G_{sb}}$$

$$P_{be} = P_b - \frac{P_{ba} \times P_s}{100}$$

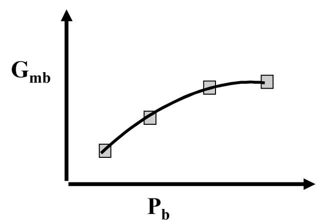
$$P_{ba} = 100 \times \left(\frac{G_{se} - G_{sb}}{G_{se} \times G_{sb}}\right) \times G_b$$

$$\text{Eff. Vol.} = VMA - V_a$$

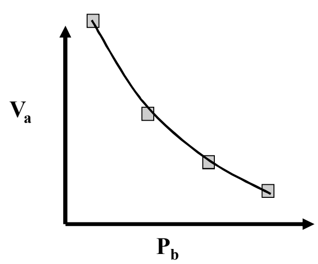
Maximum Theoretical Specific Gravity at Other Asphalt Binder Contents



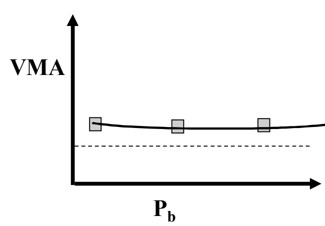
Bulk Specific Gravity at Other Asphalt Binder Contents



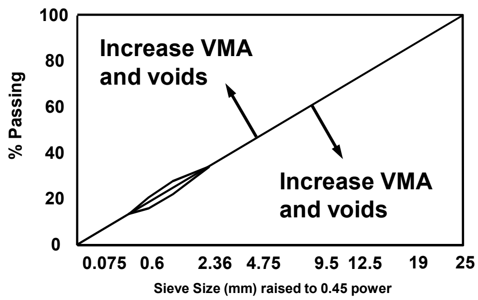
Air Void Content



Voids in the Mineral Aggregate



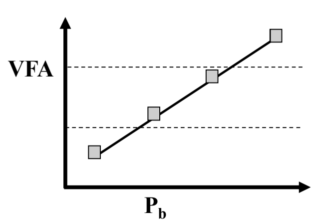
Voids in the Mineral Aggregate



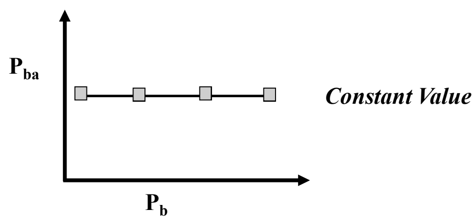
VMA Adjustments

1. Increase or decrease manufactured/natural sand blend.
   - Changes 600 μm
   - Changes on minus 75 μm
2. Increase or decrease chips in intermediate or base mixture
   - Changes 4.75 mm to 2.36 mm material
3. Increase or decrease minus 75 μm (MF)
4. Change sources

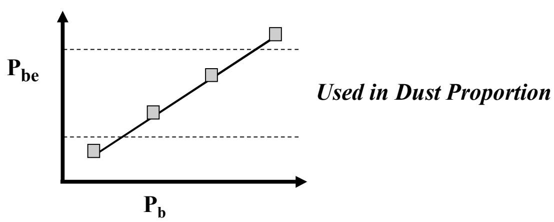
Voids Filled With Asphalt



Absorbed Asphalt Binder Content

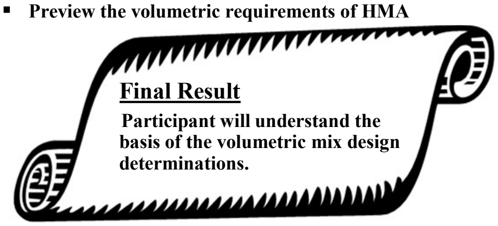


Effective Asphalt Binder Content



Asphalt Mixture Volumetrics

- **Section Objectives**
  - **Review the component relationships of an asphalt mixture**
  - **Step through example mass/volume calculations**
  - **Preview the volumetric requirements of HMA**



Volumetric's Problem

Reference last page of Chapter…

BINDER HOMEWORK PROBLEM
SUMMARY – COMPACTED MIX PROPERTIES

P_b	G_{mm}	G_{mb}	G_{se}	V_a	VMA	VFA	P_{ba}	P_{be}	Eff. Vol.	G_{sb}	G_b
4.0	2.526	2.417									1.030
4.5	2.510	2.422									1.030
5.0	2.495	2.434									1.030
5.5	2.480	2.442									1.030

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I. INTRODUCTION

A. Write-up

B. Simple Terms/Definitions

C. Example Calculations and Mix Design Sheet (show calculations by hand)

II. EXAMPLE OF VOLUME / WEIGHT RELATIONSHIP

- Sample calculation

III. CALCULATIONS OF VOLUMETRIC PROPERTIES

A. Mix Design Terminology / Symbols Used in Analyzing a Compacted Paving Mixture

B. Order of Calculations / Equations

C. Sample Surface Design Problems and Graphing

- Homework binder problem discussion
- Course example calculations
- Graphing

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I. INTRODUCTION

In the volumetric analysis of paving mixtures, it can be very confusing when discussing percents whether it is ingredient materials or volumetric properties. This section will attempt to show how to easily make conversion between descriptions made on a percent weight basis and an equivalent percent volume basis.

This class will also attempt to describe the various parameters and test results listed in the summary section of the Test Data. This description will include calculations as well as theoretical and practical relationships of the test values as far as mixture performance is concerned.

A. Write-up

1. Background

One of the crucial steps in designing HMA is determining and evaluating weight and volume characteristics. Quality control procedures also require these analyses. Individuals concerned with compacted HMA in the mix design and quality control phases must have a thorough understanding of weight and volume properties. They must know what they are, how to calculate them, and the implications of their numerical value.

2. Component Diagram Approach

The model used to describe HMA weight and volume properties is the component diagram. It considers a compacted sample of HMA with its constituent air voids, asphalt binder, and mineral aggregate shown as distinct components. The compacted sample is assumed to consist of a unit volume, e.g., one cubic foot, one cubic meter, etc.

The component diagram provides a clear definition of density, that is, the weight of a unit volume of compacted material. Since the model consists of several distinct materials, the density of the entire sample is often called its "bulk density". It is determined by dividing the total weight of the sample by its total volume.

For a given asphalt binder content, the maximum theoretical density is the weight of aggregate and asphalt divided by the volume of only these two components. In other words, the volume of air voids is not included. Maximum theoretical density is an extremely useful property because the density of a voidless mixture can be used as a reference to calculate several other important properties such as air void content.

Asphalt binder content is the weight concentration of asphalt binder. It is expressed as a percent by total weight of mixture or percent by total weight of aggregate. Most agencies use percent by weight of mixture.

The volume concentration of air within the compacted sample is usually termed "air void content" or, more simply, "voids". Air voids are always expressed as a percentage of total volume.

The intergranular space occupied by asphalt binder and air is called the "voids in the mineral aggregate" or "VMA". In the component diagram, the sum of the volume of air and the volume of asphalt binder, expressed as a percent of total volume, is the VMA.

Although contrary to physical laws, the model shows weight and volume on the same diagram with the same scale. Another deceptive feature of the component diagram is that it does not consider secondary weights and volumes such as absorbed asphalt. Furthermore, narrow reliance on the physical model sometimes inhibits a fundamental understanding of the changing nature of volumetric properties such as VMA. Even with these flaws, the component diagram is still the best way to define and illustrate determination of the properties of compacted HMA.

Note that when calculating HMA properties during mix design, asphalt technologists seldom work from or otherwise use a sketch of a component diagram. They normally use well established formulas originally derived from a component diagram to arrive at the various properties of interest. It is not the intent of this chapter to derive these formulas; rather, the intent is to use the component diagram to analyze a sample of compacted mixture and define its properties. Following the example will be a list of all formulas to determine weight and volume properties of HMA.

B. Simple Terms / Definitions

In order to use the component diagram, it is necessary to be able to convert between weight and volume. Specific gravity is the tool employed for this purpose.

As previously stated, specific gravity is the ratio of the weight of a given volume of a substance to the weight of an equal volume of water, both at the same temperature. It is a unique material property that allows for two important determinations.

First, specific gravity is used to determine density by:

$$D = G \times \left(1 g / cm^3\right)$$

where: D = density of material in grams per cubic centimeter,

G = specific gravity of material,

and $1 g/cm^3$ = density of water in grams per cubic centimeter.

The terms "density" and "specific gravity" are often interchanged which suggests they have the same meaning. While this usage is technically incorrect, context most often conveys the intended meaning. The equation offers the most precise meaning of each.

Second, by knowing the weight and specific gravity of a material, the volume can be determined:

$$V = \frac{W}{G \times \left(1 g / cm^3\right)}$$

where: V = volume of material,

W = weight of material,

G = specific gravity of material

and dividing by 0.001 converts g/cm^3 to kg/m^3.

Use of this equation is best understood by the following example.

Consider an object placed on a scale and found to weigh 74.8 kg (165 lbs). This object is thought to have a specific gravity very nearly that of water, or 1.000. Using these values in the above equation indicates the object has a volume of about 0.075 m^3, that is:

$$74.8\,\text{kg x } \frac{1\,\text{m}^3}{1{,}000\,\text{kg}} = 74.8\,\text{kg x } \frac{0.001\,\text{m}^3}{\text{kg}} = 0.075\,\text{m}^3$$

This example is also useful to illustrate the fact that different specific gravities must often be considered. The conditions of the example were somewhat obscure with respect to the precise meaning of the specific gravity used.

While the object may be a homogeneous material, it is more likely a composite of several materials. As such, the conditions of the example should have been more precise and specified bulk specific gravity. Bulk specific gravity is least determinate since it considers the object in whole or "bulk" form and is blind to the individual contributions of the object's possible components. A volume determined from a bulk specific gravity must be assumed to include the total volume and not unique component volumes.

In the case of mineral aggregate, bulk, effective, and apparent specific gravities have been previously defined. Each is used during mix design calculations. Volumes calculated with each of these would have a different meaning and numeric value.

Analysis of compacted HMA utilizes many specific gravities. The wide array of specific gravities is often confusing to those new to asphalt technology. Careful attention to the meaning of each and the desired HMA property will clarify the analysis.

C. Formulas for Analysis of Compacted Paving Mixtures

As previously stated, normal analyses of compacted paving mixtures does not proceed with the use of a component diagram. Standardized formulas have been developed to more quickly determine these properties. The most comprehensive source of this information is in Chapter IV of Manual Series No. 2 published by The Asphalt Institute.

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DATE:

SEQ NO:

HMA Mixture Design

Design Number: →	00BIT1374
Lab Preparing the design?(PP,PL,IL,etc.)	PP
XProducer Name & Number->	
Material Code Number->	HMA Surface Course, Mix D, N70

Agg. No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	032CMM16			037FAM01	004MFM01		
Source (PROD#)							
(NAME)							
(LOC)							
Aggregate Blend	62.8	0.0	0.0	33.8	3.4	0.0	100.0

Agg. No. Sieve Size	#1	#2	#3	#4	#5	#6	Blend	Specifications Min	Specifications Max	FORMULA	FORMULA RANGE Min	FORMULA RANGE Max
25.4 (1)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	--	100	100	100
19.0 (3/4)	100.0	100.0	100.0	100.0	100.0	100.0	100.0		100	100	100	100
12.5 (1/2)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	90	100	100	94	106
9.5 (3/8)	95.0	100.0	100.0	100.0	100.0	100.0	96.9		90	97	--	--
4.75 (#4)	30.0	100.0	100.0	99.0	100.0	100.0	55.7	24	65	56	51	61
2.36 (#8)	7.0	100.0	100.0	89.0	100.0	100.0	37.9		48	38	33	43
1.18 (#16)	4.0	100.0	100.0	73.0	100.0	100.0	30.6	10	32	31	31	31
600µm (#30)	4.0	100.0	100.0	51.0	100.0	100.0	23.2	--	--	23	--	--
300µm (#50)	3.0	100.0	100.0	24.0	100.0	100.0	13.4	4	15	13	9	17
150µm (#100)	3.0	100.0	100.0	7.0	97.0	100.0	7.5	3	10	8	8	8
75µm (#200)	3.0	100.0	100.0	1.9	82.4	100.0	5.3	4	6	5.3	3.8	6.8

Bulk Sp Gr	2.645	1	1	2.554	2.67	1	2.614
Apparent Sp Gr	2.783	1	1	2.682	2.67	1	
Absorption, %	1.4	1	1	0.5	0	0	
						SP GR AC	1.032

SUMMARY OF TEST DATA

	AC % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (P_a)	VMA	VOIDS FILLED	EFFECTIVE AC, VOL	EFFECTIVE AC, % WT	G_{se}	ABSORPTION AC, % WT
MIX 1	4.0	2.366	2.521	6.2	13.1	53.1	7.0	3.0	2.682	1.0
MIX 2	4.5	2.412	2.503	3.6	11.9	69.4	8.3	3.5	2.683	1.0
MIX 3	5.0	2.429	2.484	2.2	11.7	81.1	9.5	4.1	2.683	1.0
MIX 4	5.5	2.431	2.467	1.5	12.1	88.0	10.7	4.5	2.684	1.0

	P_b	d (G_{mb})	D (G_{mm})	% VOIDS (P_a) Target	VMA	VFA	G_{se}	G_{sb}
OPTIMUM DESIGN DATA:---	4.4	2.403	2.507	4.0	12.1	66.2	2.683	2.614

REMARKS:

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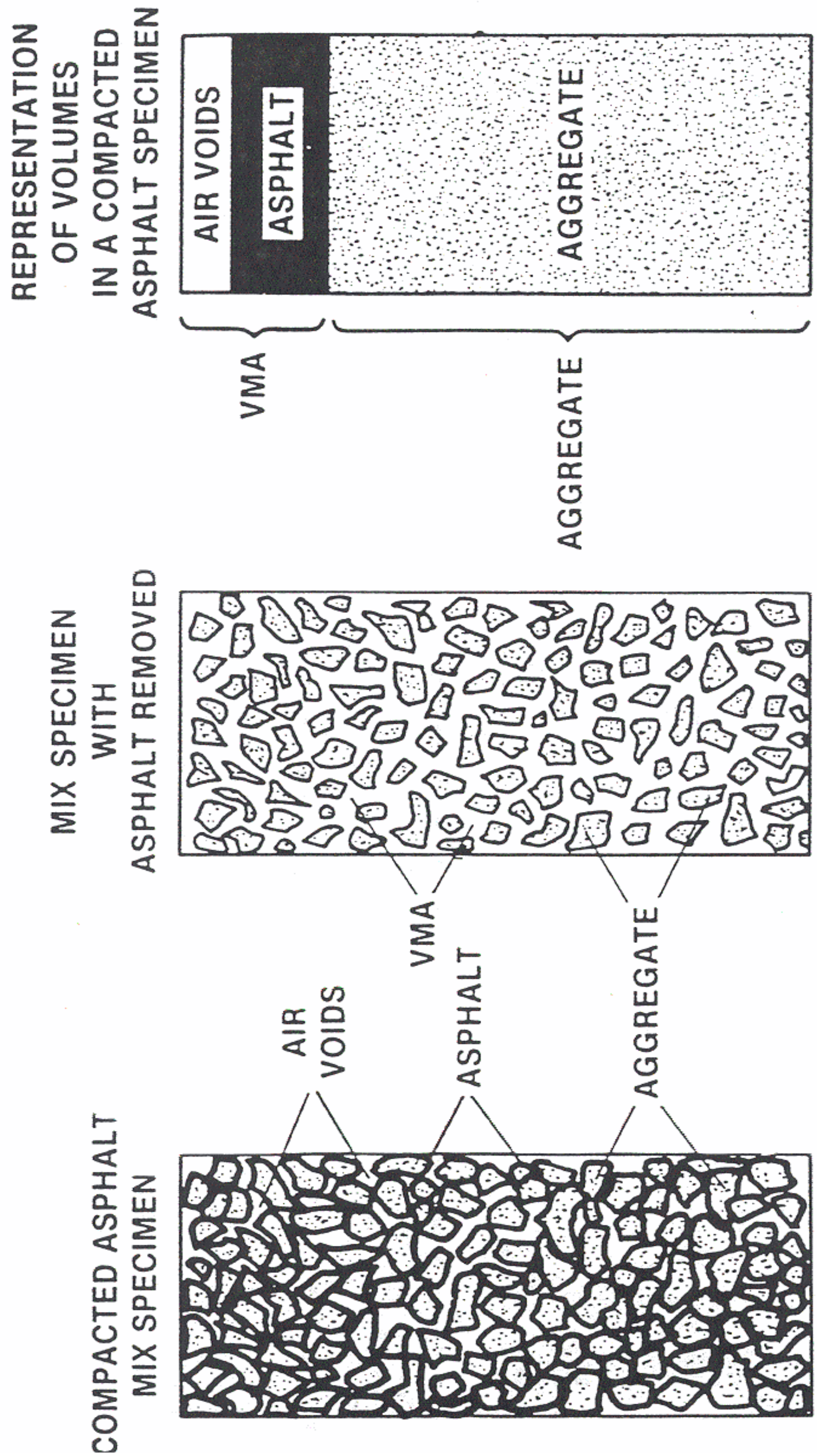
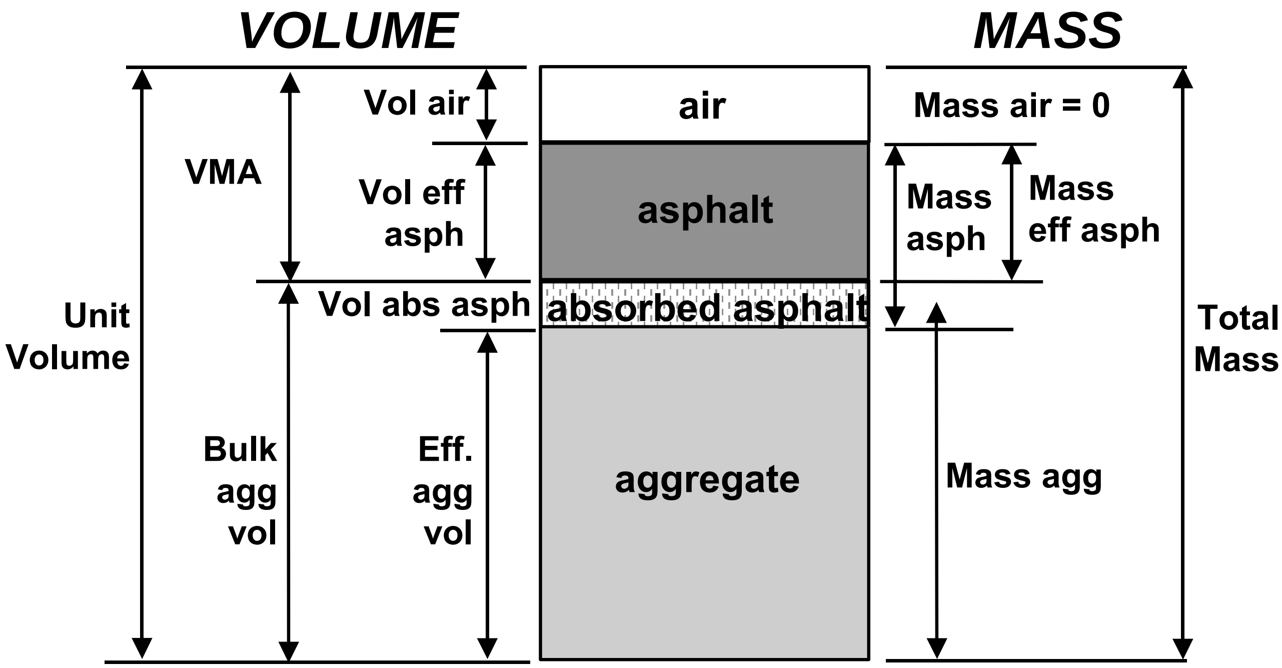


FIGURE 3.1—Illustration of VMA in a Compacted Mix Specimen (Note: For simplification the volume of absorbed asphalt is not shown).

II. VOLUME / WEIGHT RELATIONSHIP



Asphalt Mixture Component Diagram

Given: Total Volume of Mixture = 1 cm^3

Mix Bulk Specific Gravity = 2.329

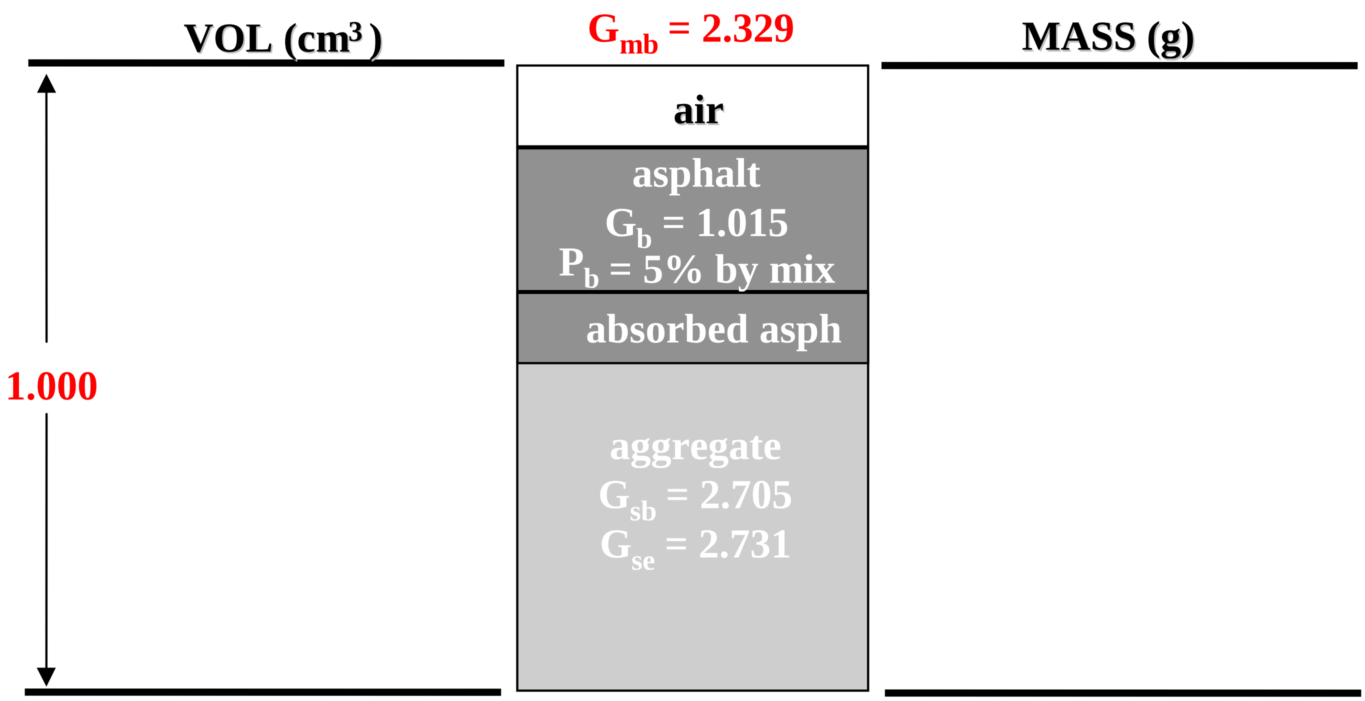
Aggregate Bulk Specific Gravity = 2.705

Aggregate Effective Specific Gravity = 2.731

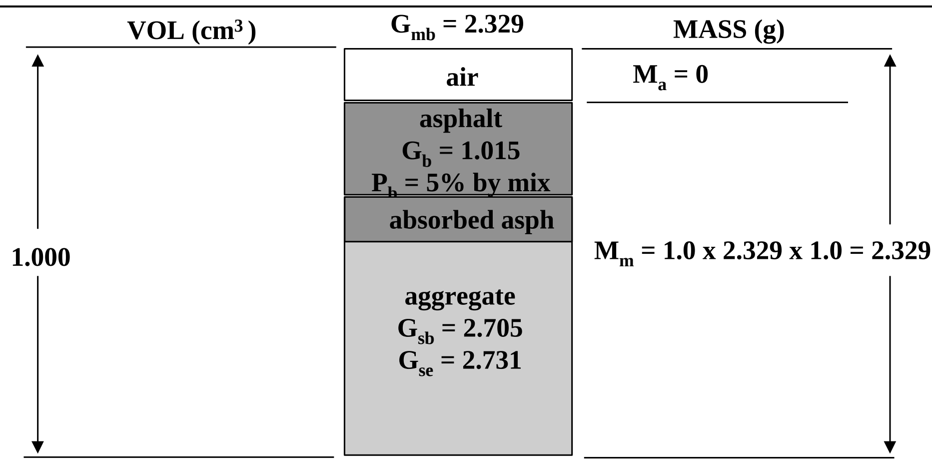
Asphalt Binder Specific Gravity = 1.015

Asphalt Binder Content (Pb) = 5.0% (weight total mix)

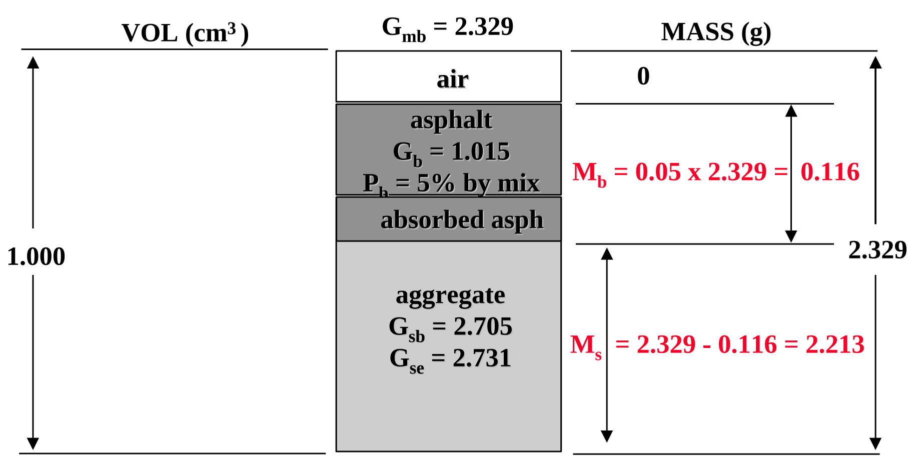
Find: Air Void Content, VMA, VFA, Maximum Theoretical Specific Gravity of Mix

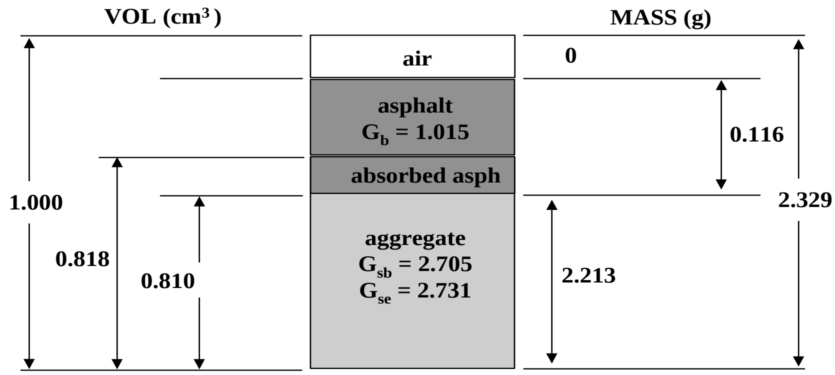

VOL (cm^3)
G_{mb} = 2.329
MASS (g)
air
asphalt
G_b = 1.015
P_b = 5% by mix
absorbed asph
1.000
aggregate
G_{sb} = 2.705
G_{se} = 2.731

- **With these specific gravities used for “bridges”, all of the volume and weight properties can be calculated using the component diagram.**
  - **G_{mb}**
  - **G_b**
  - **G_{sb}**
  - **G_{se}**
  - **P_b**
- **To start, assume the volume equals 1.000**



$$M = V \times G \times 1.000$$

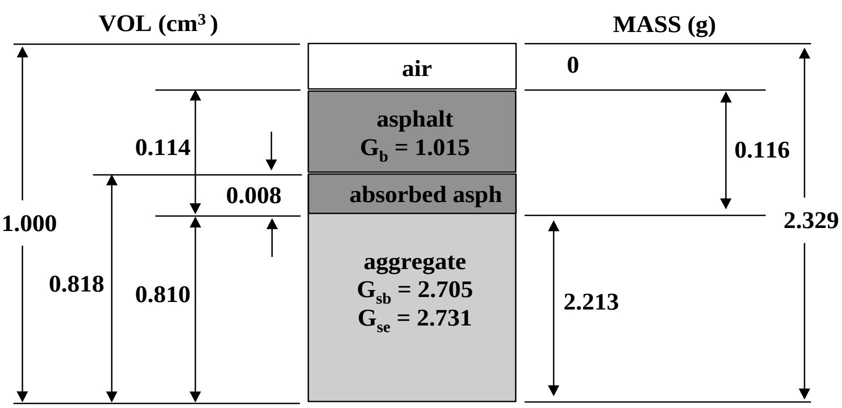




$V_{se} = \frac{2.213}{2.731 \text{x } 1.0} = 0.810$

$V_{sb} = \frac{2.213}{2.705 \text{x } 1.0} = 0.818$

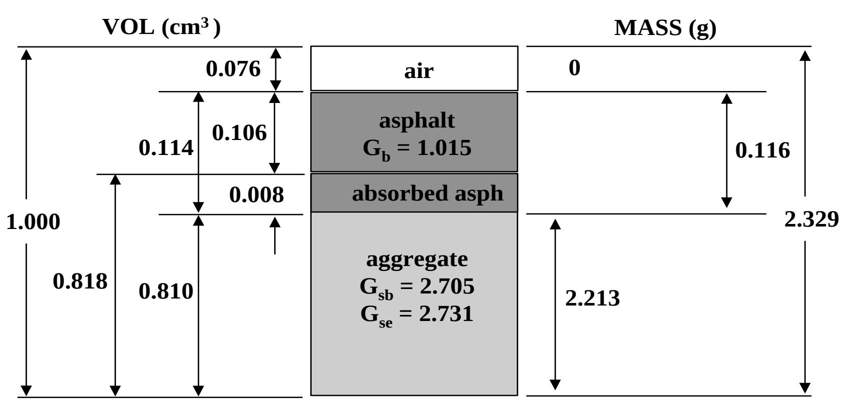
$$V = \frac{M}{G \text{ x } 1.000}$$



$V_b = \frac{0.116}{1.015 \text{ x } 1.0} = 0.114$

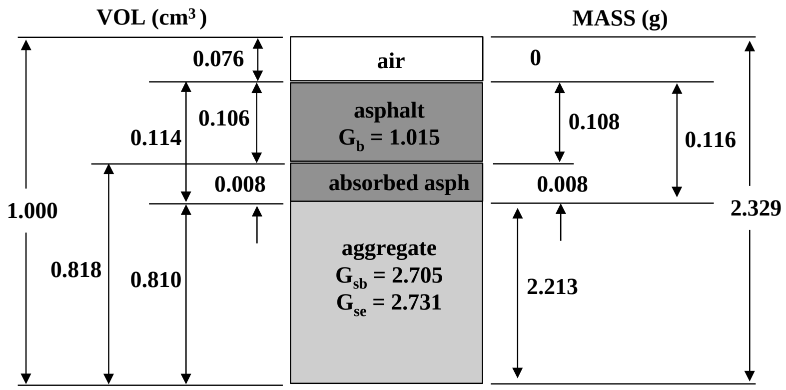
$$V = \frac{M}{G \text{ x } 1.000}$$

$V_{ba} = 0.818 - 0.810 = 0.008$



$V_{be} = 0.114 - 0.008 = 0.106$

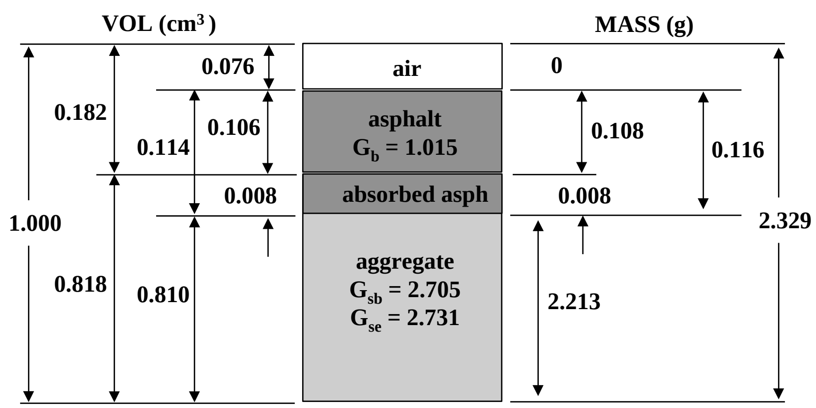
$V_a = 1.000 - 0.114 - 0.810 = 0.076$



M = V x G x 1.000

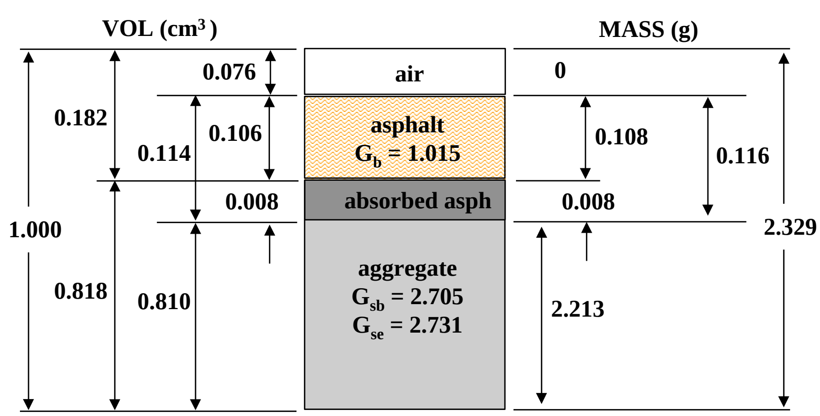
M_{be} = 0.106 x 1.015 x 1.000 = 0.108

M_{ba} = 0.116 - 0.108 = 0.008

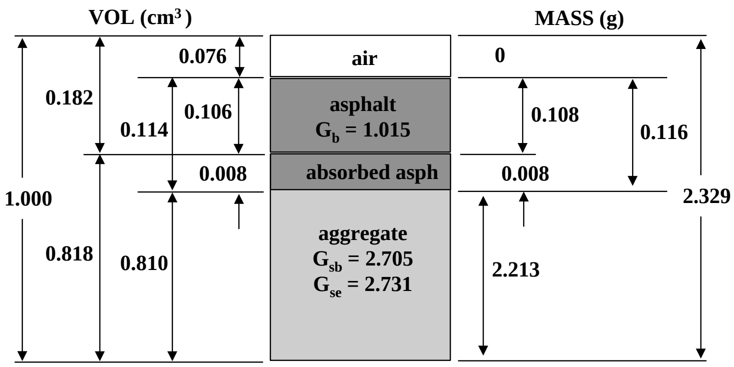


Air Voids = 0.076 x 100 = 7.6 %

VMA = V_{be} + V_a = (0.106 + 0.076) x 100 = 18.2 %

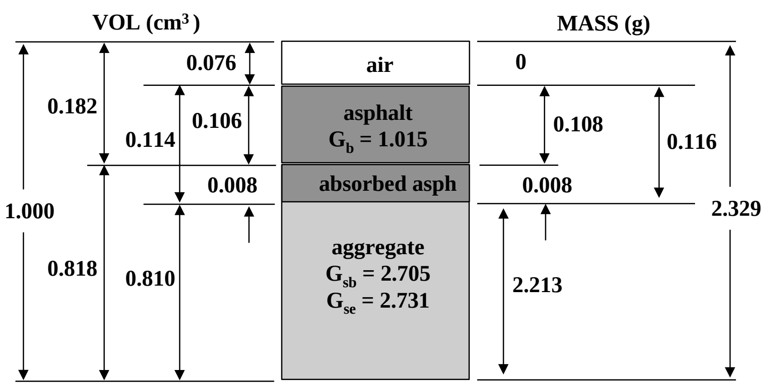


Air Voids = 7.6 %
VMA = 18.2 %
VFA = (0.106 / 0.182) x 100 = 58.2 %



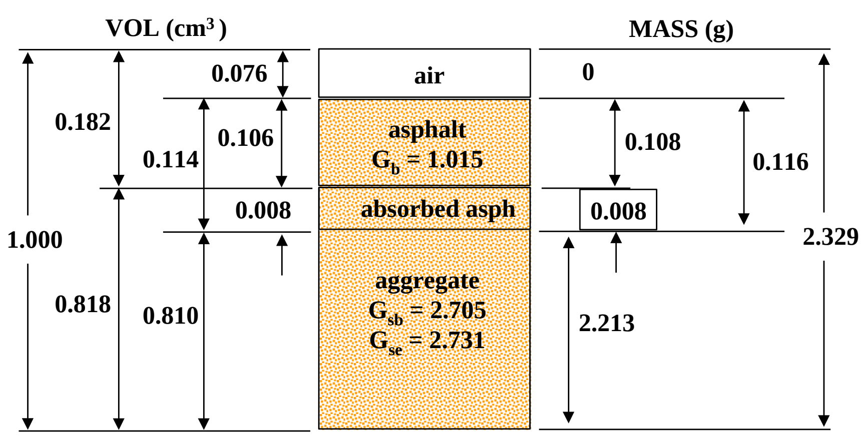
Air Voids = 7.6 %
VMA = 18.2 %
VFA = 58.2 %

Eff. Asp. Cont. = (0.108 / 2.329) x 100 = 4.6 %



Air Voids = 7.6%
VMA = 18.2 %
VFA = 58.2 %

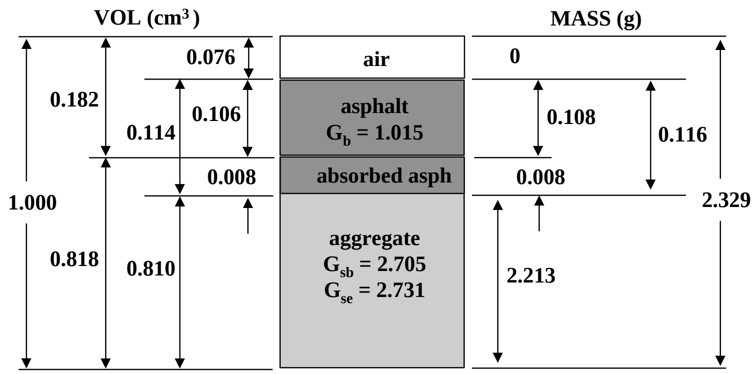
Effective Asphalt Content = 4.6%
Abs. Asph. Cont. = (0.008 / 2.213) x 100 = 0.4%



Air Voids = 7.6%
VMA = 18.2 %
VFA = 58.2 %

Max Theo Sp Grav =

$$\frac{2.329}{\frac{1.000 - 0.076}{1.000}} = 2.521$$



Air Voids = 7.6%
VMA = 18.2 %
VFA = 58.2 %

Effective Asphalt Content = 4.6%
Absorbed Asphalt Content = 0.4%
Max Theo Sp Grav = 2.521

$$G_{mm} = \frac{100}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

$$V_a = \left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right) \times 100$$

$$VMA = 100 - \frac{G_{mb} \times P_s}{G_{sb}}$$

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

$$P_{be} = P_b - \frac{P_{ba} \times P_s}{100}$$

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

$$\text{Eff. Vol.} = VMA - V_a$$

III. CALCULATIONS OF VOLUMETRIC PROPERTIES

A. Mix Design Terminology / Symbols Used in Analyzing a Compacted Paving Mixture

G = Specific Gravity

G_b = specific gravity of asphalt (Gravity $_{\text{Binder}}$)

G_{sb} = bulk specific gravity of combined aggregate (Gravity $_{\text{Stone Bulk}}$)

G_{se} = effective specific gravity of combined aggregate (Gravity $_{\text{Stone Effective}}$)

G_{sa} = apparent specific gravity of combined aggregate (Gravity $_{\text{Stone Apparent}}$)

G_{mb} = bulk specific gravity of compacted mixture (Gravity $_{\text{Mix Bulk}}$)

G_{mm} = maximum theoretical specific gravity of mixture (Gravity $_{\text{Mix Maximum}}$)

P = Percentage

P_b = asphalt, percent by total weight of mixture (Percentage $_{\text{Binder}}$)

P_s = aggregate, percent by total weight of mixture (Percentage $_{\text{Stone}}$)

P_{mm} = loose mix, percent by total weight of mixture (= 100%) (Percentage $_{\text{mix Max}}$)

P_{be} = effective AC, percent by total weight of mixture (Percentage $_{\text{Binder Effective}}$)

P_a = air voids in compacted mixture, percent of total volume (Percentage $_{\text{Air}}$)

P_{ba} = absorbed AC, percent by total weight of aggregate (Percentage $_{\text{Binder Absorbed}}$)

B. Order of Calculations / Equations

1. Calculate G_{sb}
2. Calculate G_{se} (at each Asphalt Binder content and average)
3. Calculate air voids ($P_{a)}$ (at each Asphalt Binder content)
4. Calculate absorbed asphalt (P_{ba})
5. Calculate effective asphalt (P_{be}) (at each Asphalt Binder content)
6. Calculate VMA (at each Asphalt Binder content)
7. Calculate effective volume of Asphalt Binder (at each Asphalt Binder content)
8. Calculate VFA (at each Asphalt Binder content)

1. Calculating G_{sb} (Bulk Specific Gravity of Aggregate)

When the total aggregate consists of separate fractions of coarse aggregate, fine aggregate, reclaimed asphalt pavement, and mineral filler, all having different specific gravities, the bulk specific gravity (dry) for the total aggregate blend is calculated using:

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

Where, G_{sb} = bulk specific gravity (dry) for the total aggregate blend,
P_1, P_2, P_n = individual percentages by mass of aggregate,
G_1, G_2, G_n = individual bulk specific gravities (dry) of aggregate.

2. <u>Calculating G_{se} (Effective Specific Gravity of Aggregate)</u>

Effective Specific Gravity of Aggregate

When based on the maximum specific gravity of a paving mixture, G_{mm}, as measured using ASTM D2041, the effective specific gravity of the aggregate, G_{se}, includes all void spaces in the aggregate particles except those that absorb asphalt. G_{se} is determined using:

$$G_{se} = \frac{(P_{mm} - P_b)}{\left(\frac{P_{mm}}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)}$$

Where, G_{se} = effective specific gravity for the total aggregate blend,
G_{mm} = maximum specific gravity of paving mixture,
P_{mm} = percent of mass of the total loose mixture = 100,
P_b = asphalt content at which G_{mm} test was performed, percent by total mass of mixture,
G_b = specific gravity of asphalt.

3. Calculating Air Voids (P_a) (Percent Air Voids in Compacted Mixture)

Percent Air Voids in a Compacted Paving Mixture

The air voids, V_a, in the total compacted paving mixture consist of the small air spaces between the coated aggregate particles. The volume percentage of air voids in a compacted paving mixture can be determined using:

$$V_a = 100 \times \left(\frac{G_{mm} - G_{mb}}{G_{mm}} \right)$$

Where, V_a = air voids in the total compacted paving mixture,

G_{mm} = maximum specific gravity of the paving mixture (AASHTO T209),

G_{mb} = bulk specific gravity of the compacted mixture (AASHTO T166).

4. Calculating Absorbed Asphalt (P_{ba}) (Asphalt Absorption)

Asphalt Absorption

Asphalt absorption is expressed as a percentage by mass of total aggregate rather than as a percentage by mass of total mixture. Asphalt absorption, P_{ba}, is determined using:

$$P_{ba} = 100 \times \frac{(G_{se} - G_{sb})}{(G_{se} \times G_{sb})} \times G_b$$

Where, P_{ba} = absorbed asphalt, percent by total mass of aggregate,
G_{se} = effective specific gravity for the total aggregate blend,
G_{sb} = bulk specific gravity (dry) of the total aggregate blend,
G_b = specific gravity of asphalt.

5. Calculating Effective Asphalt (P_{be}) (Efffective Asphalt Binder Content)

Effective Asphalt Content of a Paving Mixture

The effective asphalt content, P_{be}, of a paving mixture is the total asphalt binder content minus the quantity of asphalt lost by absorption into the aggregate particles. It is the portion of the total asphalt content that remains as a coating on the outside of the aggregate particles and it is the asphalt binder content that governs the performance of an asphalt paving mixture. The formula is:

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

Where, P_{be} = effective asphalt binder content, percent by total mass of mixture,
P_b = asphalt binder content, percent by total mass of mixture,
P_{ba} = absorbed asphalt, percent by total mass of aggregate,
P_s = aggregate content, percent by total mass of the mixture.

6. Calculating VMA (Percent VMA in Compacted Paving Mixture)

Percent Voids in the Mineral Aggregate (VMA) in a Compacted Paving Mixture

The voids in the mineral aggregate, VMA, are defined as the intergranular void space between the aggregate particles in a compacted paving mixture that includes the air voids and the effective asphalt content, expressed as a percent of the total volume. The VMA is calculated on the basis of the bulk specific gravity (dry) of the aggregate and is expressed as a percentage of the bulk volume of the compacted paving mixture.

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

Where, VMA = voids in the mineral aggregate, percent of bulk volume,
G_{sb} = bulk specific gravity (dry) of the total aggregate mass,
G_{mb} = bulk specific gravity of the compacted mixture (AASHTO T166),
P_s = aggregate content, percent by total mass of the mixture.

7. Calculating Effective Volume of AC (Percent of Total Mix)

Effective Volume of Asphalt Cement of a Paving Mixture

The effective asphalt volume, V_{be}, of a paving mixture is the total volume of asphalt surrounding the aggregate particle but not in the pores of the aggregate particle. The effective asphalt volume is the voids in the mineral aggregate (VMA) minus the void level (V_a) in the compacted asphalt mixture. The formula is:

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

Where, VMA = voids in the mineral aggregate,
V_a = void level in the compacted mixture at any given asphalt content.

8. Calculating VFA (Voids Filled with Asphalt)

Percent Voids Filled with Asphalt (VFA) in a Compacted Paving Mixture

The percentage of the voids in the mineral aggregate that are filled with asphalt, VFA, not including the absorbed asphalt, is determined using:

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

Where, VFA = voids filled with asphalt, percent of the VMA,
VMA = voids in the mineral aggregate, percent of bulk volume,
V_a = air voids in the total compacted paving mixture.

DATE:

SEQ NO:

Bituminous Mixture Design
Design Number: → Page 11-5
Lab Preparing the design?(PP,PL,IL,etc.) PP

Producer Name & Number->
Material Code Number-> HMA Binder Course, IL-19.0, N90

Agg. No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	032CMM11	032CMM16	038FAM20	037FAM01	004FAM01		10112
Source (PROD#)							
(NAME)							
(LOC)							
Aggregate Blend	49.5	20.6	16.5	11.8	1.6	0.0	100.0

Agg. No. Sieve Size	#1	#2	#3	#4	#5	#6	Blend
25.4 (1)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19.0 (3/4)	94.3	100.0	100.0	100.0	100.0	100.0	97.2
12.5 (1/2)	40.0	100.0	100.0	100.0	100.0	100.0	70.3
9.5 (3/8)	17.9	96.9	100.0	100.0	100.0	100.0	58.7
4.75 (#4)	4.9	30.8	97.7	96.8	100.0	100.0	37.9
2.36 (#8)	3.0	7.7	66.8	80.8	100.0	100.0	25.1
1.18 (#16)	2.7	4.9	36.9	64.8	100.0	100.0	17.7
600µm (#30)	2.6	4.1	20.1	48.4	100.0	100.0	12.8
300µm (#50)	2.5	3.7	11.6	18.5	100.0	100.0	7.7
150µm (#100)	2.4	3.5	7.9	3.1	99.0	100.0	5.2
75µm (#200)	2.0	3.0	4.8	1.5	88.0	100.0	4.0

Specifications		FORMULA	FORMULA RANGE	
Min	Max		Min	Max
	100	100	100	100
82	100	97	97	97
50	85	70	64	76
--	--	59	--	--
24	40	38	33	43
16	36	25	20	30
10	25	18	18	18
--	--	13	--	--
4	12	8	4	12
3	9	5	5	5
3	6	4.0	2.5	6.5

Bulk Sp Gr	2.642	2.634	2.619	2.571	2.800	1
Apparent Sp Gr	2.751	2.768	2.817	2.687	2.800	1
Absorption, %	1.5	1.9	2.8	1.9	0	0
					SP GR AC	1.03

HOMEWORK #4
(Page 1 of 2)

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HOMEWORK #4
(Page 2 of 2)

BINDER HOMEWORK PROBLEM

SUMMARY – COMPACTED MIX PROPERTIES

P_b	G_{mm}	G_{mb}	G_{se}	V_a	VMA	VFA	P_{ba}	P_{be}	Eff. Vol.	G_{sb}	G_b
4.0	2.526	2.417									1.030
4.5	2.510	2.422									1.030
5.0	2.495	2.434									1.030
5.5	2.480	2.442									1.030

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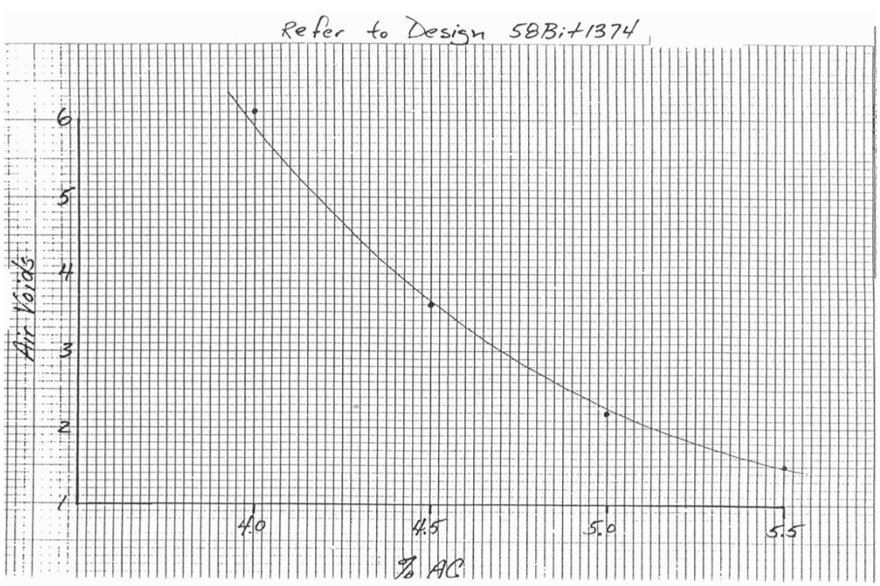
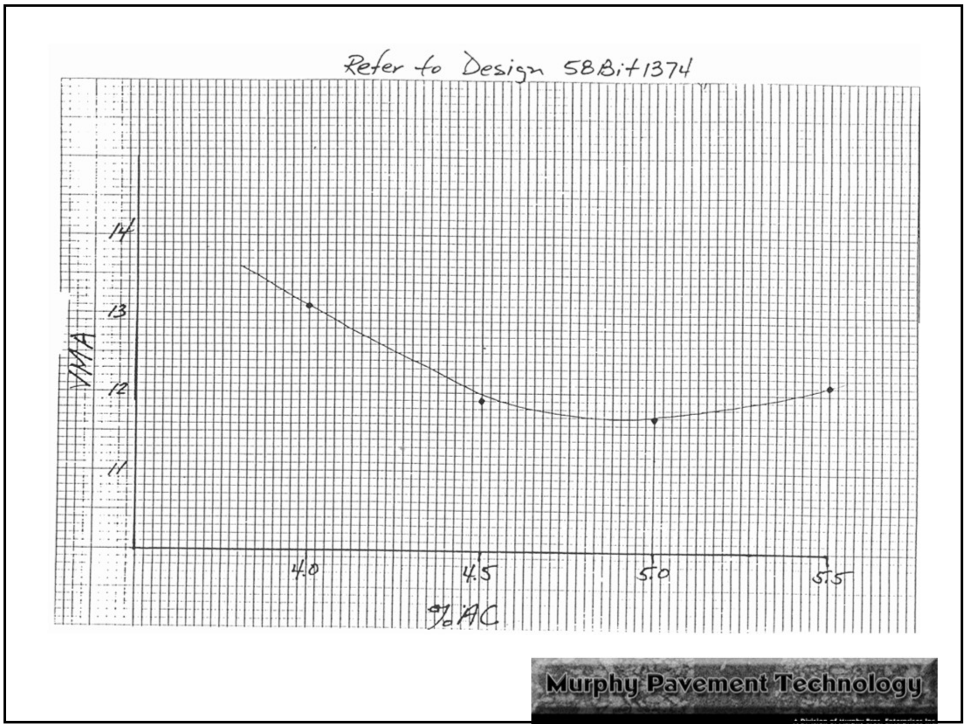
Optimum Design
Asphalt Concepts

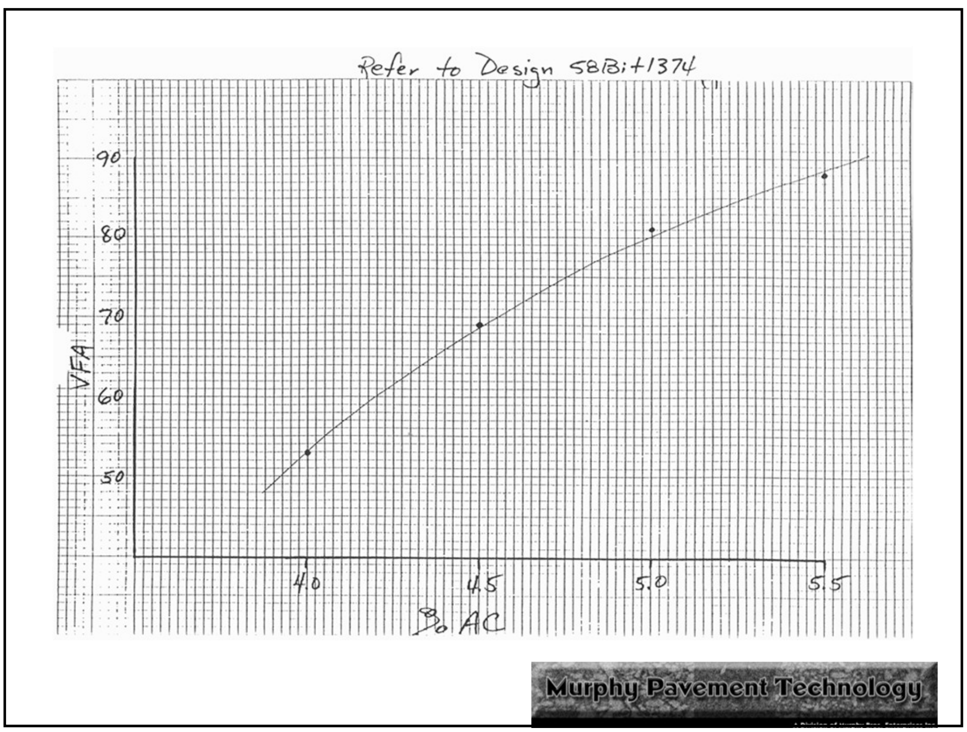
- P_b @ 4.0% Voids
- Care-AC vs. Best-Fit-Curves
- Judgment of values chosen

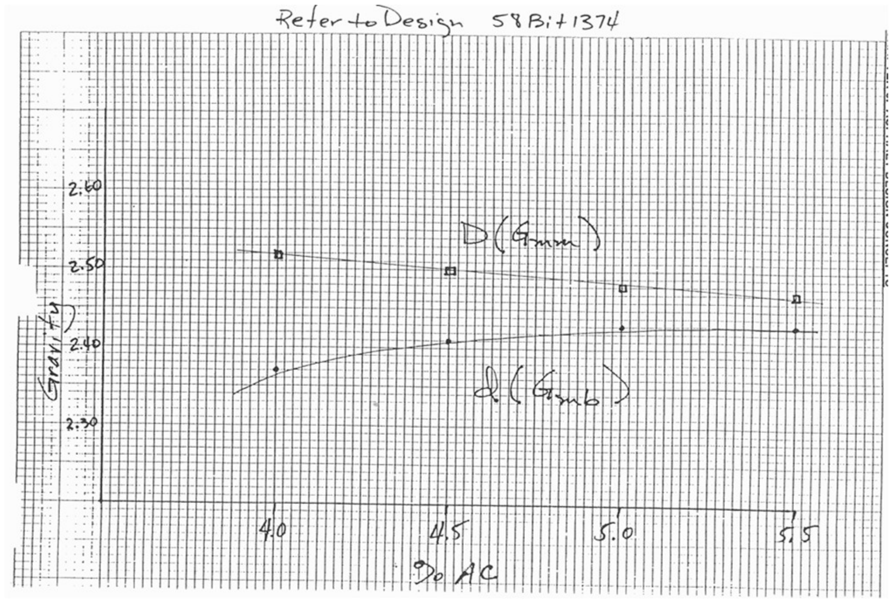
Murphy Pavement Technology



Murphy Pavement Technology


Refer to Design 58Bit1374
VMA
14
13
12
11
4.0
4.5
5.0
5.5
% AC
Murphy Pavement Technology


Refer to Design 58Bit1374
VFA
90
80
70
60
50
4.0
4.5
5.0
5.5
% AC
Murphy Pavement Technology



Murphy Pavement Technology

Interpolation

- Based on linear graphs and y = *m*x + b
- Used to approximate an optimum design asphalt content
- Example:

Asphalt Binder, P_b	Air Voids, V_a
5.0%	4.6%
5.5%	3.7%

Murphy Pavement Technology

Interpolation: Example

Asphalt Binder, P_b	Air Voids, V_a
5.0%	4.8%
5.5%	3.7%

Murphy Pavement Technology

Interpolation: Homework

- Based on linear graphs and y = mx + b
- Used to approximate an optimum design asphalt content
- Example:

Asphalt Binder, P_b	Air Voids, V_a
4.0%	4.7%
4.5%	3.4%

Murphy Pavement Technology

ASPHALT DESIGN CONTENT

- Pick Asphalt Binder Content at 4.0% Air Voids (V_a / P_a) @ N_{design}

- Verify selected Asphalt Binder content meets:
  - Minimum VMA
  - VFA limits

- Adjust Asphalt Binder Content, if necessary, around 4.0% Air Voids to meet above minimum criteria

- Check for Rice Gravity “flyers”, and recalculate if necessary

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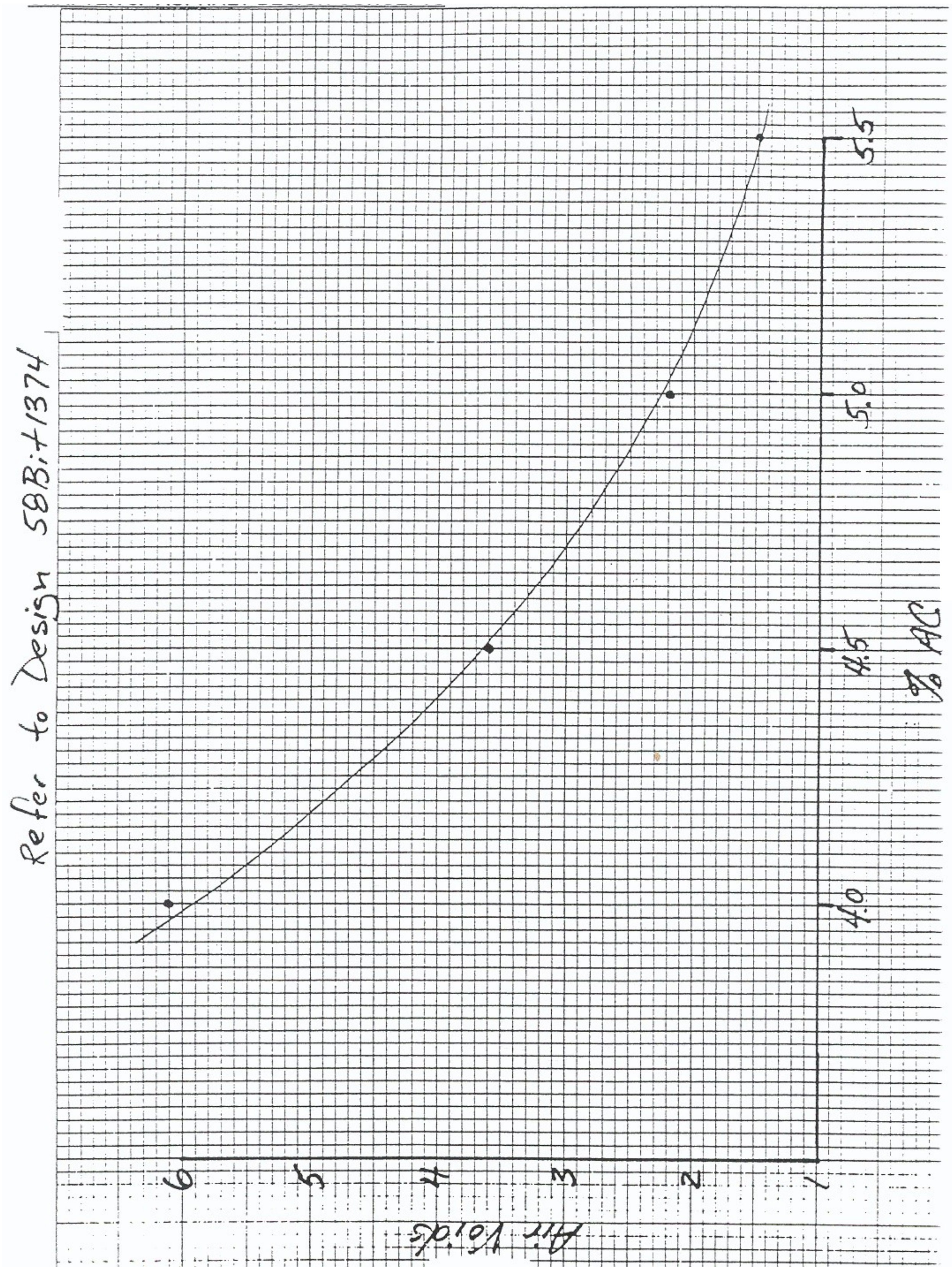
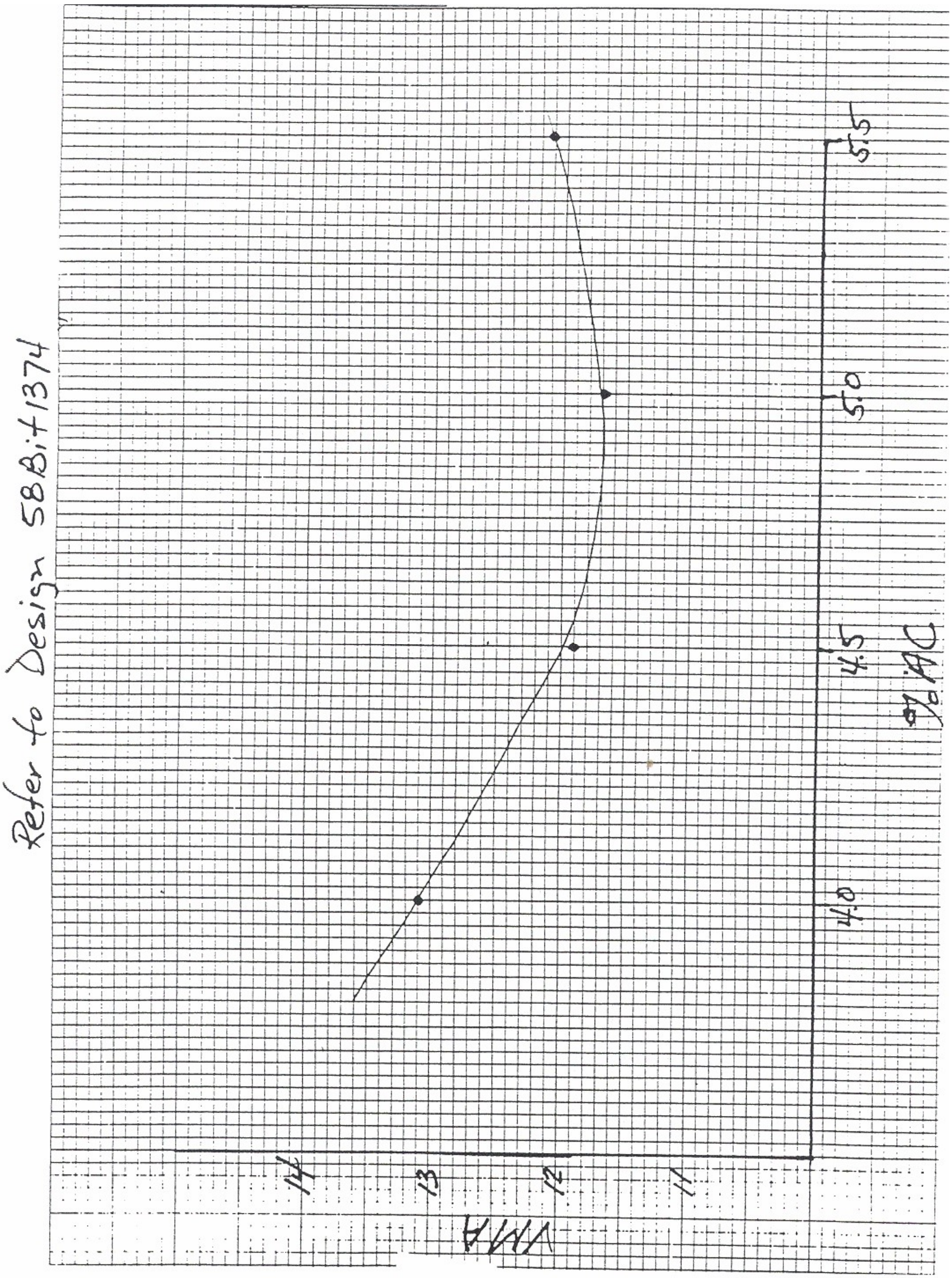
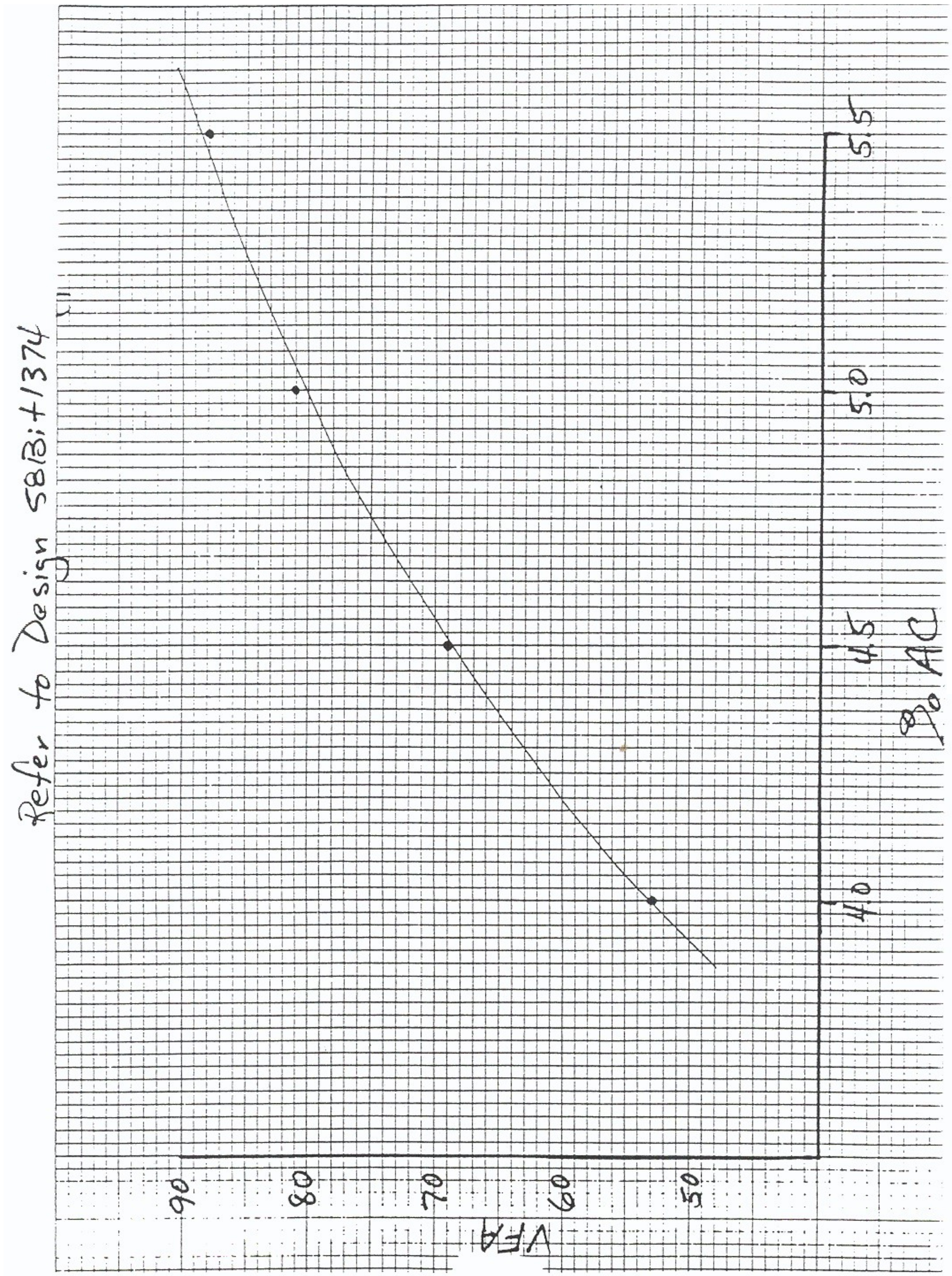


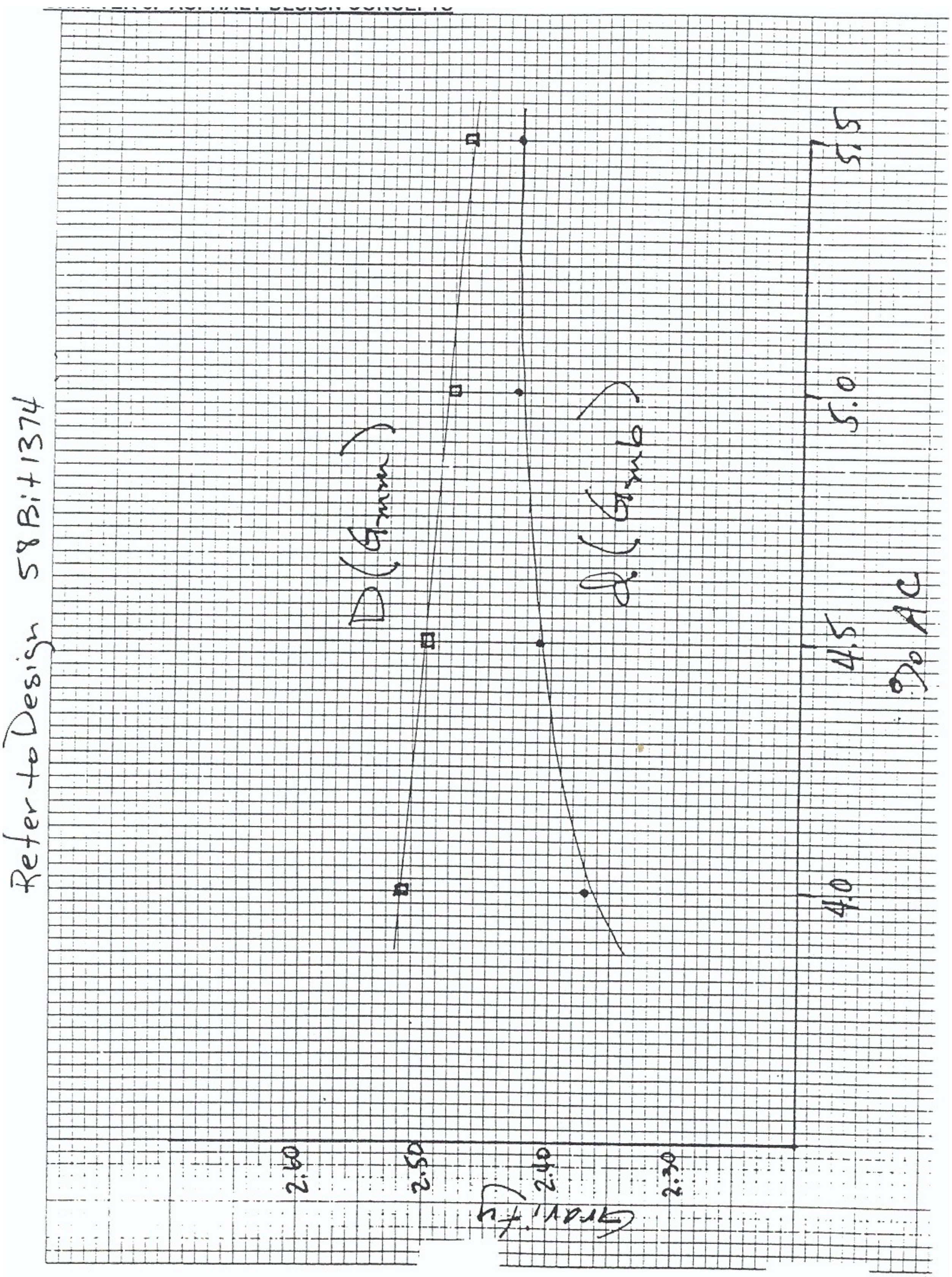
Pb



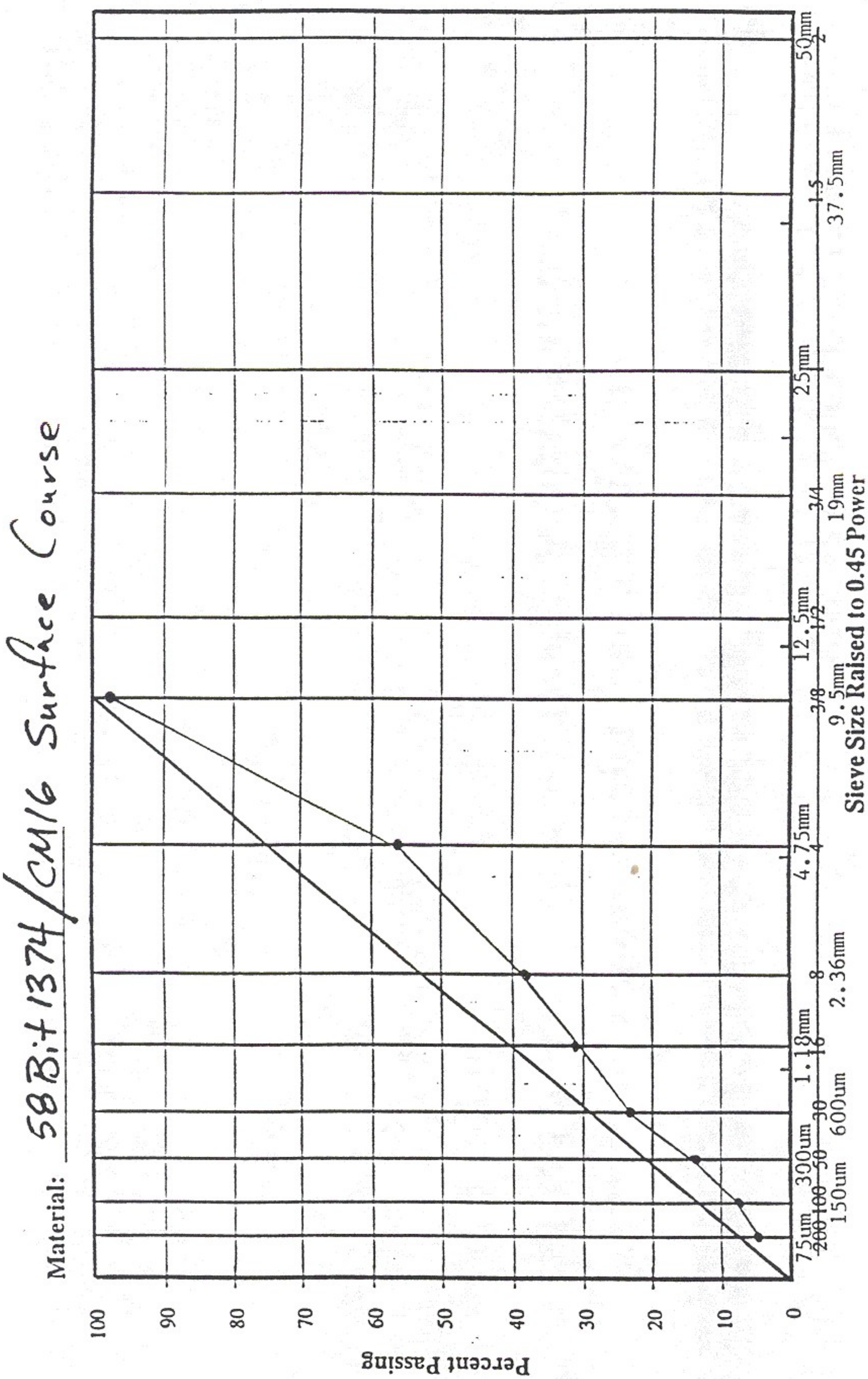
P_b



P_b


Refer to Design 58Bit 1374
D (Gmm)
d (Gmb)
% AC
4.0
4.5
5.0
5.5
2.60
2.50
2.40
2.30
Gravity

Pb


Material: 58Bit1374/CM16 Surface Course
Percent Passing
0
10
20
30
40
50
60
70
80
90
100
Sieve Size Raised to 0.45 Power
75um 200
150um 100
300um 50
600um 30
1.18mm 16
2.36mm 8
4.75mm 4
9.5mm 3/8
12.5mm 1/2
19mm 3/4
25mm
37.5mm 1.5
50mm 2

INTERPOLATION

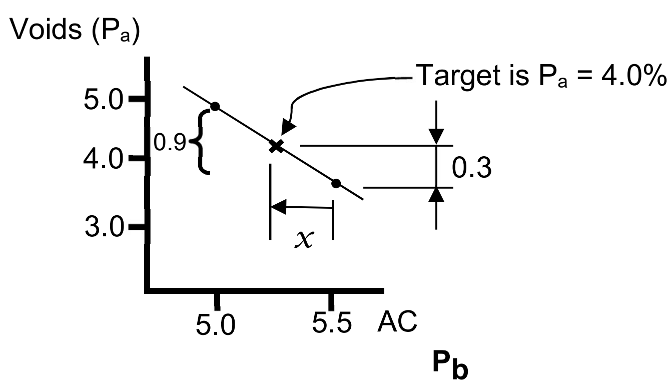
- Based on Linear Graphs and $y = mx + b$
- Used to Approximate a Design Asphalt Binder Content
- Example:

Asphalt Content	Air Voids
5.0%	4.6%
5.5%	3.7%

INTERPOLATION

- Based on Linear Graphs and y = mx + b
- Used to Approximate a Design Asphalt Binder Content
- Example:

Asphalt Content	Air Voids
5.0%	**4.6%**
5.5%	**3.7%**

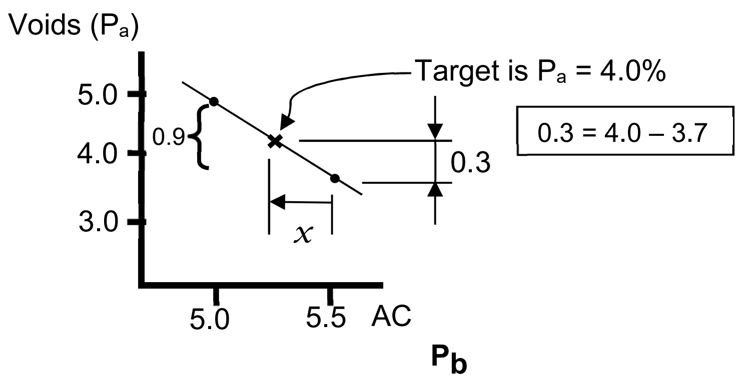


- **Plot actual points on graph and create a line**
- **Determine P_b at P_a = 4.0% from the line**

INTERPOLATION

- Based on Linear Graphs and y = mx + b
- Used to Approximate a Design Asphalt Binder Content
- Exampe:

Asphalt Content	Air Voids
5.0%	**4.6%**
5.5%	**3.7%**



From Similar Triangles

$$\frac{0.9}{0.5} - \frac{0.3}{x}$$

0.9 = 4.6 – 3.7
0.5 = 5.5 – 5.0

$$\left(\frac{0.9}{0.5}\right) = 0.3$$

$$x = 0.3\left(\frac{0.9}{0.5}\right) = 0.17$$

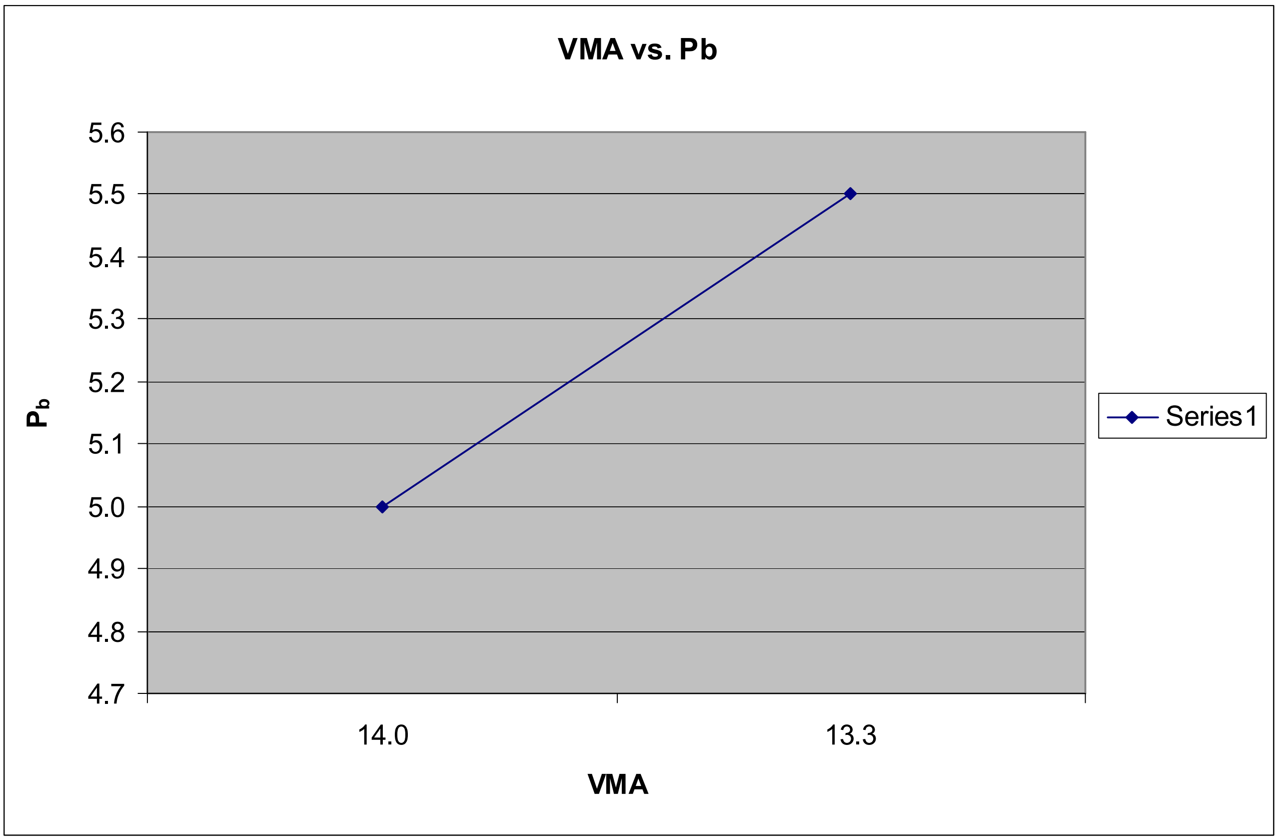
5.5% AC – 0.17% = 5.33% or
5.3% AC @ 4.0% Air Voids

- **Multiply both sides by X**
- **Multiply by inverse to get X alone**
- **Solve for X**
- **Subtract X from AB Content of second pt.**

INTERPOLATION

■ Example 2: Find VMA at 5.3% Asphalt Content

Asphalt Content	VMA
5.0	14.0
5.5	13.3



X = 14.0 - 13.3 = 0.7

Y = 5.5 - 5.0 = 0.5

$$\frac{0.7}{0.5} = \frac{X}{0.3}$$

INTERPOLATION

- Example 2: Find VMA at 5.3% Asphalt Content

Asphalt Content	**VMA**
5.0	**14.0**
5.5	**13.3**

$$\frac{0.7}{0.5} = \frac{X}{0.3} \Bigg\} \; 0.42 = X$$

14.0 - 0.4 = 13.6% VMA

Cross multiply yields 0.5X = 0.21
Divide both sides by 0.5 yields X = 0.42
Subtract 0.4 from the starting VMA of 14.0 as shown above

INTERPOLATION HOMEWORK

- Find Design Asphalt Content By Air Voids; Given:

Asphalt Content	Air Voids
4.0	4.7
4.5	3.4

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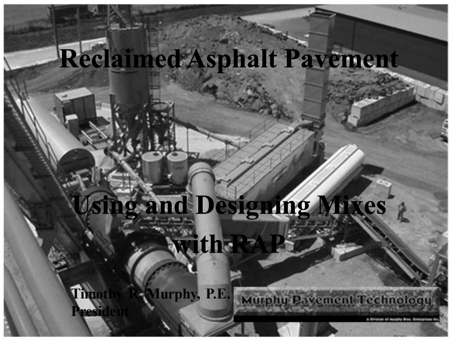
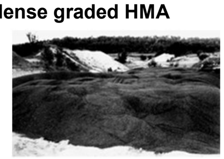


Review of RAP Materials

RAP is reclaimed asphalt pavement resulting from cold milling or crushing of an existing dense graded HMA pavements.



Use and Designing With RAP

- Benefits of Using RAP
- RAP in Mix Design
  - RAP characterization
  - Blending asphalt
  - Batching procedures
- Class Problem

Benefits of using RAP

- Recycling of construction material
- Savings of non-renewable resource
- Cost savings

What is Green Engineering?

Green engineering embraces the concept that decisions to protect human health and the environment can have the greatest impact and cost effectiveness when applied early to the design and development phase of a process or product.

Principles of Green Engineering

1. Use life-cycle thinking in all engineering activities.
2. Minimize depletion of natural resources and strive to prevent waste.
3. Develop and apply engineering solutions, while being cognizant of local geography, aspirations, and cultures.
4. Create engineering solutions beyond current or dominant technologies; improve, innovate, and invent (technologies) to achieve sustainability.
5. Actively engage communities and stakeholders in development of engineering solutions.

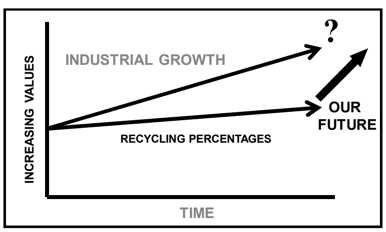
The impact of 'green government'

Today, governments at all levels — Federal, state, county and municipal — are seeking to incorporate environmental considerations into their activities.

They want a healthier environment for their citizens and employees, and they know they need to lower costs at every stage along the supply chain.

With a combined purchasing power of over half a trillion dollars annually at all levels, governments have the largest potential to help society achieve sustainable consumption.

Growth vs. Recycling over Time



Recycling is all around us

However, asphalt is the most recycled product in the world!

Resourcefulness in action: Recycling of asphalt pavements benefits everyone!

- Maintains high quality
- Reduces taxpayer cost
- Rewards good environmental stewardship

Economics are many things

Financially impacted items are:

- Production,
- Trucking,
- Diminishing resources.

Energy costs are climing rapidly. Why? Will they ever decrease?

Potential Savings, 2012

Rock ($12/ton)	New Asphalt ($550/ton)	RAP w/5% AC ($8/ton)	Mix
94% = $11.28	6% = $33.00		Cost = $44.28
75% = $9.00	5% = $27.50	20% = $1.60	Cost = $38.10
		Total Savings	$3.09 @ 10% $6.18 @ 20%

If placed cost /ton = $60.00 this represents a 10% savings.

Let's just look at the road system today…

What we know:
0% RAP costs approximately $6.00/ton more than a 20% RAP mixture.

Somewhere Illinois:
Place 1-mile by 30 ft. wide, 4" of HMA.

Question: What can you pave?

Let's just look at the road system today…

What we know:
0% RAP costs approximately $6.00/ton more than a 20% RAP mixture.

Somewhere Illinois:
Place 1-mile by 30 ft. wide, 4" of HMA.

Question: What can you pave?

Asphalt density ~
[112 lb. / sq. yd. / inch] / [2,000 lb./ton]

Sq. yds. = [5,280 ft. / mile x 30 ft.] = 17,600
9 sq. ft. / sq. yd.

Tons = 17,600 s. yds. x 4" x Asphalt density = 3,942

Savings of $23,652 / mile

Asphalt plant quality inputs

Look at the Volumes!!!

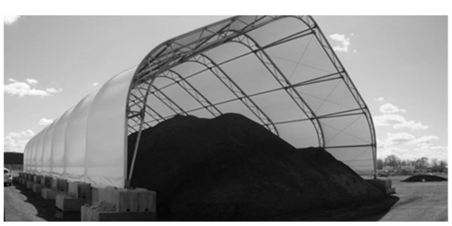
Raw feed; recycled asphalt

Contractor owns and must manage the material.

Stockpiling RAP

- Use a Stacker - DO NOT DRIVE ON STOCKPILE!
- RAP does not re-compact, if left alone
- Forms "crust" 8-10 inches
- Crust sheds water and easily broken
- Can be stored under sheds

RAP storage is suggested



RAP in Mix Design

- RAP characterization
- Blending asphalt
- Batching procedures

RAP for Hot Mix Asphalt

- RAP shall only originate from agency projects,
- RAP for surface usually originates from surface mixes,
- No contaminants (brick, concrete, sheet asphalt, sand, earth, fabrics)

RAP Stockpiles

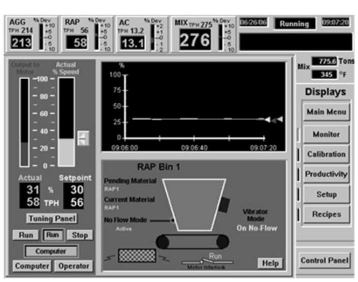
- FRAP
  - At least "C" quality
  - Can be of more that one type or quality
  - Fractionated between #4 and the 12.5mm
- Homogeneous
  - Same aggregate quality
  - Same aggregate type (natural, steel slag, ACBF slag)
  - Similar gradation and asphalt binder content
- Conglomerate - different quality or type, inconsistent gradation or AC

RAP Characterization


RAP Usage

- Allows new RAP stockpile which requires RAP to be processed into a minimum of two size fractions with separation between the 4.75 and 12.5mm sieves.
- Allows FRAP at higher uses than RAP.
- Allows use in polymer modified mixes.
- Requires Automated Recordation and Positive Dust Control systems.
- Provides for additional uses for RAP not in HMA.

RAP Usage



Updated RAP Stockpiles

- Fractionated Rap (FRAP)
- Homogeneous (Binder / Surface)
- Conglomerate
- Conglomerate “D” Quality (DQ)
- Non - Quality

Testing of RAP

- All RAP: Asphalt Content and Gradation
- RAP containing Slags or other heavy or light aggregate: Maximum Theoretical Specific Gravity
  - 1 / 500 tons for first 2,000 tons.
  - 1 / 2,000 tons thereafter.
  - Min. 5 / 4,000 tons.

RAP Characterization… for existing stockpiles

RAP / FRAP / RAS Limits of Precision Between Contractor & Department Splits

Test Parameter	Limits of Precision		
% Passing	RAP	FRAP	RAS
1/2 in. (12.5 mm)	6.0 %	5.0 %	
# 4 (4.75 mm)	6.0 %	5.0 %	
# 8 (2.36 mm)	4.0 %	3.0 %	4.0 %
# 30 (600 µm)	3.0 %	2.0 %	4.0 %
# 200 (75 µm)	2.5 %	2.2 %	4.0 %
Asphalt Binder	0.4 %	0.3 %	3.0 %
G_{mm}	0.035	0.030	

Evaluation of RAP / FRAP / RAS Test Results

Parameter	FRAP/Homogeneous/ Conglomerate
1 in. (25 mm)	
1/2 in. (12.5 mm)	± 8 %
# 4 (4.75 mm)	± 6 %
# 8 (2.36 mm)	± 5 %
# 16 (1.18 mm)	
# 30 (600 µm)	± 5 %
# 200 (75 µm)	± 2.0 %
Asphalt Binder	± 0.4 % 1/
G_{mm}	± 0.03 2/

1/ The tolerance for FRAP shall be ± 0.3 percent.

2/ For stockpile with slag or steel slag present as determined in the Manual of Test Procedures Appendix B 21, "Determination of Aggregate Bulk (Dry) Specific Gravity (Gsb) of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)".

Evaluation of RAP / FRAP / RAS Test Results

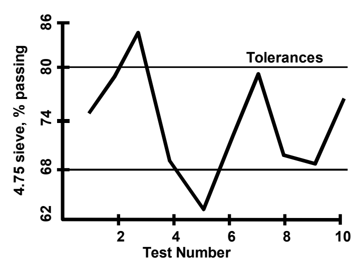
If more than 20 percent of the test results for an individual parameter(individual sieves, Gmm, and/or asphalt binder content) are out of the above tolerances, the RAP/FRAP shall not be used in HMA unless the RAP/FRAP representing the failing tests is removed from the stockpile. All test data and acceptance ranges shall be sent to the Department for evaluation.

With the approval of the Engineer, the ignition oven may be substituted for solvent extractions according to the document "Calibration of the Ignition Oven for the Purpose of Characterizing Reclaimed Asphalt Pavement(RAP)".

This is a consistency rewarding specification.

RAP Characterization

RAP Characterization



Asphalt Binder

Note 3 –
When RAP exceeds 20%, (25% for WMA) the high & low virgin asphalt binder grades shall each be reduced by one grade.

Extra Credit: Is there a difference between full-depth and overlay applications?

Class Participation: WHY?

Illinois Asphalt Binder Selection

- On lower volume roads, a softer liquid binder may be desired to reduce weathering and raveling and improve durability.
- On high volume roads and in areas of slower moving or standing loads, a stiffer liquid binder should be used.
- In some cases, it may be desirable to use one liquid binder grade for the lower course and another grade for the top / surface course.

RAP in HMA Mixes

- Type of RAP and maximum allowable percentages are based on mix type and traffic loading.
- Polymer mixes now allow use of up to 10% RAP.

RAP Usage Chart Notes

- Need to document location where RAP came from.
- Need gradation and asphalt content.
- Must sign products similar to virgin aggregate program. (AGCS)
- Maximum % is still Contractor option.
- Testing protocol remains in check.
- Slag to surface will require weight adjustment.

(1) RAP/RAS. When RAP is used alone or RAP is used in conjunction with RAS, the percentage of virgin ABR shall not exceed the amounts listed in the following table.

HMA Mixtures - RAP/RAS Maximum ABR % 1/ 2/			
Ndesign	Binder	Surface	Polymer Modified Binder or Surface
30	30	30	10
50	25	15	10
70	15	10	10
90	10	10	10

1/ For Low ESAL HMA shoulder and stabilized subbase, the RAP/RAS ABR shall not exceed 50 percent of the mixture.

2/ When RAP/RAS ABR exceeds 20 percent, the high and low virgin asphalt binder grades shall each be reduced by one grade (i.e. 25 percent ABR would require a virgin asphalt binder grade of PG 64-22 to be reduced to a PG 58-28).

(2) FRAP/RAS. When FRAP is used alone or FRAP is used in conjunction with RAS, the percentage of virgin asphalt binder replacement shall not exceed the amounts listed in the following table.

HMA Mixtures - FRAP/RAS Maximum ABR % 1/ 2/			
Ndesign	Binder	Surface	Polymer Modified Binder or Surface
30	55	45	15
50	45	40	15
70	45	35	15
90	45	35	15
SMA	- -	- -	25
IL-4.75	- -	- -	35

1/ For Low ESAL HMA shoulder and stabilized subbase, the FRAP/RAS ABR shall not exceed 50 percent of the mixture.

2/ When FRAP/RAS ABR exceeds 20 percent for all mixes, the high and low virgin asphalt binder grades shall each be reduced by one grade (i.e. 25 percent ABR would require a virgin asphalt binder grade of PG 64-22 to be reduced to a PG 58-28).

RAP Batching Example

Given: **RAP asphalt = 4.8%**
Optimum Binder Content = 5.0%
Batch Mass = 10,000 g

<u>Blend %</u>
RAP = 25.0%
CM11 = 42.0%
CM16 = 16.5%
FA20 = 16.5%

RAP Batching Example

Determine Mass of the Aggregates

Mass of Aggregate = (Aggregate % x Mass Batch)

Blend %		Masses of Aggregate:
RAP = 25.0%	x 10,000 =	2,500 g (Aggregate Only)
CM11 = 42.0%	x 10,000 =	4,200 g
CM16 = 16.5%	x 10,000 =	1,650 g
FA02 = 16.5%	x 10,000 =	1,650 g
	Total	10,000 g

RAP Batching Example

Determine Mass of Recycle (Agg & Binder)

Rap = (Batch Mass x %Rap) / (100 - % Binder in Rap)

RAP = 10,000 x 25.0 / (100-4.8) = 2626 grams

Determine Mass of Binder in Recycle

Binder = (Mass of RAP – Mass of Aggregate in RAP)

Binder = (2626 – 2500) = 126 grams

RAP Batching Example

Determine Corrected Mass of the Aggregates

Mass of Aggregate = (Aggregate % x Mass Batch of Aggregates)

Rap = (Batch Mass of Aggregates x %Rap) / (100 - % Binder in Rap)

Blend %	Masses of Aggregate:
RAP =	2,626 g (RAP with Aggregate & Binder)
CM11 =	4,200 g
CM16 =	1,650 g
FA02 =	1,650 g
Total	10,126 g

RAP Batching Example

Calculate the corrected batch mass (including asphalt):

$$\frac{\text{Batch Mass of Aggregate. (grams)}}{\text{1.0 - \% Optimum AC (Decimal Form)}}$$

10,000 g / 0.95 = 10,526 g

RAP Batching Example

Determine total grams of binder needed:

(New Corrected Batch Mass) - (Batch Mass of Aggregate)

10,526 g – 10,000 g = 526 g

RAP Batching Example

Calculate mass of virgin binder needed:

(Total Binder Needed) - (Binder in RAP)

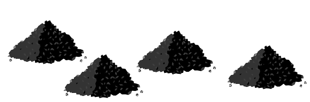
526 g – 126 g = 400 g

RAP Batching Example

Students perform work on pages 10.1-17 & 10.1-19

Combined Aggregate Bulk Specific Gravity

$$G_{sb}\,(\text{comb.}) = \frac{100}{\left(\frac{P_1\%}{G_{sb1}}\right) + \left(\frac{P_2\%}{G_{sb2}}\right) + \left(\frac{P_3\%}{G_{sb3}}\right) + \left(\frac{RAP\%}{G_{sbRAP}}\right)}$$



What is the G_{sb} of RAP?

- D1 – D2 = 2.660
- D3 – D9 = 2.630
- Slag RAP and Research please see, ***'Determination of Reclaimed Asphalt Pavement (RAP) Aggregate Bulk (Dry) Specific Gravity (G_{sb})'*** at back of chapter.

Questions

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Givens:			
	Optimum Binder Content	=	5.1%
	Aggregate Batch Size (Weight)	=	10,000 g
	RAP Binder Content	=	4.3%

Blend Percentages	Aggregate Mass	Aggregate & Recycle Binder Mass
CM-11 - 42.0 %		
CM-16 - 18.0 %		
FM-20 - 15.0 %		
RAP - 25.0 %		
Total - 100.0%		

1) Determine Aggregate Mass
   (Blend %) x (Aggregate Batch Weight) =

2) Determine Aggregate & Recycle Binder Mass of Recycle
   (Aggregate Batch Size) x (% of Recycle (in decimal form)) / (1.0 – Binder Content (in decimal form)) =

3) Determine Mass of Binder in Recycle
   (Aggregate & Recycle Binder Mass) – (Recycle Aggregate Mass) =

4) Determine Mass of Batch (Binder Included)
   (Aggregate Batch Size) / ((1.0 – (Optimum Binder Content (in decimal form))) =

5) Determine Mass of Binder
   (Mass of the Batch (Binder Included)) – (Aggregate Batch Size) =

6) Determine Mass of New Binder
   (Mass of Binder) – (Mass of Binder in Recycle) =

7) Determine the Percentage of Recycle Binder & New Binder
   (Mass of Binder in Recycle) / (Mass of Batch (Binder Included)) x 100

   (Mass of New Binder) / (Mass of Batch (Binder Included)) x 100

8) Determine Asphalt Binder Replacement (% ABR)
   (Percent of Recycle Binder) / (Percent Optimum Binder Content) x 100

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Givens:			
	Optimum Binder Content	=	5.1%
	Aggregate Batch Size (Weight)	=	10,000 g
	RAP Binder Content	=	4.3%
	RAS Binder Content	=	26.2 %

Blend Percentages	Aggregate Mass	Aggregate & Recycle Binder Mass
CM-16 - 45.5 %		
FM-20 - 37.0 %		
RAP - 15.0 %		
RAS - 2.5 %		
Total - 100.0%		

1) Determine Aggregate Mass
   (Blend %) x (Aggregate Batch Weight) =

2) Determine Aggregate & Recycle Binder Mass of Recycle
   (Aggregate Batch Size) x (% of RAP (in decimal form)) / (1.0 – Rcycle Binder Content (in decimal form)) =

3) Determine Mass of Binder in Recycle
   (Aggregate & Recycle Binder Mass) – (Recycle Aggregate Mass) =

4) Determine Mass of Batch (Binder Included)
   (Aggregate Batch Size) / ((1.0 – (Optimum Binder Content (in decimal form))) =

5) Determine Mass of Binder
   (Mass of Batch (Binder Included)) – (Aggregate Batch Size) =

6) Determine Mass of New Binder
   (Mass of Binder) – (Mass of Binder in Recycle) =

7) Determine the Percentage of Recycle Binder & New Binder
   (Mass of Binder in Recycle) / (Mass of Batch (Binder Included)) x 100

   (Mass of New Binder) / (Mass of Batch (Binder Included)) x 100

8) Determine Asphalt Binder Replacement (% ABR)
   (Percent of Recycle Binder) / (Percent Optimum Binder Content) x 100

This Page Is Reserved

Givens:
- Optimum Binder Content =
- Aggregate Batch Size (Weight) =
- RAP Binder Content =

Blend Percentages	Aggregate Mass	Aggregate & Recycle Binder Mass

1) Determine Aggregate Mass
   (Blend %) x (Aggregate Batch Weight) =

2) Determine Aggregate & Recycle Binder Mass of Recycle
   (Aggregate Batch Size) x (% of Recycle (in decimal form)) / (1.0 – Binder Content (in decimal form)) =

3) Determine Mass of Binder in Recycle
   (Aggregate & Recycle Binder Mass) – (Recycle Aggregate Mass) =

4) Determine Mass of Batch (Binder Included)
   (Aggregate Batch Size) / ((1.0 – (Optimum Binder Content (in decimal form))) =

5) Determine Mass of Binder
   (Mass of Batch (Binder Included)) – (Aggregate Batch Size) =

6) Determine Mass of New Binder
   (Mass of Binder) – (Mass of Binder in Recycle) =

7) Determine the Percentage of Recycle Binder & New Binder
   (Mass of Binder in Recycle) / (Mass of Batch (Binder Included)) x 100

   (Mass of New Binder) / (Mass of Batch (Binder Included)) x 100

8) Determine Asphalt Binder Replacement (% ABR)
   (Percent of Recycle Binder) / (Percent Optimum Binder Content) x 100

This Page Is Reserved

Givens: Optimum Binder Content =

Aggregate Batch Size (Weight) =

RAP Binder Content =

RAS Binder Content =

Blend Percentages	Aggregate Mass	Aggregate & Recycle Binder Mass
CM-16 -		
FM-20 -		
RAP -		
RAS -		
Total -		

1) Determine Aggregate Mass
   (Blend %) x (Aggregate Batch Weight) =

2) Determine Aggregate & Recycle Binder Mass of Recycle
   (Aggregate Batch Size) x (% of Recycle (in decimal form)) / (1.0 – Binder Content (in decimal form)) =

3) Determine Mass of Binder in Recycle
   (Aggregate & Recycle Binder Mass) – (Recycle Aggregate Mass) =

4) Determine Mass of Batch (Binder Included)
   (Aggregate Batch Size) / ((1.0 – (Optimum Binder Content (in decimal form))) =

5) Determine Mass of Binder
   (Mass of Batch (Binder Included)) – (Aggregate Batch Size) =

6) Determine Mass of New Binder
   (Mass of Binder) – (Mass of Binder in Recycle) =

7) Determine the Percentage of Recycle Binder & New Binder
   (Mass of Binder in Recycle) / (Mass of Batch (Binder Included)) x 100

   (Mass of New Binder) / (Mass of Batch (Binder Included)) x 100

8) Determine Asphalt Binder Replacement (% ABR)
   (Percent of Recycle Binder) / (Percent Optimum Binder Content) x 100

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Mixture Composition	
Fine Aggregate (FA 1, FA 2 or FA 3)	93 - 96 %
Asphalt Binder (PG 58-28, PG 64-22)	6 - 9 %

With the permission of the Engineer, an approved cold-lay sand asphalt mixture may be used in lieu of the above mixture.

1030.12 Transportation. Vehicles used in transporting HMA shall have clean and tight beds. The beds shall be sprayed with asphalt release agents from the Department's qualified product list. In lieu of a release agent, the Contractor may use a light spray of water with a light scatter of manufactured sand (FA 20 or FA 21) evenly distributed over the bed of the vehicle. After spraying, the bed of the vehicle shall be in a completely raised position and it shall remain in this position until all excess asphalt release agent or water has been drained.

When the air temperature is below 60 °F (15 °C), the bed, including the end, endgate, sides and bottom shall be insulated with fiberboard, plywood, or other approved insulating material and shall have a thickness of not less than 3/4 in. (19 mm). When the insulation is placed inside the bed, the insulation shall be covered with sheet steel approved by the Engineer. Each vehicle shall be equipped with a cover of canvas or other suitable material meeting the approval of the Engineer which shall be used if any one of the following conditions is present.

(a) Ambient air temperature is below 60 °F (15 °C).

(b) The weather is inclement.

(c) The temperature of the HMA immediately behind the paver screed is below 250 °F (120 °C).

(d) The mixture being placed is SMA.

The cover shall extend down over the sides and ends of the bed for a distance of approximately 12 in. (300 mm) and shall be fastened securely. The covering shall be rolled back before the load is dumped.

SECTION 1031. RECLAIMED ASPHALT PAVEMENT AND RECLAIMED ASPHALT SHINGLES

1031.01 Description. Reclaimed asphalt pavement and reclaimed asphalt shingles shall be according to the following.

(a) Reclaimed Asphalt Pavement (RAP). RAP is the material produced by cold milling or crushing an existing hot-mix asphalt (HMA) pavement. The Contractor shall supply written documentation that the RAP originated from roadways or airfields under federal, state, or local agency jurisdiction.

(b) Reclaimed Asphalt Shingles (RAS). RAS is the material produced from the processing and grinding of preconsumer or post-consumer shingles. RAS shall be a clean and uniform material with a maximum of 0.5 percent unacceptable material by weight of RAS, as defined in Bureau of Materials Policy Memorandum, "Reclaimed Asphalt Shingle (RAS) Sources". RAS shall come from a facility source on the Department's "Qualified Producer List of Certified Sources for Reclaimed Asphalt Shingles" where it shall be ground and processed to 100 percent passing the 3/8 in. (9.5 mm) sieve and 93 percent passing the #4 (4.75 mm) sieve based on a dry shake gradation. RAS shall be uniform in gradation and asphalt binder content and shall meet the testing requirements specified herein. In addition, RAS shall meet the following Type 1 or Type 2 requirements.

(1) Type 1. Type 1 RAS shall be processed, preconsumer asphalt shingles salvaged from the manufacture of residential asphalt roofing shingles.

(2) Type 2. Type 2 RAS shall be processed post-consumer shingles only, salvaged from residential, or four unit or less dwellings not subject to the National Emission Standards for Hazardous Air Pollutants (NESHAP).

1031.02 Stockpiles. RAP and RAS stockpiles shall be according to the following.

(a) RAP Stockpiles. The Contractor shall construct individual RAP stockpiles meeting one of the following definitions. Stockpiles shall be sufficiently separated to prevent intermingling at the base. Stockpiles shall be identified by signs indicating the type as listed below (i.e. "Homogeneous Surface").

Prior to milling, the Contractor shall request the Department provide documentation on the quality of the RAP to clarify the appropriate stockpile.

(1) Fractionated RAP (FRAP). FRAP shall consist of RAP from Class I, HMA (High and Low ESAL) mixtures. The coarse aggregate in FRAP shall be crushed aggregate and may represent more than one aggregate type and/or quality, but shall be at least C quality. FRAP shall be fractionated prior to testing by screening into a minimum of two size fractions with the separation occurring on or between the No. 4 (4.75 mm) and 1/2 in. (12.5 mm) sieves. Agglomerations shall be minimized such that 100 percent of the RAP in the coarse fraction shall pass the maximum sieve size specified for the mixture composition of the mix design.

(2) Homogeneous. Homogeneous RAP stockpiles shall consist of RAP from Class I, HMA (High and Low ESAL) mixtures and represent: 1) the same aggregate quality, but shall be at least C quality; 2) the same type of crushed aggregate (either crushed natural aggregate, ACBF slag, or steel slag); 3) similar gradation; and 4) similar asphalt binder content. If approved by the Engineer, combined single pass surface/binder millings may be considered "homogeneous" with a quality rating dictated by the lowest coarse aggregate quality present in the mixture.

(3) Conglomerate. Conglomerate RAP stockpiles shall consist of RAP from Class I, HMA (High and Low ESAL) mixtures. The coarse aggregate in this RAP shall be crushed aggregate and may represent more than one

aggregate type and/or quality, but shall be at least C quality. This RAP may have an inconsistent gradation and/or asphalt binder content prior to processing. Conglomerate RAP shall be processed prior to testing by crushing to where all RAP shall pass the 5/8 in. (16 mm) or smaller screen. Conglomerate RAP stockpiles shall not contain steel slag.

(4) Conglomerate "D" Quality (Conglomerate DQ). Conglomerate DQ RAP stockpiles shall be according to Articles 1031.02(a)(1) through 1031.02(a)(3), except they may also consist of RAP from HMA shoulders, bituminous stabilized subbases, or HMA (High or Low ESAL) binder mixture. The coarse aggregate in this RAP may be crushed or round but shall be at least D quality. This RAP may have an inconsistent gradation and/or asphalt binder content.

(5) Non-Quality. RAP stockpiles that do not meet the requirements of the stockpile categories listed above shall be classified as "Non-Quality".

RAP/FRAP containing contaminants, such as earth, brick, sand, concrete, sheet asphalt, non-bituminous surface treatment (i.e. high friction surface treatments), pavement fabric, joint sealants, plant cleanout, etc., will be unacceptable unless the contaminants are removed to the satisfaction of the Engineer. Sheet asphalt shall be stockpiled separately.

(b) RAS Stockpiles. Type 1 and Type 2 RAS shall be stockpiled separately and shall not be intermingled. Each stockpile shall be signed indicating what type of RAS is present.

Unless otherwise specified by the Engineer, mechanically blending manufactured sand (FM 20 or FM 22) or fine FRAP up to an equal weight of RAS with the processed RAS will be permitted to improve workability. The sand shall be B quality or better from an approved Aggregate Gradation Control System source. The sand shall be accounted for in the mix design and during HMA production.

Records identifying the shingle processing facility supplying the RAS, RAS type, and lot number shall be maintained by project contract number and kept for a minimum of three years.

Additional processed RAP/FRAP/RAS shall be stockpiled in a separate working pile, as designated in the QC Plan, and only added to the original stockpile after the test results for the working pile are found to meet the requirements specified in Articles 1031.03 and 1031.04.

1031.03 Testing. RAP/FRAP and RAS testing shall be according to the following.

(a) RAP/FRAP Testing. When used in HMA, the RAP/FRAP shall be sampled and tested either during or after stockpiling.

(1) During Stockpiling. For testing during stockpiling, washed extraction samples shall be run at the minimum frequency of one sample per 500 tons (450 metric tons) for the first 2,000 tons (1,800 metric tons)

and one sample per 2,000 tons (1,800 metric tons) thereafter. A minimum of five tests shall be required for stockpiles less than 4,000 tons (3,600 metric tons).

(2) After Stockpiling. For testing after stockpiling, the Contractor shall submit a plan for approval to the Department proposing a satisfactory method of sampling and testing the RAP/FRAP pile either in-situ or by restockpiling. The sampling plan shall meet the minimum frequency required above and detail the procedure used to obtain representative samples throughout the pile for testing.

Each sample shall be split to obtain two equal samples of test sample size. One of the two test samples from the final split shall be labeled and stored for Department use. The Contractor shall perform a washed extraction on the other test sample according to Illinois Modified AASHTO T 164. The Engineer reserves the right to test any sample (split or Department-taken) to verify Contractor test results.

(b) RAS Testing. RAS or RAS blended with manufactured sand shall be sampled and tested during stockpiling according to the Bureau of Materials Policy Memorandum, "Reclaimed Asphalt Shingle (RAS) Source".

Samples shall be collected during stockpiling at the minimum frequency of one sample per 200 tons (180 metric tons) for the first 1,000 tons (900 metric tons) and one sample per 500 tons (450 metric tons) or a minimum of once per week, whichever is more frequent, thereafter. A minimum of five samples are required for stockpiles less than 1,000 tons (900 metric tons).

Before testing, each sample shall be split to obtain two test samples. One of the two test samples from the final split shall be labeled and stored for Department use. The Contractor shall perform a washed extraction and test for unacceptable materials on the other test sample according to Illinois Modified AASHTO T 164. The Engineer reserves the right to test any sample (split or Department-taken) to verify Contractor test results.

The Contractor shall obtain and make available all of the test results from the start of the original stockpile.

1031.04 Evaluation of Tests. Evaluation of test results shall be according to the following.

(a) Limits of Precision. The limits of precision between the Contractor's and the Department's split sample test results shall be according to the following.

Test Parameter	Limits of Precision		
% Passing	RAP	FRAP	RAS
1/2 in. (12.5 mm)	6.0 %	5.0 %	
# 4 (4.75 mm)	6.0 %	5.0 %	
# 8 (2.36 mm)	4.0 %	3.0 %	4.0 %
# 30 (600 µm)	3.0 %	2.0 %	4.0 %
# 200 (75 µm)	2.5 %	2.2 %	4.0 %
Asphalt Binder	0.4 %	0.3 %	3.0 %
G_{mm}	0.035	0.030	

If the test results are outside the above limits of precision, the Engineer will immediately investigate.

(b) Evaluation of RAP/FRAP Test Results. All of the extraction results shall be compiled and averaged for asphalt binder content and gradation, and when applicable G_{mm}. Individual extraction test results, when compared to the averages, will be accepted if within the tolerances listed below.

Parameter	FRAP/Homogeneous/ Conglomerate
1 in. (25 mm)	
1/2 in. (12.5 mm)	± 8 %
# 4 (4.75 mm)	± 6 %
# 8 (2.36 mm)	± 5 %
# 16 (1.18 mm)	
# 30 (600 µm)	± 5 %
# 200 (75 µm)	± 2.0 %
Asphalt Binder	± 0.4 % 1/
G_{mm}	± 0.03 2/

1/ The tolerance for FRAP shall be ± 0.3 percent.

2/ For stockpile with slag or steel slag present as determined in the Manual of Test Procedures Appendix B 21, "Determination of Aggregate Bulk (Dry) Specific Gravity (Gsb) of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)".

If more than 20 percent of the test results for an individual parameter (individual sieves, G_{mm}, and/or asphalt binder content) are out of the above tolerances, the RAP/FRAP shall not be used in HMA unless the RAP/FRAP representing the failing tests is removed from the stockpile. All test data and acceptance ranges shall be sent to the Department for evaluation.

With the approval of the Engineer, the ignition oven may be substituted for solvent extractions according to the document "Calibration of the Ignition

Oven for the Purpose of Characterizing Reclaimed Asphalt Pavement (RAP)".

(c) Evaluation of RAS and RAS Blended with Manufactured Sand or Fine FRAP Test Results. All of the test results, with the exception of percent unacceptable materials, shall be compiled and averaged for asphalt binder content and gradation. Individual test results, when compared to the averages, will be accepted if within the tolerances listed below.

Parameter	RAS
# 8 (2.36 mm)	± 5 %
# 16 (1.18 mm)	± 5 %
# 30 (600 µm)	± 4 %
# 200 (75 µm)	± 2.5 %
Asphalt Binder Content	± 2.0 %

If more than 20 percent of the test results for an individual parameter (individual sieves and/or asphalt binder content) are out of the above tolerances, or if the unacceptable material exceeds 0.5 percent by weight of material retained on the No. 4 (4.75 mm) sieve, the RAS or RAS blend shall not be used in Department projects. All test data and acceptance ranges shall be sent to the Department for evaluation.

1031.05 Quality Designation of Aggregate in RAP/FRAP.

(a) RAP. The aggregate quality of the RAP for homogeneous, conglomerate, and conglomerate DQ stockpiles shall be set by the lowest quality of coarse aggregate in the RAP stockpile. RAP originating from roadways under state jurisdiction shall be designated as follows.

Class B Quality	Class C Quality	Class D Quality
Class I Surface	Class I Binder	Bituminous Aggregate Mixture (BAM) Stabilized Subbase
HMA (High ESAL) Surface	HMA (High ESAL) Binder	
SMA	HMA (Low ESAL)	BAM Shoulder

(b) FRAP. If the Engineer has documentation of the quality of the FRAP aggregate, the Contractor shall use the assigned quality provided by the Engineer.

If the quality is not known, the quality shall be determined as follows. Coarse and fine FRAP stockpiles containing plus No. 4 (4.75 mm) sieve coarse aggregate shall have a maximum tonnage of 5,000 tons (4,500 metric tons). The Contractor shall obtain a representative sample witnessed by the Engineer. The sample shall be a minimum of 50 lb (25 kg). The sample shall be extracted according to Illinois Modified AASHTO T 164 by a consultant laboratory prequalified by the Department for the specified testing. The consultant laboratory shall submit the test results along with the recovered aggregate sample to the District Office. Consultant laboratory services will be at no additional cost to the Department. The District will forward the sample to the Central Bureau of Materials Aggregate Lab for MicroDeval Testing, according to Illinois Modified AASHTO T 327. A maximum loss of 15.0 percent will be applied for all HMA applications.

1031.06 Use of RAP/FRAP and/or RAS in HMA. The use of RAP/FRAP l/or RAS shall be the Contractor's option when constructing HMA in all contracts.

(a) RAP/FRAP. The use of RAP/FRAP in HMA shall be as follows.

(1) Coarse Aggregate Size. The coarse aggregate in all RAP shall be equal to or less than the nominal maximum size requirement for the HMA mixture to be produced.

(2) Steel Slag Stockpiles. Homogeneous RAP stockpiles containing steel slag will be approved for use in all HMA (High ESAL and Low ESAL) surface and binder mixture applications.

(3) Use in HMA Surface Mixtures (High and Low ESAL). RAP/FRAP stockpiles for use in HMA surface mixtures (High and Low ESAL) shall be FRAP or homogeneous in which the coarse aggregate is Class B quality or better. FRAP from conglomerate stockpiles shall be considered equivalent to limestone for frictional considerations. Known frictional contributions from plus No. 4 (4.75 mm) homogeneous FRAP stockpiles will be accounted for in meeting frictional requirements in the specified mixture.

(4) Use in HMA Binder Mixtures (High and Low ESAL), HMA Base Course, and HMA Base Course Widening. RAP/FRAP stockpiles for use in HMA binder mixtures (High and Low ESAL), HMA base course, and HMA base course widening shall be FRAP, homogeneous, or conglomerate, in which the coarse aggregate is Class C quality or better.

(5) Use in Shoulders and Subbase. RAP/FRAP stockpiles for use in HMA shoulders and stabilized subbase (HMA) shall be FRAP, homogeneous, or conglomerate.

(6) When the Contractor chooses the RAP option, the percentage of asphalt binder replacement (ABR) shall not exceed the amounts indicated in Article 1031.06(c)(1) below for a given Ndesign.

(b) RAS. RAS meeting Type 1 or Type 2 requirements will be permitted in all HMA applications as specified herein.

(c) RAP/FRAP and/or RAS Usage Limits. Type 1 or Type 2 RAS may be used alone or in conjunction with RAP or FRAP in HMA mixtures up to a maximum of 5.0 percent by weight of the total mix.

(1) RAP/RAS. When RAP is used alone or RAP is used in conjunction with RAS, the percentage of virgin ABR shall not exceed the amounts listed in the following table.

HMA Mixtures - RAP/RAS Maximum ABR % 1/ 2/			
Ndesign	Binder	Surface	Polymer Modified Binder or Surface
30	30	30	10
50	25	15	10
70	15	10	10
90	10	10	10

1/ For Low ESAL HMA shoulder and stabilized subbase, the RAP/RAS ABR shall not exceed 50 percent of the mixture.

2/ When RAP/RAS ABR exceeds 20 percent, the high and low virgin asphalt binder grades shall each be reduced by one grade (i.e. 25 percent ABR would require a virgin asphalt binder grade of PG 64-22 to be reduced to a PG 58-28).

(2) FRAP/RAS. When FRAP is used alone or FRAP is used in conjunction with RAS, the percentage of virgin asphalt binder replacement shall not exceed the amounts listed in the following table.

HMA Mixtures - FRAP/RAS Maximum ABR % 1/ 2/			
Ndesign	Binder	Surface	Polymer Modified Binder or Surface
30	55	45	15
50	45	40	15
70	45	35	15
90	45	35	15
SMA	- -	- -	25
IL-4.75	- -	- -	35

1/ For Low ESAL HMA shoulder and stabilized subbase, the FRAP/RAS ABR shall not exceed 50 percent of the mixture.

2/ When FRAP/RAS ABR exceeds 20 percent for all mixes, the high and low virgin asphalt binder grades shall each be reduced by one grade (i.e. 25 percent ABR would require a virgin asphalt binder grade of PG 64-22 to be reduced to a PG 58-28).

1031.07 HMA Mix Designs. At the Contractor's option, HMA mixtures may be constructed utilizing RAP/FRAP and/or RAS material meeting the detailed requirements specified herein.

(a) RAP/FRAP and/or RAS. RAP/FRAP and/or RAS mix designs shall be submitted for verification. If additional RAP/FRAP and/or RAS stockpiles are tested and found that no more than 20 percent of the individual parameter test results, as defined in Article 1031.04, are outside of the control tolerances set for the original RAP/FRAP and/or RAS stockpile and HMA mix design, and meets all of the requirements herein, the additional

RAP/FRAP and/or RAS stockpiles may be used in the original mix design at the percent previously verified.

(b) RAS. Type 1 and Type 2 RAS are not interchangeable in a mix design.

The RAP, FRAP, and RAS stone bulk specific gravities (G_{sb}) shall be according to the "Determination of Aggregate Bulk (Dry) Specific Gravity (G_{sb}) of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)" procedure in the Department's Manual of Test Procedures for Materials.

1031.08 HMA Production. HMA production utilizing RAP/FRAP and/or RAS shall be as follows.

To remove or reduce agglomerated material, a scalping screen, gator, crushing unit, or comparable sizing device approved by the Engineer shall be used in the RAP/FRAP and/or RAS feed system to remove or reduce oversized material.

If the RAP/FRAP and/or RAS control tolerances or HMA test results require corrective action, the Contractor shall cease production of the mixture containing RAP/FRAP and/or RAS and either switch to the virgin aggregate design or submit a new mix design.

(a) RAP/FRAP. The coarse aggregate in all RAP/FRAP used shall be equal to or less than the nominal maximum size requirement for the HMA mixture being produced.

(b) RAS. RAS shall be incorporated into the HMA mixture either by a separate weight depletion system or by using the RAP weigh belt. Either feed system shall be interlocked with the aggregate feed or weigh system to maintain correct proportions for all rates of production and batch sizes. The portion of RAS shall be controlled accurately to within ± 0.5 percent of the amount of RAS utilized. When using the weight depletion system, flow indicators or sensing devices shall be provided and interlocked with the plant controls such that the mixture production is halted when RAS flow is interrupted.

(c) RAP/FRAP and/or RAS. HMA plants utilizing RAP/FRAP and/or RAS shall be capable of automatically recording and printing the following information.

(1) Dryer Drum Plants.

a. Date, month, year, and time to the nearest minute for each print.

b. HMA mix number assigned by the Department.

c. Accumulated weight of dry aggregate (combined or individual) in tons (metric tons) to the nearest 0.1 ton (0.1 metric ton).

d. Accumulated dry weight of RAP/FRAP/RAS in tons (metric tons) to the nearest 0.1 ton (0.1 metric ton).

e. Accumulated mineral filler in revolutions, tons (metric tons), etc. to the nearest 0.1 unit.

f. Accumulated asphalt binder in gallons (liters), tons (metric tons), etc. to the nearest 0.1 unit.

g. Residual asphalt binder in the RAP/FRAP/RAS material as a percent of the total mix to the nearest 0.1 percent.

h. Aggregate and RAP/FRAP/RAS moisture compensators in percent as set on the control panel. (Required when accumulated or individual aggregate and RAP/FRAP/RAS are recorded in a wet condition.)

i. A positive dust control system shall be utilized when the combined contribution of reclaimed material passing the No. 200 sieve exceeds 1.5 percent.

(2) Batch Plants.

a. Date, month, year, and time to the nearest minute for each print.

b. HMA mix number assigned by the Department.

c. Individual virgin aggregate hot bin batch weights to the nearest pound (kilogram).

d. Mineral filler weight to the nearest pound (kilogram).

e. RAP/FRAP/RAS weight to the nearest pound (kilogram).

f. Virgin asphalt binder weight to the nearest pound (kilogram).

g. Residual asphalt binder in the RAP/FRAP/RAS material as a percent of the total mix to the nearest 0.1 percent.

The printouts shall be maintained in a file at the plant for a minimum of one year or as directed by the Engineer and shall be made available upon request. The printing system will be inspected by the Engineer prior to production and verified at the beginning of each construction season thereafter.

1031.09 RAP in Aggregate Applications. RAP in aggregate applications shall be according to the Bureau of Materials Policy Memorandum, “Reclaimed Asphalt Pavement (RAP) for Aggregate Applications” and the following.

(a) RAP in Aggregate Surface Course and Aggregate Wedge Shoulders, Type B. The use of RAP in aggregate surface course (temporary access entrances only) and aggregate wedge shoulders, Type B shall be as follows.

(1) Stockpiles and Testing. RAP stockpiles may be any of those listed in Article 1031.02, except “Non-Quality” and “FRAP”. The testing requirements of Article 1031.03 shall not apply.

(2) Gradation. One hundred percent of the RAP material shall pass the 1 1/2 in. (37.5 mm) sieve. The RAP material shall be reasonably well graded from coarse to fine. RAP material that is gap-graded or single sized will not be accepted.

SECTION 1032. BITUMINOUS MATERIALS

1032.01 Description. Bituminous materials shall include asphalt binders, emulsified asphalts, rapid curing liquid asphalt, medium curing liquid asphalts, slow curing liquid asphalts, asphalt fillers, and road oils. All bituminous materials used in a given construction shall be prepared from petroleum and be uniform in character, appearance, and consistency.

1032.02 Measurement. Asphalt binders, emulsified asphalts, rapid curing liquid asphalts, medium curing liquid asphalts, slow curing liquid asphalts, asphalt fillers, and road oils will be measured by weight.

A weight ticket for each truck load shall be furnished to the Engineer. The truck shall be weighed at a location approved by the Engineer. The ticket shall show the weight of the empty truck (the truck being weighed each time before it is loaded), the weight of the loaded truck, and the net weight of the bituminous material.

When an emulsion or cutback is used for prime or tack coat, the percentage of asphalt residue of the actual certified product shall be shown on the producer's bill of lading or attached certificate of analysis. If the producer adds extra water to an emulsion at the request of the purchaser, the amount of water shall also be shown on the bill of lading.

Payment will not be made for bituminous materials in excess of 105 percent of the amount specified by the Engineer.

1032.03 Delivery. When bituminous materials are not approved at their source by the Department, they shall be delivered far enough in advance of their use to permit the necessary tests to be made. When not delivered in tank cars or tank trucks, the bituminous materials shall be delivered in suitable containers or packages, plainly labeled to show the kind of material, the name of manufacturer, and the lot or batch number. Each shipment and each carload shall be kept separate until the material has been accepted.

Asphalt binder, when delivered in tank cars or tank trucks, shall be delivered at a temperature not to exceed 350 °F (175 °C).

Petroleum asphalts PAF-1 and PAF-2 shall be shipped in new, double end, metal drums. The thickness of the metal used shall not be less than 0.0149 in. (0.4 mm). The side seams of the drums shall be double lapped, spot welded single lapped, or stitch welded single lapped. The seams shall meet the approval of the Engineer. The drums shall be manufactured so that there will be no leakage during hot weather. The capacity of each drum shall be approximately 460 lb (210 kg), the drums being 35 in. (890 mm) maximum in height and approximately 22 in. (560 mm) in diameter.

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Determination of
Aggregate Bulk (Dry) Specific Gravity (Gsb) of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)
Appendix B.21

Effective: May 1, 2007
Revised: December 1, 2019

A. Natural Aggregate RAP G_{sb}

If the RAP consists of natural aggregates only, the RAP G_{sb} shall be as follows:

District	RAP G_{sb}
1 & 2	2.660
3 - 9	2.630

B. Slag RAP Gsb

If the RAP contains slag aggregate the following procedure shall be used by an independent AASHTO accredited laboratory to determine the slag RAP G_{sb}.

1. Slag RAP G_{sb} Summary of Method

A representative slag RAP sample shall be thoroughly prepared prior to testing by reheating and remixing the reclaimed material. A solvent extraction, including washed gradation for Department comparison, and two maximum theoretical specific gravity (G_{mm}) tests are performed so that an effective specific gravity (G_{se}) can be calculated. The G_{se} value is used in the calculation to determine the bulk specific gravity (G_{sb}) of the RAP.

a. Slag RAP Sampling

The slag RAP stockpile, in its final usable form, shall be sampled by obtaining a minimum of five representative samples from the slag RAP stockpile. The samples shall be thoroughly blended and split into two- 20,000 gram samples. One of the samples shall be submitted to an independent AASHTO accredited IDOT approved laboratory for the subsequent preparation and testing as specified herein. The other sample shall be submitted to the Department for optional verification testing.

b. Slag RAP Testing Equipment

Equipment including oven balances, HMA sample splitter, vacuum setup and solvent extractor shall be according to the HMA QC/QA Laboratory Equipment document in the Manual of Test Procedures for Materials. In addition the following equipment will also be required:

- Sample pans - Large, flat and capable of holding 20,000 grams of RAP material.
- Chopping utensil – Blade trowel or other utensil used to separate the large conglomerations of a RAP sample into a loose-flowing condition.

c. Slag RAP Sample Preparation

1) Transfer the entire 20,000 gram sample into a large flat pan(s).
2) Place sample into a preheated oven at 230 ± 9° F. (110 ± 5° C.) and heat for 30 to 45 minutes.
3) Remove the sample from the oven and begin breaking up the larger conglomerations of RAP with the chopping utensil.
4) As the material begins to soften, blend the heated RAP by mixing the freshly chopped material with the fines in the pan.
5) Return the RAP into the oven and continue heating for another 15 - 20 minutes.
6) Remove the RAP from the oven and repeat the chopping of the conglomerations and blending of the fines until the RAP sample is homogeneous and conglomerations of fine aggregate complies with Illinois Modified AASHTO T-209.
7) Place the loose RAP into a hopper or pan and uniformly pour it through a riffle splitter. Take each of the halves and re-pour through the splitter. Thoroughly blend the sample by repeating this process 2 - 3 times.

d. Slag RAP Testing

1) Percent Asphalt Binder P_b:

   a) Split out a 1,500 - 2,000 gram prepared RAP sample.
   b) Dry the RAP sample to a constant weight in an oven at 230 ± 9° F. (110 ± 5° C.).
   c) Determine the P_b of the dried RAP sample according to Illinois Modified T 164. Record the P_b.

2) Maximum Specific Gravity determination, G_{mm}:

   a) Split out one 3,000 gram prepared RAP sample.
   b) Dry the sample to a constant weight in an oven at 230 ±9° F. (110 ± 5° C.) While drying, chop and break up the sample as you would with a standard G_{mm} sample. Record as “dry RAP mass”.
   c) Place the sample in 295° ± 5° F. (146° ± 3° C.) oven for one hour.
   d) Add 1.5 percent virgin asphalt binder (PG64-22 or PG58-22) at 295° ± 5° F. (146° ± 3° C.), based on the “dry RAP mass” from step 6.B.2, to the RAP and thoroughly mix at 295° ± 5° F. (146° ± 3° C.) to ensure uniform coating of all particles.
   e) Split sample into two equal samples.
   f) Determine the G_{mm} of the prepared RAP samples according to Illinois Modified AASHTO T209.

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g) Calculate the individual G_{mm} values. The average result will be used in the calculation provided the individual results do not vary by more than 0.011. If the individual results vary more than 0.011, repeat steps in 6.B., discard the high and low values and average the remaining individual results provided they do not vary more than 0.011. If remaining individual results vary more than 0.011 repeat steps in 6.B. until individual results compare within 0.011.

e. Slag RAP Calculations:

1) Calculate the "adjusted Pb" of the RAP to account for the addition of the 1.5 percent virgin asphalt binder as follows:

a) Calculate "mass of RAP Asphalt Cement (AC)":

b) *Mass of RAP AC* = $Dry\ RAP\ mass \times \frac{P_b}{100}$

c) Calculate "mass of virgin AC added":

Mass of virgin AC added = 0.015 x Dry RAP mass

d) Determine "New RAP mass":

New RAP mass = Dry RAP mass + Mass of virgin AC added

e) Calculate "Adjusted P_b":

$$\text{Adjusted } P_b = \frac{Mass\ of\ RAP\ AC + Mass\ of\ virgin\ AC\ added}{New\ RAP\ Mass} \times 100$$

2) Calculate the effective specific gravity (G_{se}) of the RAP:

$$G_{se}\ (RAP) = \frac{(100 - Adjusted\ P_b)}{\left(\frac{100}{G_{mm}} - \frac{Adjusted\ P_b}{1.040}\right)}$$

3) Calculate the stone bulk gravity (G_{sb}) of the RAP:

$G_{sb}\ (RAP) = G_{se}\ (RAP) - 0.100$

f. Example Slag RAP G_{sb} Calculation:

- Dry RAP mass = 3,000 g

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- P_b, (% AC) in RAP = 4.9%
- Determine "mass of RAP AC":
  - *Mass of RAP AC = Dry RAP mass x (P_b / 100)*
    = 3,000 x (4.9% / 100)
    = 147 grams

- Add 1.5 percent virgin AC:
  - Determine "mass of virgin AC added":

    Mass of virgin AC added = 0.015 x Dry RAP mass
    = 0.015 x 3,000 grams
    = 45 grams

  - Determine "New RAP mass":

    New RAP mass = Dry RAP mass + Mass of virgin AC added
    = 3,000 + 45
    = 3,045 grams

- Calculate "Adjusted P_b":

$$\text{Adjusted } P_b = \frac{Mass\ of\ RAP\ AC + Mass\ of\ virgin\ AC\ added}{New\ RAP\ Mass} \times 100$$

$$= \frac{147\ grams + 45\ grams}{3{,}045\ grams} \times 100 = 6.3\%$$

- Calculate G_{se}:

$$G_{se} = \frac{100 - P_b}{\frac{100}{G_{mm}} - \frac{P_b}{1.04}} = \frac{100 - 6.3}{\frac{100}{2.505} - \frac{6.3}{1.04}} = \frac{93.7}{39.9 - 6.1} = 2.772$$

Adjusted P_b = 6.3%
Rice Test, G_{mm} = 2.505

- Calculate Slag RAP G_{sb}:

$$G_{sb} = G_{se} - 0.10 = 2.772 - 0.10 = 2.672$$

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C. RAS G_{sb}

The RAS G_{sb}, prior to adjustment using AASHTO PP78-14, is defined as 2.500. In accordance with AASHTO PP78-14 Note 6, the RAS asphalt binder availability factor is assumed equal to 0.85. The reduction in available RAS asphalt binder content equates to a reduction in G_{sb} of 0.200. This availability factor G_{sb} reduction is then applied to the RAS G_{sb} resulting in an adjusted G_{sb} of **2.300** which shall be used for all subsequent mix design and production mixture volumetric calculations.

D. G_{sb} for RAS Pre-blended with Fine Fractioned Reclaimed Asphalt Pavement (FRAP)

When RAS is mechanically pre-blended with fine FRAP, the G_{sb} for the final blended product shall be calculated as follows.

1. Calculate the weighted final blend RAS G_{sb} ($G_{sb,blended}$) using the following equations.

   a. Determine the weighting factor for the percentage of combined aggregate (P_{agg}) using: the percentage of RAS in the combined blend (P_{RAS}), the percentage of RAP in the combined blend (P_{RAP}), the asphalt binder content of the RAS before adjustment using the availability factor of 0.85 ($P_{b,RAS}$), and the asphalt binder content of the RAP ($P_{b,RAP}$).

$$P_{agg} = \frac{P_{RAS} - P_{RAS}\left(\frac{P_{b,RAS}}{100}\right) + P_{RAP} - P_{RAP}\left(\frac{P_{b,RAP}}{100}\right)}{100}$$

   b. Determine the combined bulk specific gravity of the blended product ($G_{sb,combined}$) using: the RAS mix design G_{sb} equal to 2.300 ($G_{sb,RAS,design}$) and the RAP G_{sb}.

$$G_{sb,combined} = \frac{100}{\frac{\frac{P_{RAS} - P_{RAS}\left(\frac{P_{b,RAS}}{100}\right)}{P_{agg}}}{G_{sb,RAS,design}} + \frac{\frac{P_{RAP} - P_{RAP}\left(\frac{P_{b,RAP}}{100}\right)}{P_{agg}}}{G_{sb,RAP}}}$$

E. Asphalt Binder Replacement Calculation (By Percent Weight of Aggregate)

The calculation of asphalt binder replacement (ABR) is completed in terms of percent weight of aggregate. It follows the percent weight of aggregate approach used in the Quality Management Program (QMP) available on the IDOT website.

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1. RAS Asphalt Binder Content

RAS available asphalt binder content ($P_{b,AV}$) is calculated using the AASHTO PP78-14 availability factor of 0.85. The value of $P_{b,AV}$ is used in calculations of ABR percentage in mix design. The following examples demonstrate the use of $P_{b,AV}$ with RAS and RAP/RAS mixtures.

a. RAS Asphalt Binder Content Calculations

1) Calculate the RAS and/or RAP aggregate percentages ($RAS_{Agg\%}$ and/or $RAP_{Agg\%}$).

$$CF = \frac{100 - P_b}{100}$$

$$RAP_{Agg\%} = \frac{RAP_{mix\%}}{CF} \times \frac{100 - P_{b,RAP}}{100}$$

$$RAS_{Agg\%} = \frac{RAS_{mix\%}}{CF} \times \frac{100 - P_{b,RAS}}{100}$$

2) Calculate the RAS Available Asphalt Binder Content ($P_{b,AV}$) given the Total RAS Asphalt Binder Content.

$$P_{b,AV} = P_{b,RAS} \times 0.85$$

3) Calculate the asphalt binder contributed ($AB_{rcy\%,mix}$) from the RAP ($AB_{RAP\%}$) and/or RAS ($AB_{RAS\%}$) given the aggregate percentages of RAP and/or RAS.

$$AB_{RAP\%} = 100 \times \left(\frac{RAP_{Agg\%}}{100 - P_{b,RAP}}\right) - RAP_{Agg\%}$$

$$AB_{RAS\%} = 100 \times \left(\frac{RAS_{Agg\%}}{100 - P_{b,AV}}\right) - RAS_{Agg\%}$$

$$AB_{rcy\%,mix} = CF(AB_{RAP\%} + AB_{RAS\%})$$

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Aggregate Bulk (Dry) Specific Gravity (Gsb) of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)
Appendix B.21
(continued)

Effective: May 1, 2007
Revised: December 1, 2019

4) Calculate the ABR for the mixture given the mixture total asphalt content (P_b).

$$ABR = 100 \times (\frac{AB_{rcy\%,mix}}{P_b})$$

b. Example Calculations for Increasing ABR to Compensate for the RAS Availability Factor Reduction of RAS asphalt binder content.

Example of Adjusting RAS for Additional ABR

- N70 Polymer Surface with RAS
  - P_b (%AC) in RAS = 25.0%
  - P_b (%AC) in Mixture = 6.0%
  - Maximum ABR = 10%
  - $RAS_{mix\%}$ Before Calculation of $P_{b,AV}$ = 2.4%

Step 1. Calculate the RAS and/or RAP aggregate percentages ($RAS_{Agg\%}$ and $RAP_{Agg\%}$). Note that $RAP_{\%}$ is equal to 0.0% in this example.

$$CF = \frac{100 - P_b}{100} = \frac{100 - 6.0}{100} = 0.94$$

$$RAS_{Agg\%} = \frac{RAS_{mix\%}}{CF} \times \frac{100 - P_{b,RAS}}{100} = \frac{2.4}{0.94} \times \frac{100 - 25.0}{100} = 1.9\%$$

Step 2. Calculate the RAS Available Asphalt Binder Content ($P_{b,AV}$) given the Total RAS Asphalt Binder Content.

$$P_{b,AV} = 25.0\% \times 0.85 = 21.3\%$$

Step 3. Calculate the asphalt binder contributed ($AB_{rcy\%,mix}$) from the RAS ($AB_{RAS\%}$) given the aggregate percentage of RAS.

Illinois Department of Transportation

Determination of
Aggregate Bulk (Dry) Specific Gravity (Gsb) of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)
Appendix B.21
(continued)

Effective: May 1, 2007
Revised: December 1, 2019

$$AB_{RAS\%} = 100 \times (\frac{RAS_{Agg\%}}{100 - P_{b,AV}}) - RAS_{Agg\%} = 100 \times (\frac{1.9}{100 - 21.3}) - 1.9 = 0.5\%$$

$$AB_{rcy\%,mix} = CF(AB_{RAP\%} + AB_{RAS\%}) = 0.94(0.0 + 0.5) = 0.5\%$$

Step 4. Calculate the ABR for the mixture given the mixture total asphalt content (P_b).

$$ABR = 100 \times (\frac{AB_{rcy\%,mix}}{P_b}) = 100 \times (\frac{0.5}{6.0}) = 8.3\%$$

Step 5. If ABR is maximized, the blend percentage of RAS can be adjusted (assuming $RAS_{mix\%}$ is less than 5.0%). In this case, the RAS content will be adjusted. In order to modify the RAS content, the additional available ABR is calculated.

$$ABR_{added} = ABR_{\max} - ABR_{current} = 10 - 8.3 = 1.7\%$$

Step 6. Calculate the additional percentage of recycled asphalt binder available in the mixture.

$$AB_{rcy\%,mix,added} = \frac{(ABR_{added})(P_b)}{100} = \frac{(1.7)(6.0)}{100} = 0.1\%$$

Step 7. Calculate the additional percentage of RAS asphalt binder available in aggregate percentage.

$$AB_{RAS\%,added} = \frac{AB_{rcy\%,mix,added}}{CF} = \frac{0.1}{0.94} = 0.1\%$$

Step 8. Calculate the additional percentage of RAS aggregate.

$$RAS_{Agg\%,added} = \frac{(AB_{RAS\%,added})(100 - P_{b,AV})}{P_{b,AV}} = \frac{0.1(100 - 21.3)}{21.3} = 0.4\%$$

Step 9. Calculate the additional percentage of RAS by weight of mixture.

Illinois Department of Transportation

Determination of
Aggregate Bulk (Dry) Specific Gravity (Gsb) of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)
Appendix B.21
(continued)

Effective: May 1, 2007
Revised: December 1, 2019

$$RAS_{mix\%,added} = \frac{100(CF)(RAS_{Agg\%,added})}{100 - P_{b,RAS}} = \frac{(100)(0.94)(0.4)}{100 - 25.0} = 0.5\%$$

In this case, the RAS blend percentage by weight of mixture increased from 2.4 to 2.9%. The RAS blend percentage by weight of aggregate increased from 2.0 (shown in Step 1) to 2.4% (additional 0.4% shown in Step 8).

Example of Adjusting RAP for Additional ABR

- N90 Surface Mixture
  - P_b (%AC) in RAS = 25.0%
  - P_b (%AC) in RAP = 5.5%
  - P_b (%AC) in Mixture = 6.0%
  - Maximum ABR = 30%
  - $RAS_{mix\%}$ Before Calculation of $P_{b,AV}$ = 5.0%
  - $RAP_{mix\%}$ Before Calculation of $P_{b,AV}$ = 10.3%

Step 1. Calculate the RAS and RAP aggregate percentages ($RAS_{Agg\%}$ and $RAP_{Agg\%}$).

$$CF = \frac{100 - P_b}{100} = \frac{100 - 6.0}{100} = 0.94$$

$$RAS_{Agg\%} = \frac{RAS_{mix\%}}{CF} \times \frac{100 - P_{b,RAS}}{100} = \frac{5.0}{0.94} \times \frac{100 - 25.0}{100} = 4.0\%$$

$$RAP_{Agg\%} = \frac{RAP_{mix\%}}{CF} \times \frac{100 - P_{b,RAP}}{100} = \frac{10.3}{0.94} \times \frac{100 - 5.5}{100} = 10.4\%$$

Step 2. Calculate the RAS Available Asphalt Binder Content ($P_{b,AV}$) given the Total RAS Asphalt Binder Content.

$$P_{b,AV} = 25.0\% \times 0.85 = 21.3\%$$

Step 3. Calculate the asphalt binder contributed ($AB_{rcy\%,mix}$) from the RAS ($AB_{RAS\%}$) and RAP ($AB_{RAP\%}$) given the aggregate percentages of RAS and RAP.

Illinois Department of Transportation

Determination of
Aggregate Bulk (Dry) Specific Gravity (Gsb) of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)
Appendix B.21
(continued)

Effective: May 1, 2007
Revised: December 1, 2019

$$AB_{RAS\%} = 100 \times (\frac{RAS_{Agg\%}}{100 - P_{b,AV}}) - RAS_{Agg\%} = 100 \times (\frac{4.0}{100 - 21.3}) - 4.0 = 1.1\%$$

$$AB_{RAP\%} = 100 \times (\frac{RAP_{Agg\%}}{100 - P_{b,RAP}}) - RAP_{Agg\%} = 100 \times (\frac{10.4}{100 - 5.5}) - 10.4 = 0.6\%$$

$$AB_{rcy\%,mix} = CF(AB_{RAP\%} + AB_{RAS\%}) = 0.94(0.6 + 1.1) = 1.6\%$$

Step 4. Calculate the ABR for the mixture given the mixture total asphalt content (P_b).

$$ABR = 100 \times (\frac{AB_{rcy\%,mix}}{P_b}) = 100 \times (\frac{1.6}{6.0}) = 26.7\%$$

Step 5. If ABR is maximized, the blend percentages of RAS and RAP can be adjusted (assuming $RAS_{mix\%}$ is less than 5.0%). In this case, the RAP content will be adjusted because the $RAS_{mix\%}$ is equal to 5.0%. In order to adjust the RAP content, the additional available ABR is calculated.

$$ABR_{added} = ABR_{\max} - ABR_{current} = 30 - 26.7 = 3.3\%$$

Step 6. Calculate the additional percentage of recycled asphalt binder available in the mixture.

$$AB_{rcy\%,mix,added} = \frac{(ABR_{added})(P_b)}{100} = \frac{(3.3)(6.0)}{100} = 0.2\%$$

Step 7. Calculate the additional percentage of RAP asphalt binder available in aggregate percentage.

$$AB_{RAP\%,added} = \frac{AB_{rcy\%,mix,added}}{CF} = \frac{0.2}{0.94} = 0.2\%$$

Step 8. Calculate the additional percentage of RAP aggregate.

Illinois Department of Transportation

Determination of
Aggregate Bulk (Dry) Specific Gravity (Gsb) of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)
Appendix B.21
(continued)

Effective: May 1, 2007
Revised: December 1, 2019

$$RAP_{Agg\%,added} = \frac{(AB_{RAP\%,added})(100 - P_{b,RAP})}{P_{b,RAP}} = \frac{0.2(100 - 5.5)}{5.5} = 3.4\%$$

Step 9. Calculate the additional percentage of RAP by weight of mixture.

$$RAP_{mix\%,added} = \frac{100(CF)(RAP_{Agg\%,added})}{100 - P_{b,RAP}} = \frac{(100)(0.94)(3.4)}{100 - 5.5} = 3.4\%$$

In this case, the RAP blend percentage by weight of mixture increased from 10.3 to 13.7%. The RAP blend percentage by weight of aggregate increased from 10.4 (shown in Step 1) to 13.8% (additional 3.4% shown in Step 8).

Example of Adjusting RAP and RAS for Additional ABR

- N90 Surface Mixture
  - P_b (%AC) in RAS = 25.0%
  - P_b (%AC) in RAP = 5.5%
  - P_b (%AC) in Mixture = 6.0%
  - Maximum ABR = 30%
  - $RAS_{mix\%}$ Before Calculation of $P_{b,AV}$ = 4.0%
  - $RAP_{mix\%}$ Before Calculation of $P_{b,AV}$ = 14.5%

Step 1. Calculate the RAS and/or RAP aggregate percentages ($RAS_{Agg\%}$ and $RAP_{Agg\%}$).

$$CF = \frac{100 - P_b}{100} = \frac{100 - 6.0}{100} = 0.94$$

$$RAS_{Agg\%} = \frac{RAS_{mix\%}}{CF} \times \frac{100 - P_{b,RAS}}{100} = \frac{4.0}{0.94} \times \frac{100 - 25.0}{100} = 3.2\%$$

$$RAP_{Agg\%} = \frac{RAP_{mix\%}}{CF} \times \frac{100 - P_{b,RAP}}{100} = \frac{14.5}{0.94} \times \frac{100 - 5.5}{100} = 14.6\%$$

Step 2. Calculate the RAS Available Asphalt Binder Content ($P_{b,AV}$) given the Total RAS Asphalt Binder Content.

$$P_{b,AV} = 25.0\% \times 0.85 = 21.3\%$$

Illinois Department of Transportation

Determination of
Aggregate Bulk (Dry) Specific Gravity (Gsb) of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)
Appendix B.21
(continued)

Effective: May 1, 2007
Revised: December 1, 2019

Step 3. Calculate the asphalt binder contributed ($AB_{rcy\%,mix}$) from the RAS ($AB_{RAS\%}$) and RAP ($AB_{RAP\%}$) given the aggregate percentages of RAS and RAP.

$$AB_{RAS\%} = 100 \times (\frac{RAS_{Agg\%}}{100 - P_{b,AV}}) - RAS_{Agg\%} = 100 \times (\frac{3.2}{100 - 21.3}) - 3.2 = 0.9\%$$

$$AB_{RAP\%} = 100 \times (\frac{RAP_{Agg\%}}{100 - P_{b,RAP}}) - RAP_{Agg\%} = 100 \times (\frac{14.6}{100 - 5.5}) - 14.6 = 0.8\%$$

$$AB_{rcy\%,mix} = CF(AB_{RAP\%} + AB_{RAS\%}) = 0.94(0.8 + 0.9) = 1.6\%$$

Step 4. Calculate the ABR for the mixture given the mixture total asphalt content (P_b).

$$ABR = 100 \times (\frac{AB_{rcy\%,mix}}{P_b}) = 100 \times (\frac{1.6}{6.0}) = 26.7\%$$

Step 5. If ABR is maximized, the blend percentage of RAS can be adjusted (assuming $RAS_{mix\%}$ is less than 5.0%). In this example, the RAP content will be adjusted by 1.0% by weight of mixture to 15.5%. Then, this increase leads to an ABR of 28.3%. In order to adjust the RAS content, the additional available ABR is calculated.

$$ABR_{added} = ABR_{max} - ABR_{current} = 30 - 28.3 = 1.7\%$$

Step 6. Calculate the additional percentage of recycled asphalt binder available in the mixture.

$$AB_{rcy\%,mix,added} = \frac{(ABR_{added})(P_b)}{100} = \frac{(1.7)(6.0)}{100} = 0.1\%$$

Step 7. Calculate the additional percentage of RAS asphalt binder available in aggregate percentage.

$$AB_{RAS\%,added} = \frac{AB_{rcy\%,mix,added}}{CF} = \frac{0.1}{0.94} = 0.1\%$$

Illinois Department of Transportation

Determination of
Aggregate Bulk (Dry) Specific Gravity (Gsb) of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)
Appendix B.21
(continued)

Effective: May 1, 2007
Revised: December 1, 2019

Step 8. Calculate the additional percentage of RAS aggregate.

$$RAS_{Agg\%,added} = \frac{(AB_{RAS\%,added})(100 - P_{b,AV})}{P_{b,AV}} = \frac{0.1(100 - 21.3)}{21.3} = 0.4\%$$

Step 9. Calculate the additional percentage of RAS by weight of mixture.

$$RAS_{mix\%,added} = \frac{100(CF)(RAS_{Agg\%,added})}{100 - P_{b,RAS}} = \frac{(100)(0.94)(0.4)}{100 - 25.0} = 0.5\%$$

In this case, the RAP blend percentage by weight of mixture increased from 14.5 to 15.5%. The RAP blend percentage by weight of aggregate increased from 14.6 (shown in Step 1) to 15.6% (additional 1.0% shown in Step 8). The RAS blend percentage by weight of mixture increased from 4.0 to 4.5%. The RAS blend percentage by weight of aggregate increased from 3.3 (shown in Step 1) to 3.7% (additional 0.4% shown in Step 8).

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High Friction Aggregates

Crushed:

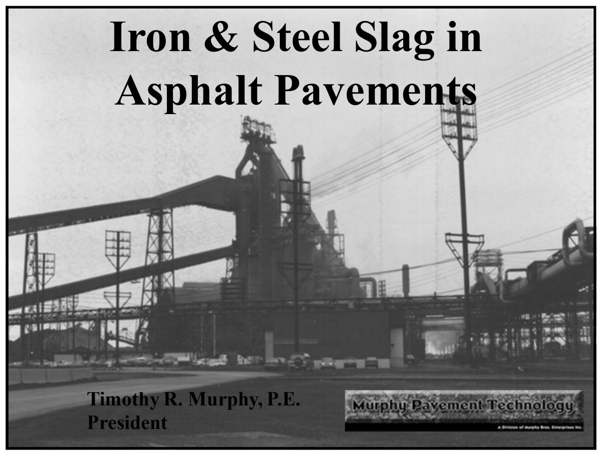
Steel Slag, Air-Cooled Slag, Trap Rock, Sandstone, Crushed Stone, and Crushed Gravel

Timothy R. Murphy, P.E.
President
Murphy Pavement Technology

SLAG MIX DESIGNS

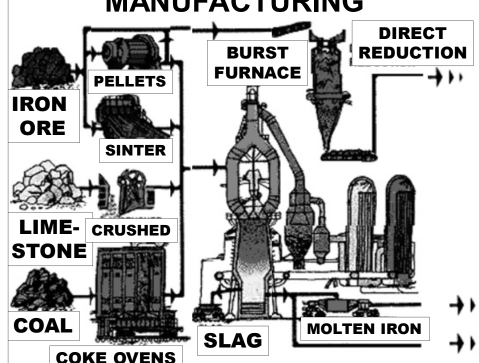
Blast Furnace Slag

In 1998, 20.5 million tons of slag was sold in the United States; of which, 13.8 million tons were blast furnace slag.



Iron Ore + Limestone + Coal into Blast Furnace = Iron + Slag

BLAST FURNACE SLAG MANUFACTURING



ASTM D-8
Standard Terminology Relating to Materials for Roads and Pavements

blast-furnace slag, n- the nonmetallic product, consisting essentially of silicates and alumino-silicates of lime and of other bases, that is developed simultaneously with iron in a blast furnace.

ASTM D-8
Standard Terminology Relating to Materials for Roads and Pavements

steel slag, n- the nonmetallic product, consisting essentially of calcium silicates and ferrite's combined with fused oxides of iron, aluminum, manganese, calcium and magnesium, that is developed simultaneously with steel in basic oxygen, electric, or open hearth furnaces.

Two primary methods to obtain slag for aggregate production include:

Blast Furnace Pots

Blast Furnace Pits

Slag is removed from furnace area …

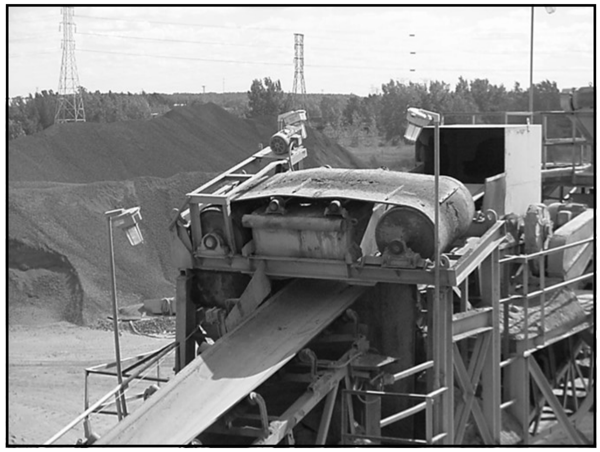
. . . and hauled to a surge pile (stockpile). . .

. . . and stored much like quarried natural aggregate.

Slag and natural aggregate plants are very similar.

Note magnet for iron recovery.

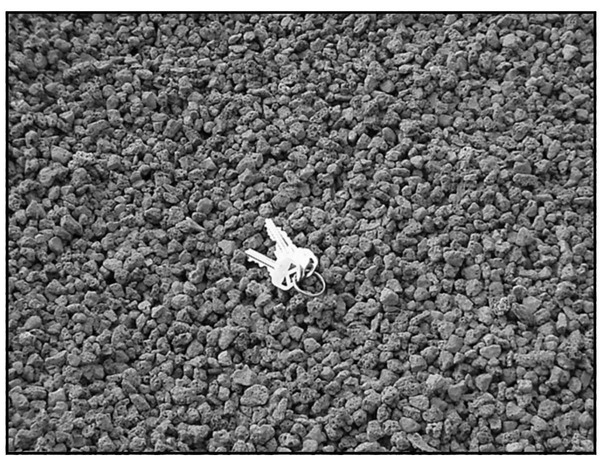
Overband magnet.



Screening and crushing tower.

End products meet DOT (and other) specifications.

½ inch chip shown here.



ACBF Slag can be used in binder, base and surface.

Chemistry is very consistent. Steel mills use the slag chemistry to control the manufacturing process.

Typical standard deviations exist for each chemical (e.g. CaO is 2.0).

Air Cooled Blast Furnace Slag

Typical Chemistry:

SiO_2	32 to 42
Al_2O_3	7 to 16
CaO	32 to 45
MgO	5 to 15
S	1 to 2
Fe_2O_3	0.1 to 1.5
MnO	0.2 to 1.0

ACBF chip weight is about 80 pcf.

Specific gravity is gradation sensitive, therefore, consistent gradation – consistent specific gravity.

LA Abrasion is not pertinent for ACBF. ACBF abrades down to #30 to #50, not to #200 (the measurement for deleterious).

Air Cooled Blast Furnace Slag

Physical Properties:

Specific Gravity	2.3 to 2.9
Absorption	2.0 to 5.0
Abrasion	N/A

Again, chemistry is fairly consistent.

Steel Furnace Slag

Typical Chemistry:

SiO_2	14.89
Al_2O_3	5.00
CaO	42.88
MgO	8.14
S	0.08
FeO	25.00
MnO	5.00
P_2O_5	0.80

B. Steel Slag

Steel slag is used primarily for surface courses.

It should not be used in confined spaces unless lack of expansion is assured.

Steel Furnace Slag

Physical Properties:

Specific Gravity	**3.2 to 3.8**
Absorption	**1.0 to 3.0**
Abrasion	**18 to 30**

Slag is a proven performer at race tracks such as Chicagoland Motor Speedway…

. . . and Indianapolis.

Friction is a critical factor in high volume pavements.

High volume traffic pavements in Illinois require an F mix surface. Slag is one of the products that satisfy the F mix requirements.

This design is a typical IDOT high volume surface design.

STEEL SLAG HOT MIX ASPHALT SURFACE DESIGN SHEET

MATERIAL:		#1	#2	#3	#4	Breakdown	FINAL
SIZE:		CM-13	CM-16	FA-20	FA-02	MF-01	BLEND
AGGREGATE		SF CHIP	LS CHIP	MF SAND	NAT SAND	Breakdown	
BLEND:		34.3	29.7	17.6	17.5	0.9	100.0
SIEVE	1"	100.0	100.0	100.0	100.0	100.0	100.0
SIZE:	3/4"	100.0	100.0	100.0	100.0	100.0	100.0
	1/2"	97.6	100.0	100.0	100.0	100.0	99.2
	3/8"	75.2	98.9	100.0	100.0	100.0	91.2
	#4	13.3	33.4	99.6	99.7	100.0	50.4
	#8	6.8	6.4	88.4	91.0	100.0	36.6
	#16	6.4	4.5	61.7	71.3	100.0	27.8
	#30	6.2	4.0	37.4	49.8	100.0	19.5
	#50	5.8	3.8	20.7	18.1	99.9	10.8
	#100	5.1	3.7	10.0	3.2	98.9	6.1
	#200	4.0	3.5	5.6	1.8	84.9	4.5

Slag helps meet VMA, angularity and stability requirements.

Items of note: steel slag SG and Absorption.

STEEL SLAG HOT MIX ASPHALT SURFACE DESIGN SHEET

MATERIAL:			#1	#2	#3	#4	Breakdown	
SIZE:			CM-13	CM-16	FA-20	FA-02	MF-01	
AGGREGATE			SF CHIP	LS CHIP	MF SAND	NAT SAND	Breakdown	
BLEND:			34.3	29.7	17.6	17.5	0.9	
BULK SpG:			3.102	2.680	2.722	2.580	2.823	
APPARENT SpG:			3.602	2.812	2.833	2.831	2.823	
ABSORPTION:			4.5	1.7	1.4	1.4	0	
			OPTIMUM DATA					
%AC	Flow	Stability	d	D	%Voids	VMA	VFA	TSR
5.1	10.7	2945	2.55	2.66	4.5	13.8	68	0.83

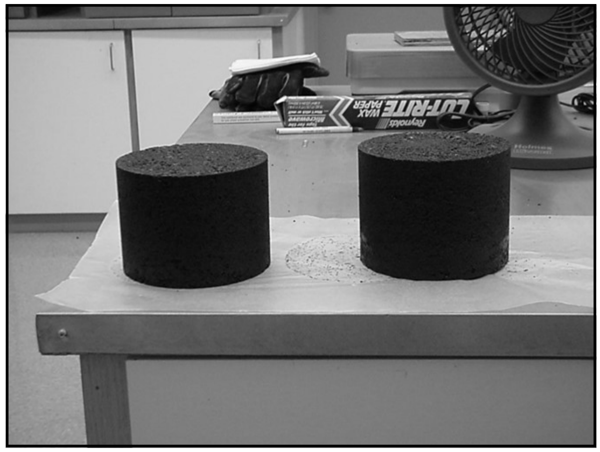
Slag Mixtures

HMA specimens.

Same sample weights
Same gyrations
Limestone on left
ABCF slag on right

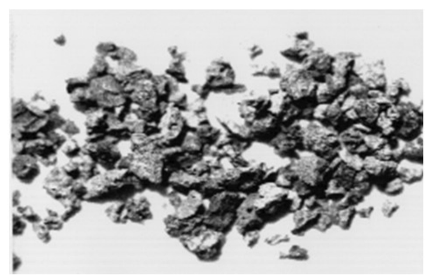
Approximate HMA sample sizes:

No slag	4850 g
50/50 Steel Slag	5150 g
50/50 ACBF Slag	4650 g



High slag Fine Aggregate Angularity allows the designer to use lower FAA materials to reach HMA Blend requirements.

ACBF Slag Sand: FAA = 48.9



This is a high volume HMA design using ACBF slag.

As noted earlier, gradation affects SG of slag. Not the SG of chips and sand.

MIXTURE SUMMARY REPORT

Project Name:	I-94 Surface	**N Initial:**	8
Workbook:		**N Design:**	109
Technician:		**N Max:**	174
Date:	Jun-99	**Nom. Sieve Size:**	9.5 mm
Asphalt Grade:	64-22	**Compaction Temp.:**	143-148
Design ESAL's:	13	**Mixture Temp.:**	155-161
Design Temp.:		**Depth (mm):**	<100

Property	Results	Aggregate	Sp G	Percentage
P_b	6.6	Dol. Chip	2.720	20%
% Air Voids	4			
% VMA	15.5	BF Chip	2.454	32%
%VFA	74.7			
Dust/Asphalt	1.0	BF Sand	2.741	47%
Max SpG	2.485			
Bulk SpG	2.423	BHD	2.750	1%
% G_{mm} @ N_{ini}	86.3			
% G_{mm} @ N_{ma}	97.5			

This is a HMA design using steel and BF slag chips.

MIXTURE SUMMARY REPORT

Project Name:	EAF/ACBF	**N Initial:**	8
Workbook:		**N Design:**	96
Technician:		**N Max:**	152
Date:	Sep-98	**Nom. Sieve Size:**	9.5 mm
Asphalt Grade:	64-22	**Compaction Temp.:**	143-148
Design ESAL's:	5	**Mixture Temp.:**	155-161
Design Temp.:	38 C	**Depth (mm):**	<100

Property	Results	Aggregate	Sp G	Percentage
P_b	6.5	SF Chip	3.610	17%
% Air Voids	4			
% VMA	16.4	BF Chip	2.478	32%
%VFA	75.9			
Dust/Asphalt	1.0	LS Sand	2.732	19%
Max SpG	2.632			
Bulk SpG	2.531	LS Fines	2.742	32%
% G_{mm} @ N_{ini}	84.6			
% G_{mm} @ N_{ma}	96.2			

There are two primary issues with using slag:

1. Effect of specific gravity on mix design weights.
2. Effect of absorption on mix design and production properties.

IDOT Mix Design Considerations for Slag

- **For Mix F, 50 to 75% of Coarse Aggregate by <u>volume</u> will be slag, with dolomite or crushed gravel.**
- **SG differences will affect weights**
- **Maximum allowable on #8 - add 2 percent in slag designs**
- **Maximum absorption - 5.0 percent**

Determining slag mix weights.

Determining slag mix weights

1. **Determine %CA**
2. **Determine volume ratio % of slag to other CA**
3. **Determine average G_{SB} for CA blend**
4. **Convert volume ratio % to weight % by dividing product G_{SB} by average G_{SB}**
5. **Using weight %, continue mix design.**

Slag mix weights example

1. % CA = 65
2. % Steel Slag = 60, % Dolomite = 40
3. Steel G_{SB} = 3.252, Dolomite G_{SB} = 2.618
4. Blend G_{SB} = 3.252 x 0.6 + 2.618 x 0.4
   = 1.951 + 1.047 = 2.998
5. %Wt Steel = 3.252/2.998 x 65 x 0.6 = 42.3
   %Wt Dol = 2.618/2.998 x 65 x 0.4 = 22.7

These are typical coarse aggregate properties.

The slag absorption cannot be over 5.0.

Steel slag must be dried to 0.3% moisture content during production.

Coarse Aggregate Properties

Aggregate	G_{SB}	Water Abs
Steel Slag	3.10 - 3.53	1.9 - 3.5%
Dolomite	2.62 - 2.64	2.1 - 2.3%
ACBF Slag	2.33 - 2.38	2.4 - 4.6%

Yield is in lbs/sy/inch in place.

Typical Mixture Properties

Mix CA	G_{mm}	P_b	Yield
100% Steel	2.800	5.3-5.6	130
50/50 Steel/ Dolomite	2.650	5.4-5.7	120
100% Dol	2.500	5.5-5.8	112
50/50 ACBF/ Dolomite	2.440	6.1-6.3	110
100% ACBF	2.380	6.4-6.7	105

Results are from Kandhal and Khatri, AAPT, 1991.

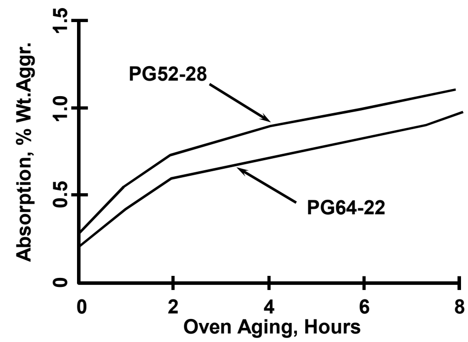
Study on performed on mineral aggregates.

As shown, the effect of absorption is more dramatic on softer asphalts.

Effect of absorption is increased with more absorptive materials like slag.

This affect translates directly to silo storage time.

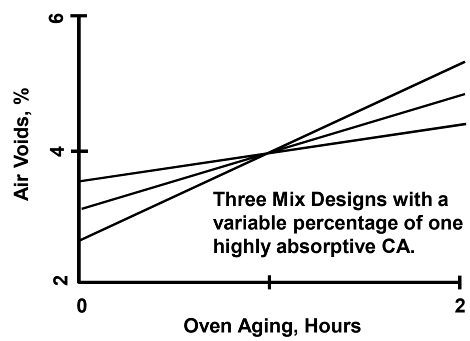
Effect of Absorption



Results are from three laboratory mix designs conducted with one common absorptive (3.6%) coarse aggregate product.

Oven aging the mixture for 2 hours resulted in 0.5 to 2.0% increase in air voids.

Effect of Absorption II



Mix F (60/40) vs. Mix D

	% by wt of Mix		
Mix Items	ACBF	Steel	Mix D
% Slag	30-40	35-45	0
% Dolomite/ Cr Gravel	21-31	16-26	58-68
% Sand	29-33	29-33	29-33
%MF Added	1-3	1-3	1-3
%AB	6.3-7.1	5.5-5.9	5.2-5.8

DATE: 11/01/99

SEQ NO:

Bituminous Mixture Design

Design Number:-------> 81BIT0002

Lab preparing the design?(PP,PL,IL ect.) IL

Producer Name & Number-->

Material Code Number---> 17565M BIT CONC SURF CSE 2 E

REQUIRED! RAP in #6

Agg No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size (eg 032CMM16)	033CMM13	032CMM16	038FMM20	037FAM02	004MF01		10129M
Source (PROD#)	52103-11	50312-78	50312-78	50890-08	547-01		1757-05
(NAME)	Levy	Vulcan	Vulcan	Chicago S&G	Dukane		Seneca
(LOC)	BH	McCook	McCook	Elgin	Addison		Lemont
					RAP Mix %=:		
Aggregate Blend	30.7	34.3	14.0	19.0	2.0		100.0

Agg No. / Sieve Size	#1	#2	#3	#4	#5	#6	Blend	Sieve Size	Mixture Composition Specification	FORMULA	FORMULA RANGE Min	Max
25.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	25.4		100	100	100
19.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	19.0	100	100	100	100
12.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	12.5	90-100	100	100	100
9.5	79.0	98.0	100.0	100.0	100.0	100.0	92.9	9.5	66-100	93	93	93
4.75	14.0	27.0	100.0	99.0	100.0	100.0	48.4	4.75	24-65	48	43	53
2.36	8.0	8.0	88.0	82.0	100.0	100.0	35.1	2.36	16-48	35	30	40
1.18	5.0	6.0	54.0	62.0	100.0	100.0	24.9	1.18	10-32	25	25	25
600µm	4.0	5.0	31.0	42.0	100.0	100.0	17.3	600µm		17	13	21
300µm	3.0	5.0	12.0	17.0	100.0	100.0	9.5	300µm	4-15	10	10	10
150µm	3.0	4.0	7.0	5.0	95.0	100.0	6.1	150µm	3-10	6	6	6
75µm	2.2	4.1	4.3	2.0	90.0	100.0	4.9	75µm	2-6	4.9	3.4	6.4

	#1	#2	#3	#4	#5	#6	Blended SpGr	Dust AC Ratio
Bulk Sp Gr	2.382	2.663	2.648	2.629	2.82	1	2.565	
Apparent Sp Gr	2.591	2.782	2.788	2.752	2.82	1		
Absorption, %	3.4	1.6	1.9	1.7	1	0.01		
						SP GR AC	1.038	0.75

SUMMARY OF MARSHALL TEST DATA

	A C %MIX	FLOW	STABILITY Kilo Newtons	MARSHALL SPEC GR (Gmb)	MAXIMUM SPEC GR (Gmm)	VOIDS TOT MIX (Pa)	VMA	VOIDS FILLED	EFFECTIVE AC, VOL	EFFECTIVE AC, %WT	ABSORPTION Gse	ABSORPTION AC, %WT
MIX 1	5.5	12.7	13.1	2.274	2.462	7.65	16.2	52.8	8.56	3.91	2.676	1.68
MIX 2	6.0	14.5	14.3	2.309	2.449	5.70	15.4	62.9	9.67	4.35	2.681	1.76
MIX 3	6.5	13.5	12.8	2.329	2.426	4.01	15.1	73.4	11.08	4.94	2.675	1.67
MIX 4	7.0	15.3	13.7	2.341	2.412	2.94	15.1	80.6	12.17	5.40	2.679	1.72

	% AC	Stability Kilo Newtons	Flow	Gmb	Gmm	% VOIDS (Pa) Target	VMA	VFA	Gse	Gsb	TSR
Asphalt determined at target voids:	6.51										
OPTIMUM DESIGN DATA:---->	6.5	12.8	13.5	2.329	2.426	4.0	15.1	73.4	2.675	2.565	0.82
REMARKS:											

Tested By:

Final Review By:

Final Approval By:

Using these gradations and a total coarse aggregate percentage of 65 percent, blended to 60/40 (slag/dolomite) by volume, design a IL-9.5 F mixture at Ndes = 90.

Date ____________

Contract **Slag Class Problem**

Mixture ____________

Aggregate Blending

Material	039CMM13			032CMM16			038FMM20						004MF01			Combined	Target	Spec.
Source	Slag			Dolomite			Manufactured Sand						Mineral Filler			Gradation	Value	Limits
Percent	____%			____%			____%			____%			____%			%	%	%
Sieves	Frac Wt. Ret	% Pass	% for Mix	Frac Wt. Ret	% Pass	% for Mix	Frac Wt. Ret	% Pass	% for Mix	Frac Wt. Ret	% Pass	% for Mix	Frac Wt. Ret	% Pass	% for Mix			
37.5																		
25.0																		
19.0																		
12.5		100			100			100						100				
9.5		83			99			100						100				
4.75		25			33			100						100				
2.36		6			6			86						100				
1.18		5			4			59						100				
0.600		4			4			32						100				
0.300		4			4			15						100				
0.150		4			4			6						95				
0.075		3.0			3.3			2.3						90.0				
G_{sb}		3.254			2.653			2.701										

Using these gradations and a total coarse aggregate percentage of 55 percent, blended for a "D" mix (Steel Slag & Limestone) by volume.
This mix will be a IL-9.5 "D" mix @ Ndes = 90

Material Source	CMM13		CMM16		FMM20		FA01		MF		Combined Gradation	Target Value	Spec. Limits
Percent	16.3		38.7		28.5		15		1.5				
Sieves	% Pass	% For Mix	% Pass	% For Mix	% Pass	% For Mix	% Pass	% For Mix	% Pass	% For Mix			
37.5													
25	100	16.3	100	38.7	100	28.5	100	15	100	1.5	100		100
19	100	16.3	100	38.7	100	28.5	100	15.0	100	1.5	100		100
12.5	100	16.3	100	38.7	100	28.5	100	15.0	100	1.5	100		100
9.5	83	13.5	99	38.3	100	28.5	100	15.0	100	1.5	97		90-100
4.75	25	4.1	35	13.5	97	27.6	97	14.6	100	1.5	61		28-65
2.36	6	1.0	7	2.7	70	20.0	82	12.3	100	1.5	37		28-40
1.18	5	0.8	6	2.3	50	14.3	65	9.8	100	1.5	29		10-32
600µ	4	0.7	5	1.9	30	8.6	50	7.5	100	1.5	20		
300µ	4	0.7	5	1.9	19	5.4	16	2.4	100	1.5	12		4-15
150µ	4	0.7	5	1.9	10	2.9	5	0.8	97	1.5	8		3-10
75µ	3.0	0.5	4.5	1.7	4.0	1.1	0.4	0.1	80	1.2	4.6		4-6
Gsb	3.345		2.648										

1. Determine the percent of coarse aggregate.
   55% in this example.

2. Determine the blend between the coarse aggregate. See Friction Aggregate (BDE) "Friction Requirements of Coarse Aggregates"
   "D" mix requires 25% Crushed Slag with 75% limestone.

3. Calculate the combined gravity of the coarse aggregates by multiplying the percent blend (as allowed in the friction aggregate spec in Chapter 2) by the gravities of the aggregates.

   (.25 x 3.345) + (.75 x 2.648) = 2.822

4. To calculate the % Blend of each aggregate divide the bulk gravity by the combined gravity of the coarse aggregate (step 3) then multiply by the percent of the coarse aggregate (Step 1), then the percent of the individual aggregate (Step 2).

   Slag CMM13 (3.345/2.822) X .55 X .25 = 16.3%

   Limestone CMM16 (2.648/2.822) x .55 x .75 = 38.7%

Using these gradations and a total coarse aggregate percentage of 50 percent, blend for a "D" mix (ACBF Slag & Limestone) by volume.

This mix will be a IL-9.5 "D" mix @ Ndes = 70

Material Source	CMM13		CMM16		FMM20		FA01		MF		Combined Gradation	Target Value	Spec. Limits
Percent	0		0		30.5		18		1.5				
Sieves	% Pass	% For Mix	% Pass	% For Mix	% Pass	% For Mix	% Pass	% For Mix	% Pass	% For Mix			
37.5													
25	100		100		100	30.5	100	18.0	100	1.5			
19	100		100		100	28.5	100	18.0	100	1.5			
12.5	100		100		100	28.5	100	18.0	100	1.5			
9.5	82		99		100	28.5	100	18.0	100	1.5			
4.75	20		35		97	27.6	97	17.5	100	1.5			
2.36	5		7		70	20.0	82	14.8	100	1.5			
1.18	4		6		50	14.3	65	11.7	100	1.5			
600µ	4		5		30	8.6	50	9.0	100	1.5			
300µ	3		5		19	5.4	16	2.9	100	1.5			
150µ	3		5		10	2.9	5	0.9	97	1.5			
75µ	2.5		4.5		3.6	1.0	0.4	0.1	80.0	1.2			
Gsb	2.404		2.648										

Data Interpretation

Allowable adjustments
Errors & Corrections
Quick checks of test precision

Timothy R. Murphy, P.E.
President

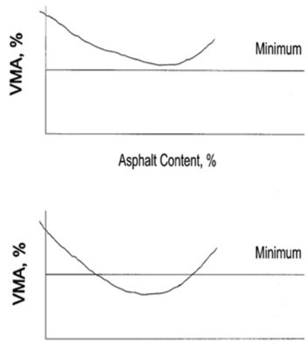
Variables

A. **Aggregate Bulk (Dry) Specific Gravity (G_{sb})**
B. **Mixture Bulk Specific Gravity (G_{mb})**
C. **Maximum Theoretical Specific Gravity (G_{mm})**
D. **Voids (P_a or V_a)**
E. **Voids in the Mineral Aggregate (VMA)**
F. **Voids Filled with Asphalt (VFA)**
G. **Effective Volume of Asphalt Binder**
H. **Effective Weight of Asphalt Binder (P_{be})**
I. **Effective Specific Gravity of Aggregate (G_{se})**
J. **Asphalt Binder Absorption, % by Weight (P_{ba})**

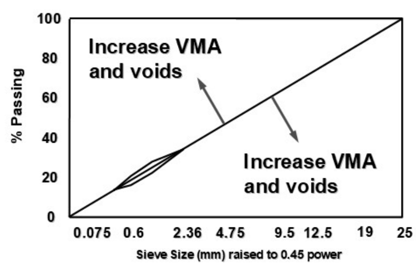
Analyze and Explain results of Class Mix Design

- Particle shape
- Surface texture
- Aggregate gradation
- CA vs. FA
- Dust
- Potential items to watch for during production.

Design 001 vs. 002



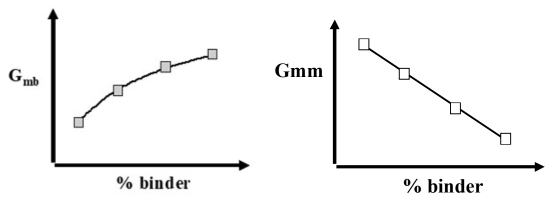
VMA Adjustments



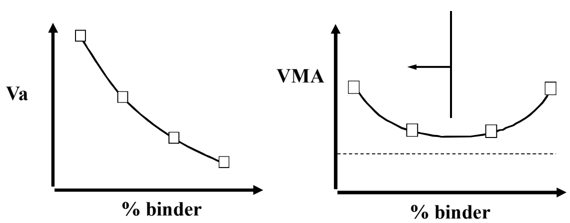
VMA Adjustments

1. Increase or decrease FA20/FA01 blend.
   - Changes 600 µm
   - Changes on minus 75 µm
2. Increase or decrease chips in binder
   - Changes 4.75 mm to 2.36 mm material
3. Increase or decrease minus 75 µm (mineral filler)
4. Change sources

Checking the Validity of Test Results



Checking the Validity of Test Results



SUMMARY OF TEST DATA

G_b = 1.030

P_b	G_{mb}	G_{mm}	Voids	VMA	VFA	Effective Binder Volume	Effective Binder Mass	G_{se}
3.5	2.326	2.473	5.9	12.9	54	6.99	3.10	2.605
4.0	2.335	2.469	5.4	13.1	58	7.63	3.36	2.622
4.5	2.341	2.435	3.9	13.3	71	9.43	4.15	2.602
5.0	2.345	2.416	2.9	13.6	78	10.65	4.68	2.600

Ref. Chapter 11 - Page 15 of 48

I. VARIABLES

A. Bulk Specific Gravity (G_{mb})

B. Maximum Theoretical Specific Gravity (G_{mm})

C. Voids (P_a)

D. Voids in the Mineral Aggregate (VMA)

E. Voids Filled with Asphalt (VFA)

F. Effective Volume of Asphalt Binder

G. Effective Weight of Asphalt Binder (P_{be})

H. Effective Specific Gravity of Combined Aggregate (G_{se})

I. Asphalt Binder (Asphalt Binder) Absorption, Percent by Weight (P_{ba})

II. ANALYZE AND EXPLAIN RESULTS OF CLASS MIX DESIGN

III. CHECK VALIDITY OF TEST RESULTS

- G_{se}
- Asphalt Binder Absorption
- Voids/Asphalt Binder Selection
- Corrective Action Example
- Sensitivity to Asphalt Binder (± 0.3%)

IV. MIXTURE ADJUSTMENTS

- Evaluation of Eight Mixtures

DATE:

SEQ NO:

Bituminous Mixture Design

Design Number: →	00BIT1374
Lab Preparing the design?(PP,PL,IL,etc.)	PP
Producer Name & Number->	
Material Code Number->	HMA Surface Course, Mix C, N70

Agg. No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	032CMM16			037FAM01	004MFM01		
Source (PROD#)							
(NAME)							
(LOC)							
Aggregate Blend	62.8	0.0	0.0	33.8	3.4	0.0	100.0

Agg. No. / Sieve Size	#1	#2	#3	#4	#5	#6	Blend
25.4 (1)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19.0 (3/4)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
12.5 (1/2)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
9.5 (3/8)	95.0	100.0	100.0	100.0	100.0	100.0	96.9
4.75 (#4)	30.0	100.0	100.0	99.0	100.0	100.0	55.7
2.36 (#8)	7.0	100.0	100.0	89.0	100.0	100.0	37.9
1.18 (#16)	4.0	100.0	100.0	73.0	100.0	100.0	30.6
600µm (#30)	4.0	100.0	100.0	51.0	100.0	100.0	23.2
300µm (#50)	3.0	100.0	100.0	24.0	100.0	100.0	13.4
150µm (#100)	3.0	100.0	100.0	7.0	97.0	100.0	7.5
75µm (#200)	3.0	100.0	100.0	1.9	82.4	100.0	5.3

Specifications Min	Specifications Max	FORMULA	FORMULA RANGE Min	FORMULA RANGE Max
--	--	100	100	100
	100	100	100	100
90	100	100	94	106
	90	97	--	--
24	65	56	51	61
16	40	38	33	43
10	32	31	31	31
--	--	23	--	--
4	15	13	9	17
3	10	8	8	8
4	6	5.3	3.8	6.8

	#1	#2	#3	#4	#5	#6	ASPHALT
Bulk Sp Gr	2.645		1	1	2.554	2.67	1
Apparent Sp Gr	2.783		1	1	2.682	2.67	1
Absorption, %	1.4		1	1	0.5	0	0

SP GR Asphalt Binder 1.032

SUMMARY OF TEST DATA

	Asphalt Binder % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (P_a)	VMA	VOIDS FILLED	EFFECTIVE Asphalt Binder, VOL	EFFECTIVE Asphalt Binder, % WT	ABSORPTION G_{se}	ABSORPTION Asphalt Binder, % WT
MIX 1	4.0	2.366	2.521	6.2	13.1	53.1	6.97	3.04	2.682	1.00
MIX 2	4.5	2.412	2.503	3.6	11.9	69.4	8.26	3.53	2.683	1.01
MIX 3	5.0	2.429	2.484	2.2	11.7	81.1	9.52	4.05	2.683	1.01
MIX 4	5.5	2.431	2.467	1.5	12.1	88.0	10.67	4.53	2.684	1.03

	P_b	d (G_{mb})	D (G_{mm})	% VOIDS (P_a) Target	VMA	VFA	G_{se}	G_{sb}
OPTIMUM DESIGN DATA:---	4.4	2.403	2.507	4.0	12.1	66.2	2.683	2.614

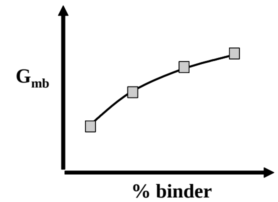
REMARKS:

This Page Is Reserved

I. VOLUMETRIC RELATIONSHIPS

A. Bulk Specific Gravity (G_{mb})

Mixture Bulk Specific Gravity



1. Calculate to three decimal places (thousandths).

2. As Asphalt Binder content increases, this value should also increase. This increase will not be in equivalent increments because aggregate properties will have a lesser or greater influence. Generally, the largest increment is at the dry or low Asphalt Binder content points. As the Asphalt Binder increases, the incremental difference decreases due to the aggregate in Asphalt Binder.

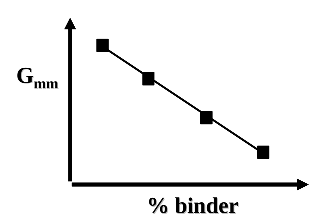
3. Should look at two lab specimens and their test values to determine if there is a flyer in that set of data. If so, need to discard bad sample and possibly redo test point.

B. Maximum Theoretical Specific Gravity (G_{mm})

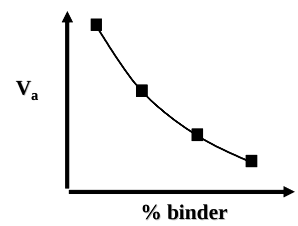
1. Calculate to three decimal places (thousandths).

2. The relationship between G_{mm} and Asphalt Binder is a straight line. As the Asphalt Binder increases, the film thickness on the aggregate increases which in turn makes the volume larger and G_{mm} becomes smaller. Generally, this should change in equivalent increments in a range of 0.018 to 0.021.

Maximum Theoretical Specific Gravity at Other Asphalt Contents



C. Voids (P_a)



1. Calculated value based on G_{mb} and G_{mm}.

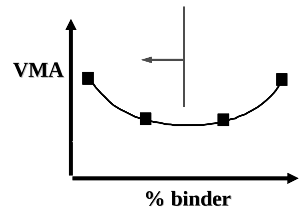
2. Calculated and reported to one decimal place (tenth).

3. Air voids decrease with increasing asphalt binder content.

4. Design criteria is 4.0% at the specified N_{design} value. Factors which may influence the engineer in selecting an N_{design} value other than what would be expected are traffic, climate, or aggregate properties.

D. Voids in the Mineral Aggregate (VMA)

Voids in the Mineral Aggregate



1. Calculated value involving G_{mb}, P_s, and G_{sb}.

2. Calculated and reported to one decimal place (tenth).

3. 12.0 or 13.0 for binder, 14.0 for surface (15 for IL-9.5 surface mixtures). Generally this is the most difficult mix criteria to achieve.

4. The only function VMA controls is durability as it relates to the amount of asphalt binder in a mixture. VMA does not directly control durability problems associated with moisture damage or premature rutting. Its goal is to furnish enough space for the Asphalt Binder so it can provide adequate adhesion to bind together the aggregate particles without bleeding when temperatures rise and asphalt expands.

   It is **highly recommended** that Asphalt Binder values which fall on the "wet" or right-hand increasing side of the curve be avoided. Mixes tend to bleed and exhibit plastic flow when placed in the field. One might expect VMA to remain the same with varying Asphalt Binder contents because it is an aggregate characteristic, but actually, with increased Asphalt Binder, the mix become more compactable - more weight and less volume up to a point. Past that point, near the beginning of the wet side, the Asphalt Binder pushes the more dense aggregate apart, which is replaced by the less dense Asphalt Binder, showing an apparent increase in VMA. If the curve remains flat on the bottom of the U-shaped curve, the mix is not as sensitive to Asphalt Binder changes because Asphalt Binder contents in this area, or the left-hand side of the curve, produce more stable mixes

5. The key items in determining adequate VMA is nominal maximum aggregate size and air voids. As the nominal maximum size of the aggregate decreases, the VMA should increase. Also, as the voids increase or decrease, so should the VMA.

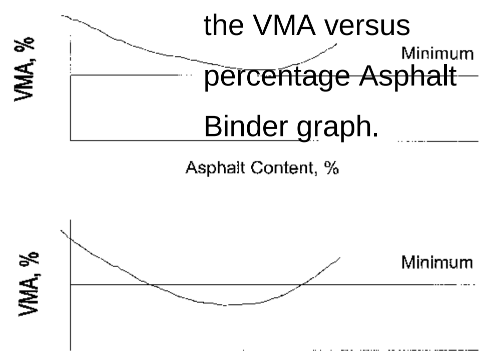
Based on this philosophy, the volume of the effective Asphalt Binder should remain constant and meet a minimum value. This ensures there is enough asphalt coating the outside surfaces of the aggregate particles. In simple terms, this is the function of VMA - to create enough film thickness on the aggregate particles. Calculation of film thickness was considered instead of VMA criteria, but two problems exist:

(a) There is no accurate way to calculate surface area of aggregates.

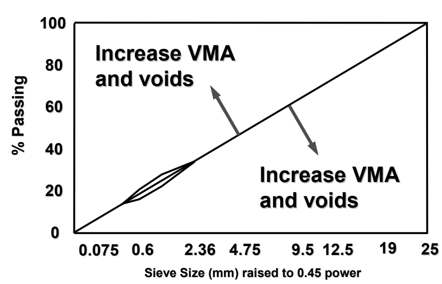
(b) Asphalt Binder film thickness assumes each aggregate particle is spread apart and coated. Normally the volume of Asphalt Binder is shared by adjacent aggregate particles.

6. Too high a VMA does not usually occur because the cost for Asphalt Binder and premium aggregate results in making an expensive mix. Low VMA tends to create problems such as raveling or premature cracking caused by dry, brittle mixtures.

7. As previously mentioned, optimum Asphalt Binder selection should be done on the basis of air voids @ N_{design}, and then verify that all other HMA mixture criteria is achieved at this Asphalt Binder content. An important concept to check is where this Asphalt Binder content plots on the VMA versus percentage Asphalt Binder graph.



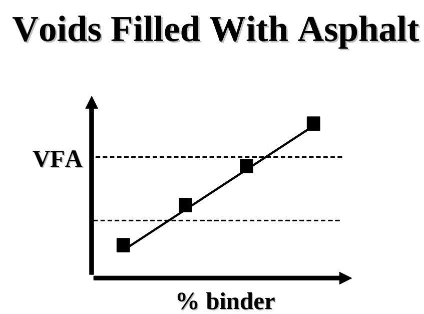
Voids in the Mineral Aggregate



VMA Adjustments

1. **Increase or decrease FA20/FA01 blend.**
   - **Changes 600 µm**
   - **Changes on minus 75 µm**
2. **Increase or decrease chips in binder**
   - **Changes 4.75 mm to 2.36 mm material**
3. **Increase or decrease minus 75 µm (mineral filler)**
4. **Change sources**

E. Voids Filled with Asphalt (VFA)



1. Calculated involving VMA and air voids.

2. Calculated and reported to one decimal place (tenth).

3. Should increase with increases in Asphalt Binder content.

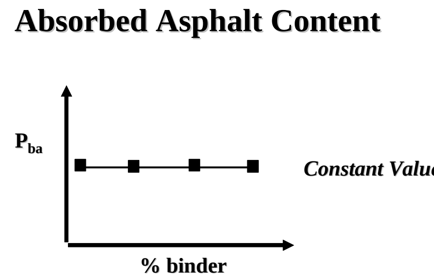
4. Requires the following ranges:
   - 70 – 80 @ N_{design} of 30
   - 65 – 78 @ N_{design} of 50
   - 65 – 75 @ N_{design} of 70, 90, or 105

5. Defined as the percentage of VMA filled with Asphalt binder and relates to the durability of a mixture.

6. The two situations VFA controls are:
   (a) Limiting the maximum levels of VMA and
   (b) Helping prevent the design of mixes with marginally acceptable VMA.

   Mixtures with high VMA and VFA (above 78 to 80) may exhibit the characteristics of a plastic mix (rutting), while low VFA results in mixtures with high air voids and low Asphalt Binder content, creating mixtures with poor durability.

F. Effective Volume of Asphalt Binder



1. Calculated value based on P_{be}, G_{mb}, and G_b.

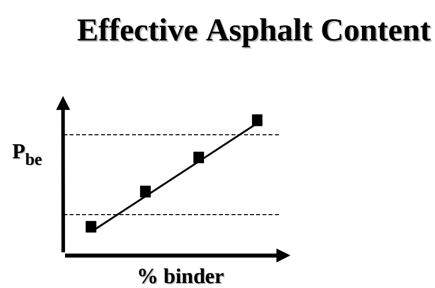
2. Calculated and reported to one decimal place (tenth).

3. No design criteria which must be achieved.

4. This is the usable volume of Asphalt Binder which coats the aggregate particles so a durable mix can be achieved. This is the total volume of Asphalt Binder minus the volume of absorbed Asphalt Binder.

5. Though this is not a design criteria, this value as determined by simple calculations should be a minimum of 9 for B binders, 10 for a surface mix using CA13, and 11 for a surface mix using CA16.

G. Effective Weight of Asphalt Binder (P_{be})



1. Calculated based on P_{ba}, P_b, and P_s.

2. Calculated and reported to one decimal place (tenth).

3. This value should increase as the Asphalt Binder content increases.

4. Serves no real purpose except to show how much of the original Asphalt Binder, by weight, which was added to the mix is actually used to coat the aggregate. This value added to the absorbed Asphalt Binder (weight) should be slightly higher than the original Asphalt Binder percent weight.

H. Effective Specific Gravity of Combined Aggregate (G_{se})

1. Calculated based on P_b, G_b, and G_{mm}.
2. Calculated and reported to three decimal places (thousandths).
3. There isn't a design criteria for this value; the value should not change with change in Asphalt Binder (discussed in previous chapter).
4. Major function of this variable is for calculation purposes and checking validity of test results.
5. Average the G_{se} values. The differences between the high and low values should be $\leq$ 0.010

I. Asphalt Binder Absorption, Percent by Weight (P_{ba})

1. Calculated based on G_{se}, G_{sb}, and G_b.
2. Calculated and reported to one decimal place (tenth).
3. Design criteria and the value should not change with changes in Asphalt Binder. This is an aggregate-dependent variable. This characteristic should be accounted for in the materials selection stage of mix design. It can have a major influence on Asphalt Binder demand and price of the mixture. This test variable is based on Asphalt Binder absorbed - not water absorption as is the case with determining the bulk specific gravity of individual aggregates.
4. One important judgment that can be made form this test variable is the amount of Asphalt Binder which can be recovered from an extraction sample. The general "rule of thumb" is 90% recoverable by extraction. If there is 1.0% mix absorption for a 4.0% air void mix, the recoverable Asphalt Binder should be about 3.9%.

II. ANALYZE AND EXPLAIN RESULTS OF CLASS MIX DESIGN

[This shall be accomplished in the classroom once the designs are completed.]
The modification in Design #1 to Design #2 is that Design #2 is much coarser on the #30 sieve. This, hopefully, should lead to higher VMA.

III. CHECK VALIDITY OF TEST RESULTS

Values for G_{se} and Asphalt Binder absorption (P_{ba}) should be the same at each of the various Asphalt Binder contents if the same blends of aggregates are used for each batch. This is one of the reasons for the care and accuracy of proportioning all the single sizes material into each batch. The Asphalt Binder absorption should be the same because the consistent blend of aggregate absorbs the same quantity of Asphalt Binder, assuming the Asphalt Binder viscosity is the same, as measured by the same Asphalt Binder mixing temperature being used.

If there is a difference in the G_{se}, it is due to human error or calculations relating to G_{mm} or P_b. The maximum difference in the range of G_{se} should be no more than 0.010 from the high to the low value. If this value of 0.010 is exceeded, one or both of the values determining G_{mm} is in error. Judgment should be used to determine the one or both values in error and discard those values. If the discarded value occurs at an area which has an influence on the selection of optimum Asphalt Binder content ± 0.6% for the desired 4.0% voids, the average of the remaining G_{se} should be used to back-calculate the G_{mm} and air voids prior to selecting the Asphalt Binder content. The designer may also wish to redo a couple of the Asphalt Binder points in question starting at the highest Asphalt Binder percent to butter the mixing bowl. All paperwork and additional testing shall be submitted with the mix design to the District office.

As an aid to this process of determining questionable test values, the Asphalt Binder percent absorbed should not differ from any of the other values by more that 0.25%. Values exceeding this amount should alert the designer to questions corresponding HMA data at that Asphalt Binder content.

Example:

SUMMARY OF TEST DATA **G_b = 1.03**

	Asphalt Binder % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (P_a)	VMA	VOIDS FILLED	EFFECTIVE Asphalt Binder, VOL	EFFECTIVE Asphalt Binder, % WT	G_{se}
MIX 1	3.5	2.326	2.473	5.9	12.9	54	6.99	3.10	2.605
MIX 2	4.0	2.335	2.469	5.4	13.1	58	7.63	3.36	2.622
MIX 3	4.5	2.341	2.435	3.9	13.3	71	9.43	4.15	2.602
MIX 4	5.0	2.345	2.416	2.9	13.6	78	10.65	4.68	2.600

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IV. MIXTURE ADJUSTMENTS

A. Coarser or finer mix - measured on 4.75-mm (No. 4) or 2.36-mm (No. 8) sieve

B. Increase or decrease FA20/FA01 blend.

1. Changes 600-µm (No. 30)
2. Changes on minus 75-µm (minus No. 200)

C. Increase or decrease chips in binder.

- Changes 4.75-mm (No. 4) to 2.36-mm (No. 8) material

D. Increase or decrease minus 75-µm (minus No. 200) material (mineral filler).

E. Reduce segregation potential.

1. Binder 12.5 mm (1/2 inch)
2. Surface < 25% 4.75-mm (No. 4) to 2.36-mm (No. 8) material

F. Change sources (aggregate characteristic).

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DATE:

SEQ NO:

Bituminous Mixture Design

Design Number: →	1211PAGEA
Lab Preparing the design?(PP,PL,IL,etc.)	PP
Producer Name & Number->	
Material Code Number->	HMA Surface Course, Mix C, N70

Agg. No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	032CMM16			037FAM02	004MFM01		
Source (PROD#)							
(NAME)							
(LOC)							
Aggregate Blend	64.7	0.0	0.0	32.4	2.9	0.0	100.0

Agg. No. Sieve Size	#1	#2	#3	#4	#5	#6	Blend
25.4 (1)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19.0 (3/4)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
12.5 (1/2)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
9.5 (3/8)	99.2	100.0	100.0	100.0	100.0	100.0	99.5
4.75 (#4)	33.9	100.0	100.0	100.0	100.0	100.0	57.2
2.36 (#8)	13.0	100.0	100.0	89.9	100.0	100.0	40.4
1.18 (#16)	4.5	100.0	100.0	55.5	100.0	100.0	23.8
600μm (#30)	4.1	100.0	100.0	23.7	100.0	100.0	13.2
300μm (#50)	3.7	100.0	100.0	8.3	100.0	100.0	8.0
150μm (#100)	3.3	100.0	100.0	3.4	99.0	100.0	6.1
75μm (#200)	2.8	100.0	100.0	1.8	88.0	100.0	4.9

Specifications		FORMULA	FORMULA RANGE	
Min	Max		Min	Max
--	--	100	100	100
	100	100	100	100
90	100	100	94	106
	90	99	--	--
24	65	57	52	62
16	40	40	35	45
10	32	24	4	24
--	--	13	--	--
4	15	8	4	12
3	10	6	6	6
4	6	4.9	3.4	6.4

	#1	#2	#3	#4	#5	#6
Bulk Sp Gr	2.645	1	1	2.554	2.670	1
Apparent Sp Gr	2.783	1	1	2.682	2.670	1
Absorption, %	1.4	1	1	0.5	0	0

SP GR Asphalt Binder
1.032

SUMMARY OF TEST DATA

	Asphalt Binder % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (P_a)	VMA	VOIDS FILLED	EFFECTIVE Asphalt Binder, VOL	EFFECTIVE Asphalt Binder, % WT	ABSORPTION G_{se}	ABSORPTION Asphalt Binder, % WT
MIX 1	4.5	2.270	2.480	8.47	17.12	50.5	8.65	3.93	2.656	0.60
MIX 2	5.0	2.270	2.460	7.72	17.55	56.0	9.83	4.47	2.653	0.56
MIX 3	5.5	2.290	2.440	6.15	17.26	64.4	11.11	5.01	2.650	0.52
MIX 4	6.0	2.300	2.430	5.35	17.34	69.1	11.99	5.38	2.660	0.66

	P_b	d (G_{mb})	D (G_{mm})	% VOIDS (P_a) Target	VMA	VFA	G_{se}	G_{sb}
OPTIMUM DESIGN DATA:---	6+				17+			
REMARKS:								

Design A

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DATE:

SEQ NO:

Bituminous Mixture Design

		Design Number: →	PAGE 10-10
		Lab Preparing the design?(PP,PL,IL,etc.)	PP
Producer Name & Number->	1111-01	Example Company Inc.	
Material Code Number->		HMA Surface Course, Mix C, N70	

Agg. No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	032CMM16		038FAM20	037FAM01	004MFM01		
Source (PROD#)							
(NAME)							
(LOC)							
Aggregate Blend	64.8	0.0	15.8	16.3	3.1	0.0	100.0

Agg. No. Sieve Size	#1	#2	#3	#4	#5	#6	Blend
25.4 (1)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19.0 (3/4)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
12.5 (1/2)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
9.5 (3/8)	99.2	100.0	100.0	100.0	100.0	100.0	99.5
4.75 (#4)	33.9	100.0	99.0	100.0	100.0	100.0	57.0
2.36 (#8)	13.0	100.0	88.4	89.9	100.0	100.0	40.1
1.18 (#16)	4.5	100.0	74.4	55.5	100.0	100.0	26.8
600µm (#30)	4.1	100.0	55.6	23.7	100.0	100.0	18.4
300µm (#50)	3.7	100.0	20.0	8.3	100.0	100.0	10.0
150µm (#100)	3.3	100.0	3.0	3.4	99.0	100.0	6.2
75µm (#200)	2.8	100.0	1.0	1.8	88.0	100.0	5.0

Specifications		FORMULA	FORMULA RANGE	
Min	Max		Min	Max
--	--	100	100	100
	100	100	100	100
90	100	100	94	106
	90	99	--	--
24	65	57	52	62
16	40	40	35	45
10	32	27	27	27
--	--	18	--	--
4	15	10	6	14
3	10	6	6	6
4	6	5.0	3.5	6.5

Bulk Sp Gr	2.645	1	2.6	2.554	2.670	1
Apparent Sp Gr	2.783	1	2.65	2.682	2.670	1
Absorption, %	1.4	1	1.2	0.5	0	0

SP GR Asphalt Binder
1.032

SUMMARY OF TEST DATA

	Asphalt Binder % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (P_a)	VMA	VOIDS FILLED	EFFECTIVE Asphalt Binder, VOL	EFFECTIVE Asphalt Binder, % WT	G_{se}	ABSORPTION Asphalt Binder, % WT
MIX 1	4.5	2.294	2.480	7.50	16.49	54.5	8.99	4.04	2.656	0.48
MIX 2	5.0	2.320	2.460	5.69	15.99	64.4	10.29	4.58	2.653	0.44
MIX 3	5.5	2.350	2.440	3.69	15.35	76.0	11.66	5.12	2.650	0.40
MIX 4	6.0	2.380	2.430	2.06	14.72	86.0	12.66	5.49	2.660	0.54

	P_b	d (G_{mb})	D (G_{mm})	% VOIDS (P_a)	VMA	VFA	G_{se}	G_{sb}
Asphalt determined at 4.0% voids	5.42			Target				
OPTIMUM DESIGN DATA:---	5.4	2.344	2.444	4.0	15.5	73.7	2.651	2.623
REMARKS:								

Design B

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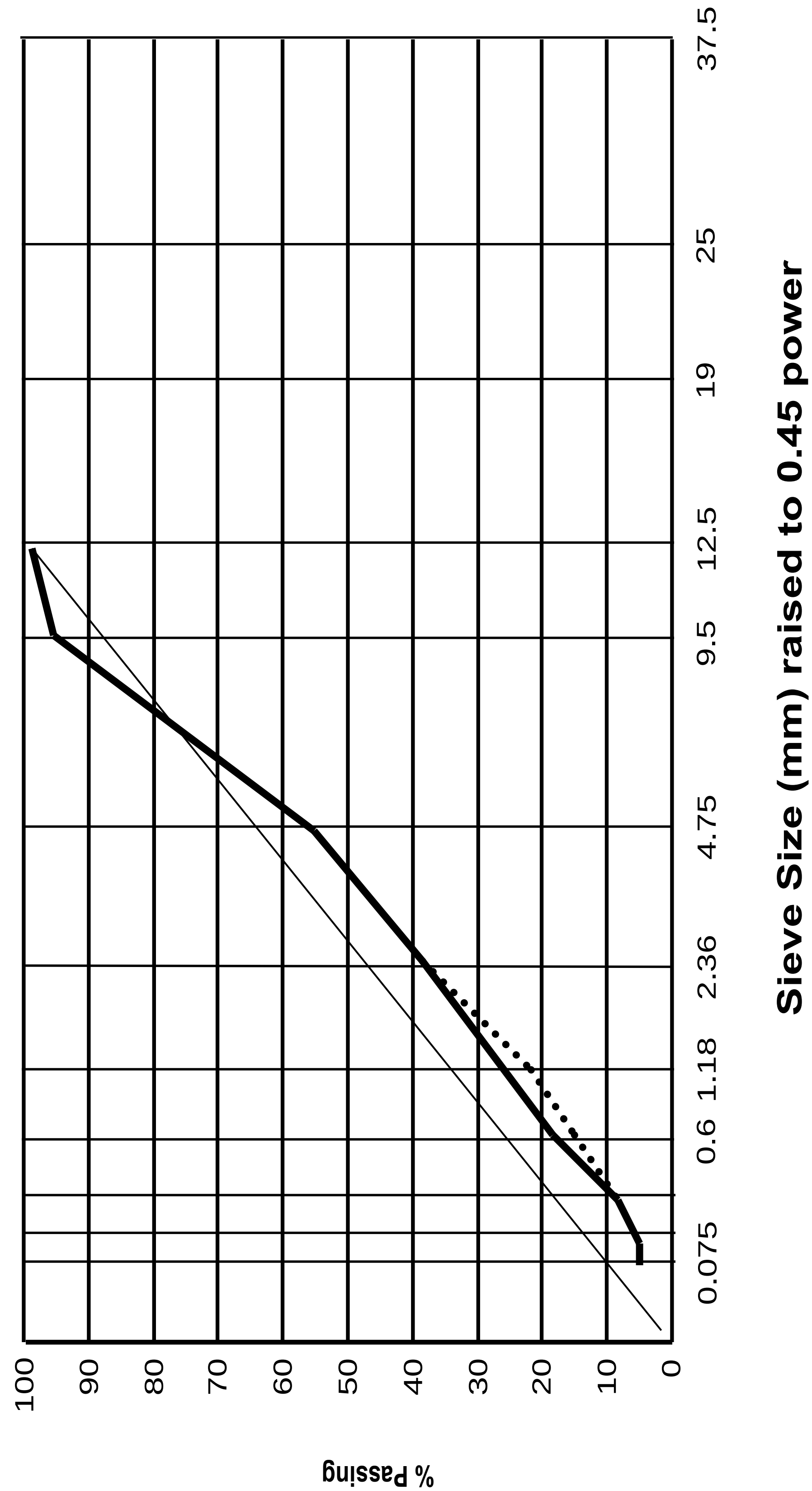

Gradation Graph Design A & B

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DATE:

SEQ NO:

Bituminous Mixture Design
Design Number: → 1211PAGEC
Lab Preparing the design?(PP,PL,IL,etc.) PP
Producer Name & Number->
Material Code Number-> HMA Surface Course, Mix D, N90

Agg. No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	031CMM16		039FAM20	037FAM01	004MFM01		
Source (PROD#)							
(NAME)							
(LOC)							
Aggregate Blend	60.5	0.0	19.4	15.9	4.2	0.0	100.0

Agg. No. Sieve Size	#1	#2	#3	#4	#5	#6	Blend	Specifications Min	Specifications Max	FORMULA	FORMULA RANGE Min	FORMULA RANGE Max
25.4 (1)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	--	--	100	100	100
19.0 (3/4)	100.0	100.0	100.0	100.0	100.0	100.0	100.0		100	100	100	100
12.5 (1/2)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	90	100	100	94	106
9.5 (3/8)	98.5	100.0	100.0	100.0	100.0	100.0	99.1		90	99	--	--
4.75 (#4)	27.2	100.0	99.0	99.7	100.0	100.0	55.7	24	65	56	51	61
2.36 (#8)	3.6	100.0	70.4	94.4	100.0	100.0	35.0	16	40	35	30	40
1.18 (#16)	1.6	100.0	40.4	69.7	100.0	100.0	24.1	10	32	24	24	24
600µm (#30)	1.4	100.0	23.9	42.4	100.0	100.0	16.4	--	--	16	--	--
300µm (#50)	1.2	100.0	14.2	15.1	100.0	100.0	10.1	4	15	10	6	14
150µm (#100)	1.0	100.0	6.8	3.1	99.0	100.0	6.6	3	10	7	7	7
75µm (#200)	0.6	100.0	2.9	1.6	88.0	100.0	4.9	4	6	4.9	3.4	6.4

Bulk Sp Gr	2.661	1	2.643	2.610	2.780	1
Apparent Sp Gr	2.694	1	2.669	2.652	2.780	1
Absorption, %	1.5	1	1.7	1.4	0	0
					SP GR Asphalt Binder 1.032	

SUMMARY OF TEST DATA

	Asphalt Binder % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (P_a)	VMA	VOIDS FILLED	EFFECTIVE Asphalt Binder, VOL	EFFECTIVE Asphalt Binder, % WT	ABSORPTION G_{se}	ABSORPTION Asphalt Binder, % WT
MIX 1	4.5	2.310	2.480	6.85	16.84	59.3	9.99	4.46	2.656	0.04
MIX 2	5.0	2.330	2.470	5.67	16.56	65.8	10.89	4.82	2.665	0.18
MIX 3	5.5	2.340	2.450	4.49	16.64	73.0	12.15	5.36	2.663	0.15
MIX 4	6.0	2.350	2.430	3.29	16.73	80.3	13.44	5.90	2.660	0.10

	P_b	d (G_{mb})	D (G_{mm})	% VOIDS (P_a) Target	VMA	VFA	G_{se}	G_{sb}
OPTIMUM DESIGN DATA:---	5.6	2.340	2.450	4.0	16.7	73.2	2.667	2.653
REMARKS:								

Design C

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DATE:

SEQ NO:

Bituminous Mixture Design

Design Number: →	1211PAGED
Lab Preparing the design?(PP,PL,IL,etc.)	PP
Producer Name & Number->	
Material Code Number->	HMA Surface Course, Mix D, N90

Agg. No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	031CMM16		039FAM20	037FAM01	004MFM01		
Source (PROD#)							
(NAME)							
(LOC)							
Aggregate Blend	59.4	0.0	23.7	13.0	3.9	0.0	100.0

Agg. No. Sieve Size	#1	#2	#3	#4	#5	#6	Blend
25.4 (1)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19.0 (3/4)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
12.5 (1/2)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
9.5 (3/8)	98.5	100.0	100.0	100.0	100.0	100.0	99.1
4.75 (#4)	27.2	100.0	99.0	99.7	100.0	100.0	56.5
2.36 (#8)	3.6	100.0	70.4	94.4	100.0	100.0	35.0
1.18 (#16)	1.6	100.0	40.4	69.7	100.0	100.0	23.5
600μm (#30)	1.4	100.0	23.9	42.4	100.0	100.0	15.9
300μm (#50)	1.2	100.0	14.2	15.1	100.0	100.0	9.9
150μm (#100)	1.0	100.0	6.8	3.1	99.0	100.0	6.5
75μm (#200)	0.6	100.0	2.9	1.6	88.0	100.0	4.7

Specifications		FORMULA	FORMULA RANGE	
Min	Max		Min	Max
--	--	100	100	100
	100	100	100	100
90	100	100	94	106
	90	99	--	--
24	65	56	51	61
16	40	35	30	40
10	32	23	23	23
--	--	16	--	--
4	15	10	6	14
3	10	6	6	6
4	6	4.7	3.2	6.2

Bulk Sp Gr	2.661	1	2.643	2.610	2.780	1
Apparent Sp Gr	2.694	1	2.669	2.652	2.780	1
Absorption, %	1.5	1	1.7	1.4	0	0

SP GR Asphalt Binder 1.032

SUMMARY OF TEST DATA

	Asphalt Binder % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (P_a)	VMA	VOIDS FILLED	EFFECTIVE Asphalt Binder, VOL	EFFECTIVE Asphalt Binder, % WT	ABSORPTION G_{se}	ABSORPTION Asphalt Binder, % WT
MIX 1	4.5	2.310	2.480	6.85	16.85	59.3	10.0	4.47	2.656	0.04
MIX 2	5.0	2.330	2.470	5.67	16.57	65.8	10.90	4.83	2.665	0.18
MIX 3	5.5	2.340	2.450	4.49	16.65	73.0	12.16	5.36	2.663	0.14
MIX 4	6.0	2.350	2.430	3.29	16.74	80.3	13.45	5.91	2.660	0.10

	P_b	d (G_{mb})	D (G_{mm})	% VOIDS (P_a) Target	VMA	VFA	G_{se}	G_{sb}
OPTIMUM DESIGN DATA:---	5.7	2.344	2.444	4.0	16.6	75.9	2.664	2.653
REMARKS:								

Design D

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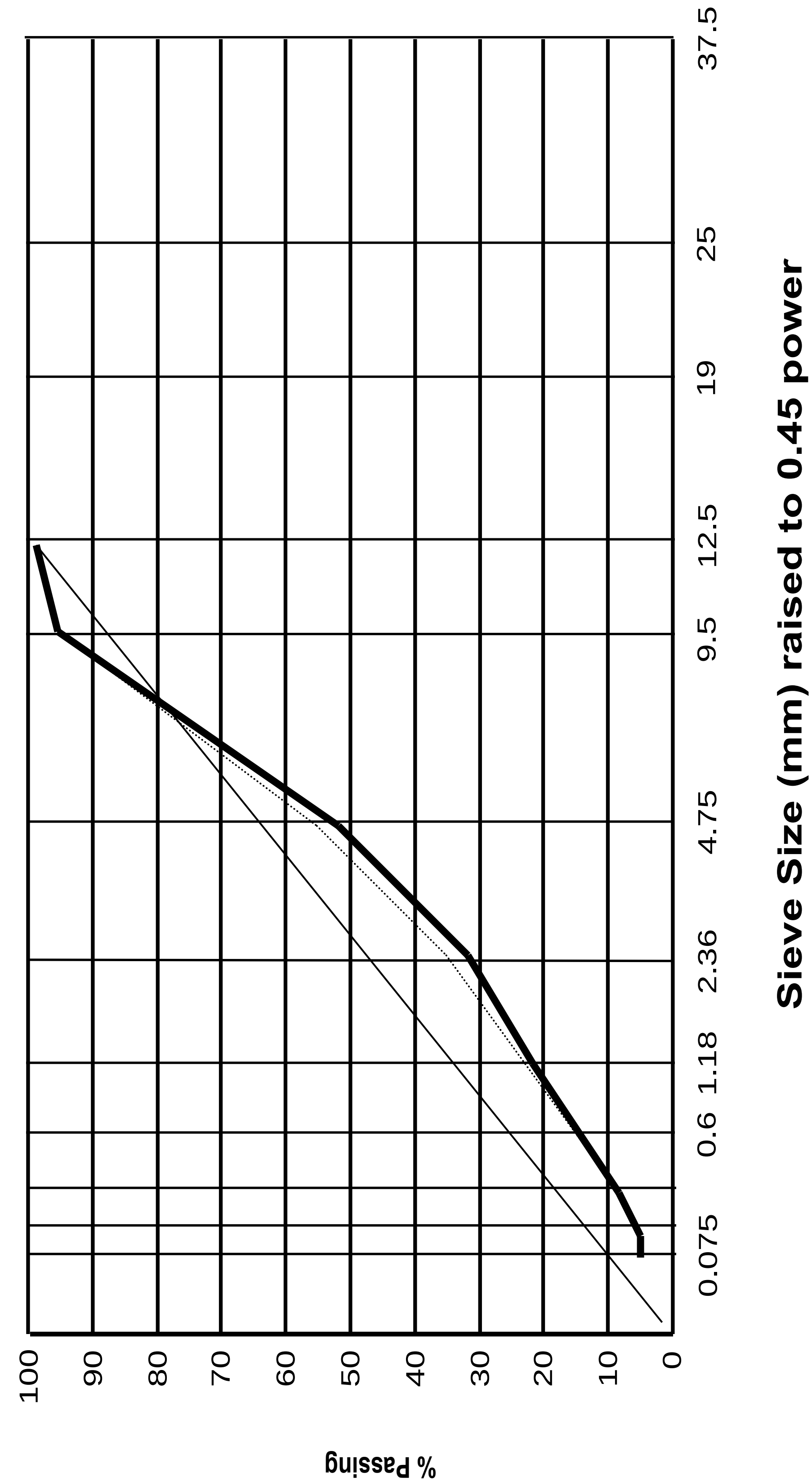

Gradation Graph Design C & D

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DATE:

SEQ NO:

Bituminous Mixture Design

Design Number: →		PAGE 12-17
Lab Preparing the design?(PP,PL,IL,etc.)		PP
Producer Name & Number->	1111-01	Example Company Ince.
Material Code Number->		HMA Binder Course, IL 25.0, N70

Agg. No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	032CMM11	032CMM16		037FAM01	004MFM01		
Source (PROD#)							
(NAME)							
(LOC)							
Aggregate Blend	47.1	23.0	0.0	28.2	1.7	0.0	100.0

Agg. No. Sieve Size	#1	#2	#3	#4	#5	#6	Blend
25.4 (1)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19.0 (3/4)	89.1	100.0	100.0	100.0	100.0	100.0	94.9
12.5 (1/2)	41.5	100.0	100.0	100.0	100.0	100.0	72.4
9.5 (3/8)	18.5	98.6	100.0	100.0	100.0	100.0	61.3
4.75 (#4)	4.5	30.0	100.0	100.0	100.0	100.0	38.9
2.36 (#8)	3.8	7.6	100.0	99.7	100.0	100.0	33.4
1.18 (#16)	3.5	5.2	100.0	72.9	100.0	100.0	25.1
600μm (#30)	3.3	4.1	100.0	49.9	100.0	100.0	18.3
300μm (#50)	3.3	3.7	100.0	10.7	100.0	100.0	7.1
150μm (#100)	3.3	3.5	100.0	0.9	97.0	100.0	4.3
75μm (#200)	3.3	3.2	100.0	0.3	94.0	100.0	4.0

Specifications Min	Specifications Max	FORMULA	FORMULA RANGE Min	FORMULA RANGE Max
90	100	100	100	100
--	90	95	95	95
45	75	72	66	78
--	--	61	--	--
24	42	39	34	44
16	31	33	28	38
10	22	25	25	25
--	--	18	--	--
4	12	7	3	11
3	9	4	4	4
3	6	4.0	2.5	5.5

	#1	#2	#3	#4	#5	#6
Bulk Sp Gr	2.634	2.634	1	2.594	2.760	1
Apparent Sp Gr	2.783	2.687	1	2.627	2.760	1
Absorption, %	1.4	1	1.2	0.5	0	0

SP GR Asphalt Binder 1

SUMMARY OF TEST DATA

	Asphalt Binder % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (P_a)	VMA	VOIDS FILLED	EFFECTIVE Asphalt Binder, VOL	EFFECTIVE Asphalt Binder, % WT	G_{se}	ABSORPTION Asphalt Binder, % WT
MIX 1	4.5	2.300	2.460	6.50	16.19	59.8	9.68	4.21	2.642	0.30
MIX 2	5.0	2.400	2.490	3.61	13.00	72.2	9.39	3.91	2.702	1.15
MIX 3	5.5	2.340	2.422	3.39	15.62	78.3	12.24	5.23	2.641	0.29
MIX 4	6.0	2.380	2.430	2.06	14.63	85.9	12.58	5.28	2.674	0.76

	P_b	d (G_{mb})	D (G_{mm})	% VOIDS (P_a)	VMA	VFA	G_{se}	G_{sb}
Asphalt determined at 4.0% voids	4.93			Target				
OPTIMUM DESIGN DATA:---	4.9	2.380	2.848	4.0	13.6	69.7	2.690	2.621
REMARKS:								

Design E

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DATE:

SEQ NO:

Bituminous Mixture Design
Design Number: →

Lab Preparing the design?(PP,PL,IL,etc.)	PAGE 12-18 / PP
Producer Name & Number-> 1111-01	Example Company Ince.
Material Code Number->	HMA Binder Course, IL-19.0, N70

Agg. No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	032CMM11	032CMM16		037FAM01	004MFM01		
Source (PROD#)							
(NAME)							
(LOC)							
Aggregate Blend	40.3	33.7	0.0	24.4	1.6	0.0	100.0

Agg. No. / Sieve Size	#1	#2	#3	#4	#5	#6	Blend
25.4 (1)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19.0 (3/4)	89.1	100.0	100.0	100.0	100.0	100.0	95.6
12.5 (1/2)	41.5	100.0	100.0	100.0	100.0	100.0	76.4
9.5 (3/8)	18.5	98.6	100.0	100.0	100.0	100.0	66.7
4.75 (#4)	4.5	30.0	100.0	100.0	100.0	100.0	37.9
2.36 (#8)	3.8	7.6	100.0	99.7	100.0	100.0	30.0
1.18 (#16)	3.5	5.2	100.0	72.9	100.0	100.0	22.6
600μm (#30)	3.3	4.1	100.0	49.9	100.0	100.0	16.5
300μm (#50)	3.3	3.7	100.0	10.7	100.0	100.0	6.8
150μm (#100)	3.3	3.5	100.0	0.9	97.0	100.0	4.3
75μm (#200)	3.3	3.2	100.0	0.3	94.0	100.0	4.0

Specifications		FORMULA	FORMULA RANGE	
Min	Max		Min	Max
	100	100	100	100
82	100	96	96	96
50	85	76	70	82
--	--	67	--	--
24	50	38	33	43
16	36	30	25	35
10	25	23	23	23
--	--	16	--	--
4	12	7	3	11
3	9	4	4	4
3	6	4.0	2.5	5.5

Bulk Sp Gr	2.634	2.634	1	2.594	2.760	1
Apparent Sp Gr	2.783	2.687	1	2.627	2.760	1
Absorption, %	1.4	1	1.2	0.5	0	0
					SP GR Asphalt Binder	1

SUMMARY OF TEST DATA

	Asphalt Binder % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (P_a)	VMA	VOIDS FILLED	EFFECTIVE Asphalt Binder, VOL	EFFECTIVE Asphalt Binder, % WT	ABSORPTION G_{se}	ABSORPTION Asphalt Binder, % WT
MIX 1	4.5	2.370	2.510	5.58	13.68	59.2	8.10	3.42	2.702	1.13
MIX 2	5.0	2.400	2.490	3.61	13.05	72.3	9.43	3.93	2.702	1.13
MIX 3	5.5	2.400	2.470	2.83	13.50	79.0	10.67	4.45	2.701	1.12
MIX 4	6.0	2.420	2.450	1.22	13.24	90.8	12.02	4.97	2.700	1.10

	P_b	d (G_{mb})	D (G_{mm})	% VOIDS (P_a)	VMA	VFA	G_{se}	G_{sb}
Asphalt determined at 4.0% voids	4.90			Target				
OPTIMUM DESIGN DATA:---	4.9	2.394	2.494	4.0	13.2	69.7	2.702	2.622
REMARKS:								

Design F

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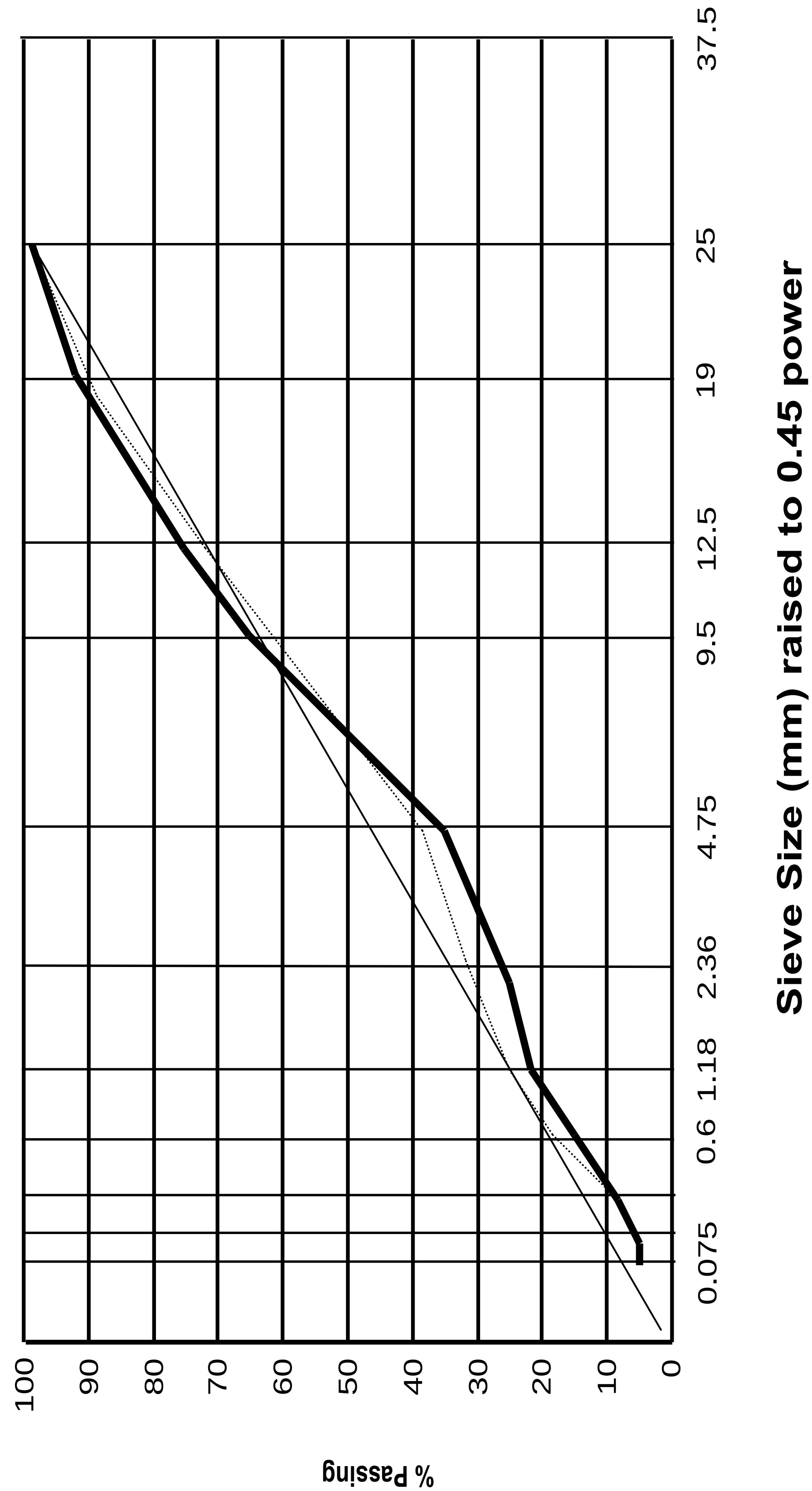

Gradation Graph Design E & F

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DATE:

SEQ NO:

Bituminous Mixture Design
Design Number: →
Lab Preparing the design?(PP,PL,IL,etc.)

Design Number: →			PAGE 12-25
Lab Preparing the design?(PP,PL,IL,etc.)			PP
Producer Name & Number->	1111-01	Example Company Ince.	
Material Code Number->		HMA Binder Course, IL-19.0, N90	

Agg. No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	032CMM11	032CMM16	038FAM20		004MFM01		
Source (PROD#)							
(NAME)							
(LOC)							
Aggregate Blend	52.6	13.3	33.8	0.0	0.3	0.0	100.0

Agg. No. / Sieve Size	#1	#2	#3	#4	#5	#6	Blend
25.4 (1)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19.0 (3/4)	91.0	100.0	100.0	100.0	100.0	100.0	95.3
12.5 (1/2)	40.0	100.0	100.0	100.0	100.0	100.0	68.4
9.5 (3/8)	15.0	99.1	100.0	100.0	100.0	100.0	55.2
4.75 (#4)	3.0	29.6	96.7	100.0	100.0	100.0	38.5
2.36 (#8)	2.9	4.3	67.4	100.0	100.0	100.0	25.2
1.18 (#16)	2.8	3.8	40.2	100.0	100.0	100.0	15.9
600µm (#30)	2.7	3.6	24.6	100.0	100.0	100.0	10.5
300µm (#50)	2.6	3.3	14.1	100.0	100.0	100.0	6.9
150µm (#100)	2.5	3.1	7.6	100.0	94.0	100.0	4.6
75µm (#200)	2.5	3.0	6.0	100.0	84.0	100.0	4.0

Specifications		FORMULA	FORMULA RANGE	
Min	Max		Min	Max
	100	100	100	100
82	100	95	95	95
50	85	68	62	74
--	--	55	--	--
24	40	38	33	43
16	36	25	20	30
10	25	16	16	16
--	--	11	--	--
4	12	7	3	11
3	9	5	5	5
3	6	4.0	2.5	5.5

Bulk Sp Gr	2.634	2.634	2.612	1	2.670	1
Apparent Sp Gr	2.783	2.687	2.639	1	2.670	1
Absorption, %	1.4	1	1.2	0.5	0	0

SP GR Asphalt Binder
1.032

SUMMARY OF TEST DATA

	Asphalt Binder % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (P_a)	VMA	VOIDS FILLED	EFFECTIVE Asphalt Binder, VOL	EFFECTIVE Asphalt Binder, % WT	ABSORPTION G_{se}	ABSORPTION Asphalt Binder, % WT
MIX 1	4.5	2.380	2.500	4.80	13.37	64.1	8.57	3.72	2.680	0.82
MIX 2	5.0	2.390	2.480	3.63	13.46	73.0	9.83	4.25	2.678	0.79
MIX 3	5.5	2.400	2.470	2.83	13.56	79.1	10.72	4.61	2.688	0.94
MIX 4	6.0	2.420	2.450	1.22	13.30	90.8	12.07	5.15	2.686	0.91

	P_b	d (G_{mb})	D (G_{mm})	% VOIDS (P_a)	VMA	VFA	G_{se}	G_{sb}
Asphalt determined at 4.0% voids	4.84			Target				
OPTIMUM DESIGN DATA:---	4.8	2.386	2.488	4.0	13.4	69.5	2.679	2.624
REMARKS:								

Design G

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DATE:

SEQ NO:

Bituminous Mixture Design
Design Number: →
Lab Preparing the design?(PP,PL,IL,etc.)

		PAGE 12-27
		PP
Producer Name & Number->	1111-01	Example Company Ince.
Material Code Number->		HMA Binder Course, IL 19.0, N90

Agg. No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	032CMM11	032CMM16	038FAM20		004MFM01		
Source (PROD#)							
(NAME)							
(LOC)							
Aggregate Blend	42.8	27.1	29.1	0.0	1.0	0.0	100.0

Agg. No. Sieve Size	#1	#2	#3	#4	#5	#6	Blend
25.4 (1)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19.0 (3/4)	91.0	100.0	100.0	100.0	100.0	100.0	96.1
12.5 (1/2)	40.0	100.0	100.0	100.0	100.0	100.0	74.3
9.5 (3/8)	15.0	99.1	100.0	100.0	100.0	100.0	63.4
4.75 (#4)	3.0	29.6	96.7	100.0	100.0	100.0	38.4
2.36 (#8)	2.9	4.3	67.4	100.0	100.0	100.0	23.0
1.18 (#16)	2.8	3.8	40.2	100.0	100.0	100.0	14.9
600μm (#30)	2.7	3.6	24.6	100.0	100.0	100.0	10.3
300μm (#50)	2.6	3.3	14.1	100.0	100.0	100.0	7.1
150μm (#100)	2.5	3.1	7.6	100.0	94.0	100.0	5.1
75μm (#200)	2.5	3.0	6.0	100.0	84.0	100.0	4.5

Specifications Min	Specifications Max	FORMULA	FORMULA RANGE Min	FORMULA RANGE Max
--	100	100	100	100
82	100	96	96	96
50	85	74	68	80
--	--	63	--	--
24	40	38	33	43
16	36	23	18	28
10	25	15	15	15
--	--	10	--	--
4	12	7	3	11
3	9	5	5	5
3	6	4.5	3.0	6.0

Bulk Sp Gr	2.634	2.634	2.612	1	2.670	1
Apparent Sp Gr	2.783	2.687	2.639	1	2.670	1
Absorption, %	1.4	1	1.2	0.5	0	0

SP GR Asphalt Binder
1.032

SUMMARY OF TEST DATA

	Asphalt Binder % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (P_a)	VMA	VOIDS FILLED	EFFECTIVE Asphalt Binder, VOL	EFFECTIVE Asphalt Binder, % WT	G_{se}	ABSORPTION Asphalt Binder, % WT
MIX 1	4.5	2.370	2.510	5.58	13.80	59.6	8.22	3.58	2.692	0.96
MIX 2	5.0	2.380	2.490	4.42	13.89	68.2	9.47	4.11	2.690	0.94
MIX 3	5.5	2.390	2.470	3.24	13.98	76.8	10.75	4.64	2.688	0.91
MIX 4	6.0	2.450	2.520	2.78	12.29	77.4	9.51	4.01	2.775	2.12

	P_b	d (G_{mb})	D (G_{mm})	% VOIDS (P_a)	VMA	VFA	G_{se}	G_{sb}
Asphalt determined at 4.0% voids	5.18			Target				
OPTIMUM DESIGN DATA:---	5.2	2.384	2.482	4.0	13.9	71.7	2.689	2.626
REMARKS:								

Design H

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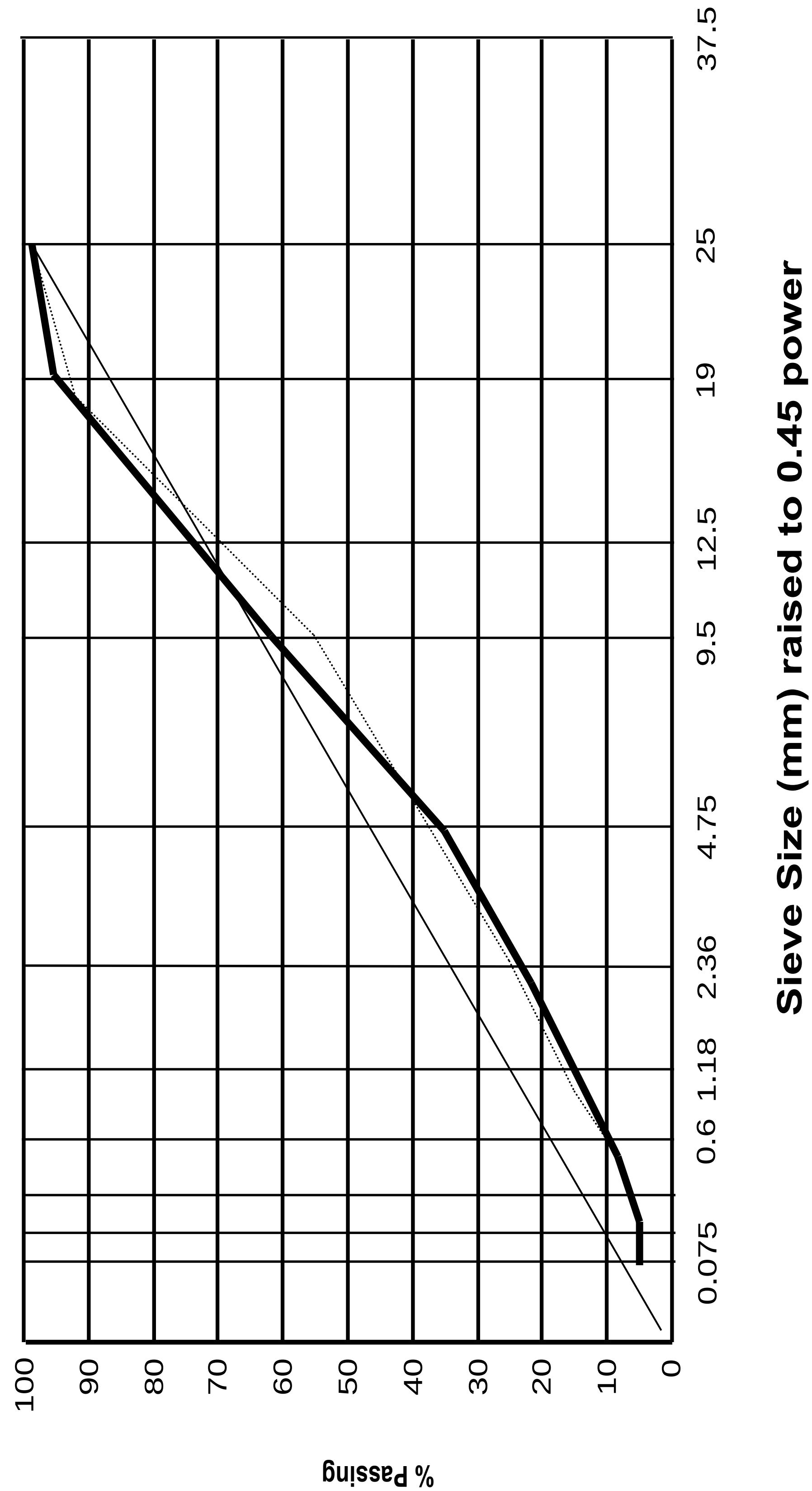

Gradation Graph Design G & H

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DATE:

SEQ NO:

Bituminous Mixture Design
Design Number: →
Lab Preparing the design?(PP,PL,IL,etc.)

			PAGE 12-31
			PP
Producer Name & Number->	1111-01	Example Company Ince.	
Material Code Number->		HMA Binder Course, IL 19.0, N90	

Agg. No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	032CMM11	032CMM16	038FAM20	037FAM02	004MFM01		
Source (PROD#)							
(NAME)							
(LOC)							
Aggregate Blend	49.5	20.6	16.5	11.8	1.6	0.0	100.0

Agg. No. / Sieve Size	#1	#2	#3	#4	#5	#6	Blend
25.4 (1)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19.0 (3/4)	94.3	100.0	100.0	100.0	100.0	100.0	97.2
12.5 (1/2)	40.0	100.0	100.0	100.0	100.0	100.0	70.3
9.5 (3/8)	17.9	96.9	100.0	100.0	100.0	100.0	58.7
4.75 (#4)	4.9	30.8	97.7	96.8	100.0	100.0	37.9
2.36 (#8)	3.0	7.7	65.8	80.8	100.0	100.0	25.1
1.18 (#16)	2.7	4.9	36.9	64.8	100.0	100.0	17.7
600µm (#30)	2.6	4.1	20.1	48.4	100.0	100.0	12.8
300µm (#50)	2.5	3.7	11.6	18.5	100.0	100.0	7.7
150µm (#100)	2.4	3.5	7.9	3.1	99.0	100.0	5.2
75µm (#200)	2.0	3.0	4.8	1.5	88.0	100.0	4.0

Specifications Min	Specifications Max	FORMULA	FORMULA RANGE Min	FORMULA RANGE Max
--	100	100	100	100
82	100	97	97	97
50	85	70	64	76
--	--	59	--	--
24	40	38	33	43
16	36	25	20	30
10	25	18	18	18
--	--	13	--	--
4	12	8	4	12
3	9	5	5	5
3	6	4.0	2.5	5.5

Bulk Sp Gr	2.641	2.632	2.624	2.573	2.800	1
Apparent Sp Gr	2.754	2.776	2.829	2.697	2.800	1
Absorption, %	1.5	1.9	2.8	1.9	0	0
					SP GR Asphalt Binder 1.032	

SUMMARY OF TEST DATA

	Asphalt Binder % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (P_a)	VMA	VOIDS FILLED	EFFECTIVE Asphalt Binder, VOL	EFFECTIVE Asphalt Binder, % WT	ABSORPTION G_{se}	ABSORPTION Asphalt Binder, % WT
MIX 1	4.0	2.420	2.530	4.35	11.62	62.6	7.27	3.10	2.693	0.94
MIX 2	4.5	2.420	2.510	3.59	12.08	70.3	8.49	3.62	2.692	0.92
MIX 3	5.0	2.430	2.500	2.80	12.18	77.0	9.38	3.98	2.702	1.07
MIX 4	5.5	2.440	2.480	1.61	12.28	86.9	10.67	4.51	2.701	1.05

	P_b	d (G_{mb})	D (G_{mm})	% VOIDS (P_a)	VMA	VFA	G_{se}	G_{sb}
Asphalt determined at 4.0% voids	4.23			Target				
OPTIMUM DESIGN DATA:---	4.2	2.420	2.522	4.0	11.8	65.7	2.692	2.629
REMARKS:								

Design I

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DATE:

SEQ NO:

Bituminous Mixture Design
Design Number: →
Lab Preparing the design?(PP,PL,IL,etc.)

		PAGE 12-33
		PP
Producer Name & Number->	1111-01	Example Company Ince.
Material Code Number->		HMA Binder Course, IL 19.0, N90

Agg. No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	032CMM11	032CMM16	038FAM20	037FAM02	004MFM01		
Source (PROD#)							
(NAME)							
(LOC)							
Aggregate Blend	50.1	20.9	20.3	7.3	1.4	0.0	100.0

Agg. No. Sieve Size	#1	#2	#3	#4	#5	#6	Blend
25.4 (1)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19.0 (3/4)	94.3	100.0	100.0	100.0	100.0	100.0	97.1
12.5 (1/2)	40.0	100.0	100.0	100.0	100.0	100.0	69.9
9.5 (3/8)	17.9	96.9	100.0	100.0	100.0	100.0	58.2
4.75 (#4)	4.9	30.8	97.7	96.8	100.0	100.0	37.2
2.36 (#8)	3.0	7.7	65.8	80.8	100.0	100.0	23.8
1.18 (#16)	2.7	4.9	36.9	64.8	100.0	100.0	16.0
600μm (#30)	2.6	4.1	20.1	48.4	100.0	100.0	11.2
300μm (#50)	2.5	3.7	11.6	18.5	100.0	100.0	7.1
150μm (#100)	2.4	3.5	7.9	3.1	99.0	100.0	5.1
75μm (#200)	2.0	3.0	4.8	1.5	88.0	100.0	3.9

Specifications Min	Specifications Max	FORMULA	FORMULA RANGE Min	FORMULA RANGE Max
--	100	100	100	100
82	100	97	97	97
50	85	70	64	76
--	--	58	--	--
24	40	37	32	42
16	36	24	19	29
10	25	16	16	16
--	--	11	--	--
4	12	7	3	11
3	9	5	5	5
3	6	3.9	2.4	5.4

Bulk Sp Gr	2.641	2.632	2.624	2.573	2.800	1
Apparent Sp Gr	2.754	2.776	2.829	2.697	2.800	1
Absorption, %	1.5	1.9	2.8	1.9	0	0

SP GR Asphalt Binder
1.032

SUMMARY OF TEST DATA

	Asphalt Binder % MIX	BULK SPEC GRAV (G_{mb})	MAXIMUM SPEC GR (G_{mm})	VOIDS TOT MIX (P_a)	VMA	VOIDS FILLED	EFFECTIVE Asphalt Binder, VOL	EFFECTIVE Asphalt Binder, % WT	ABSORPTION G_{se}	ABSORPTION Asphalt Binder, % WT
MIX 1	4.0	2.370	2.520	6.0	13.5	56.0	7.56	3.29	2.681	0.74
MIX 2	4.5	2.370	2.500	5.2	14.0	62.8	8.76	3.82	2.680	0.72
MIX 3	5.0	2.400	2.480	3.2	13.3	75.8	10.11	4.35	2.678	0.69
MIX 4	5.5	2.410	2.470	2.4	13.4	81.9	11.00	4.71	2.688	0.84

	P_b	d (G_{mb})	D (G_{mm})	% VOIDS (P_a)	VMA	VFA	G_{se}	G_{sb}
Asphalt determined at 4.0% voids	4.80			Target				
OPTIMUM DESIGN DATA:---	4.8	2.388	2.488	4.0	13.6	70.6	2.679	2.631
REMARKS:								

Design J

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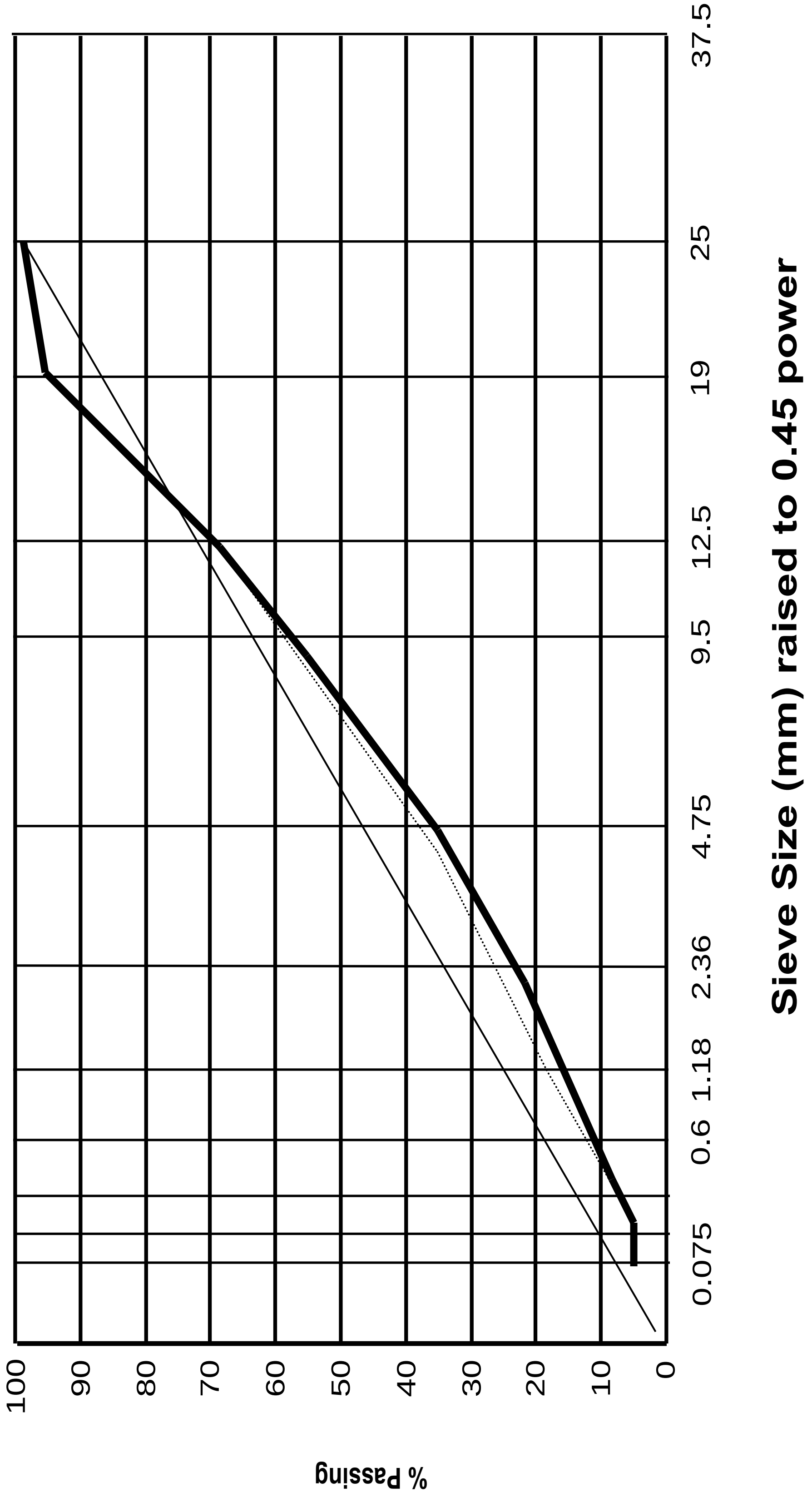

Gradation Graph Design I & J

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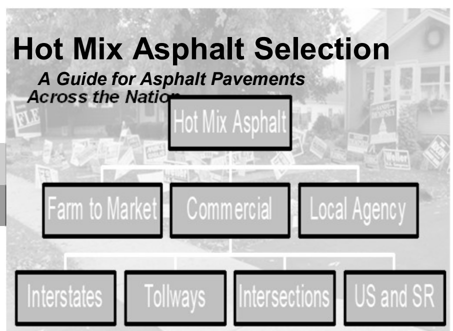
Specialty Mixes in HMA

Various high quality mixes for various applications.

Murphy Pavement Technology



Murphy Pavement Technology

Standard HMA Mixes

N_{des} Gyratory Levels

- N30, Low Volume, Local Municipalities
- N50
- N70, Medium Volume, State Routes
- N90, High Volume, Interstates

PG 52-28
PG 58-28
PG 64-28
PG 70-22
PG 76-22
Polymers

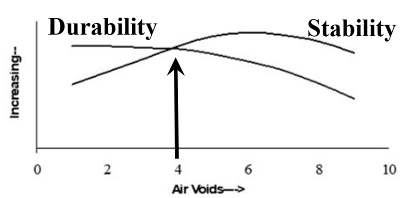
Full – Depth vs. Overlay

Is there a difference in the asphalt material for these two types of pavement structures?

How do you build from bottom to top with FD Asphalt?

HMA Goal

Maximize performance & minimize cost!



Importance of VMA to Compaction Efforts

- Improve Mechanical Stability
- Improve Resistance to Permanent Deformation
- Reduce Moisture / Air Penetration
- Improve Fatigue Resistance
- Reduce Low-Temperature Cracking Potential

Voids, VMA and VFA

- The Building Blocks of Hot Mix Asphalt are these three very important volumetric measures. They provide for durability and assist in measuring the pavements "Life Potential".
- The variability in Voids typically manifests itself in the field with variability to in-place density.

Asphalt Content

- Optimum is selected during Mix Design and usually does not vary significantly from design to production.
- Gradation variability is greater for larger particles than smaller ones because of the cause and effect relationship of these size materials.

VMA and Voids drop as P200 rises; Not Good!

Specialty Mixes in HMA

- Full-depth base asphalt, patches:
  - Large Aggregate Mixture @ N50 – N105
  - a/k/a 'A' Binder, a/k//a IL-25.0 mm
- Stone Matrix Asphalt
- Polymerized Level Course; IL-4.75 mm
- Low ESAL:
  - N_{des} = 30
  - N_{des} = 50; IL-9.5FG

Large Aggregate Mixture (LAM) @ N50

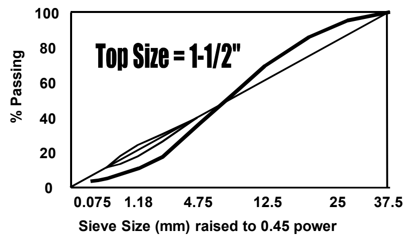
- Maximum aggregate size up to 1-1/2"
- *Old* 6 inch Marshall design (112-blow)

LAM Mixture Composition (a/k/a IL-25.0 mm, 'A' Binder,Deep Base)

Sieve Size	Min	Max
1-1/2"		100
1	90	100
¾"		90
½"	45	75
#4	24	42/2
#8	16	31
#16	10	22
#50	4	12
#100	3	9
#200	3	6

LAM	CM08	CM16/ CM13	FM20	RAP
N105	60%	22%	18%	0%
N50	30%	10%	10%	50%

LAM Gradation



Large Aggregate Mix, N90

MAT'L:	CA #1	CA #2	FA #1	Breakdown	FINAL
SIZE:	1"	3/8"	Man. Sand		BLEND
AGG. %:	60.0	22.5	17.0	0.5	100.0
SIEVE					
1-1/2"	100	100	100	100	100
1"	92	100	100	100	95
3/4"	78	100	100	100	87
1/2"	57	100	100	100	74
3/8"	28	97	100	100	56
#4	6	25	100	100	27
#8	4	6	84	100	18
#16	3	5	52	100	12
#30	3	5	29	100	8
#50	1	5	16	100	6
#100	2	5	10	99	5
#200	2.2	4.3	7.1	83.9	3.9

Interstate Patching

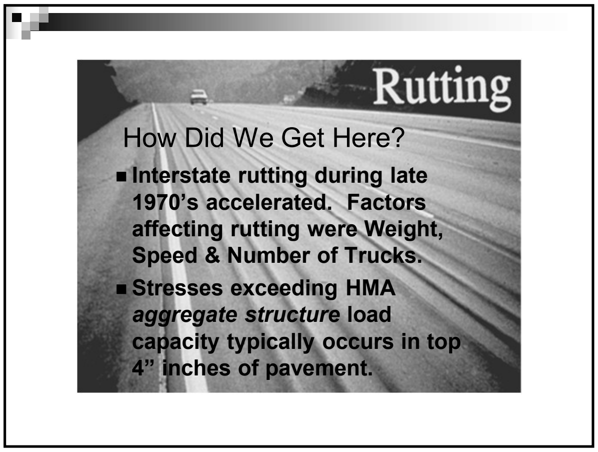
Deep Strength; Base Asphalt

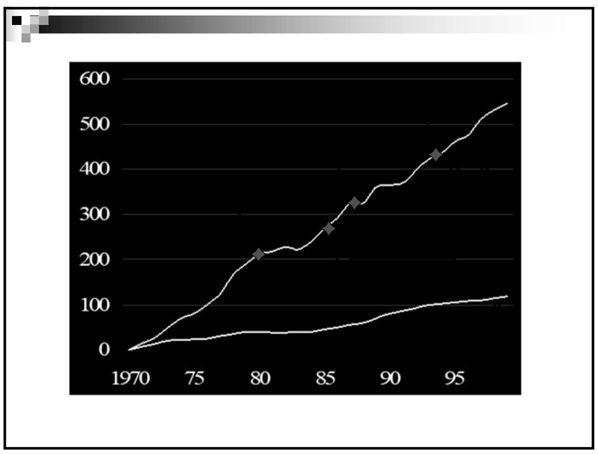
Stone Matrix Asphalt

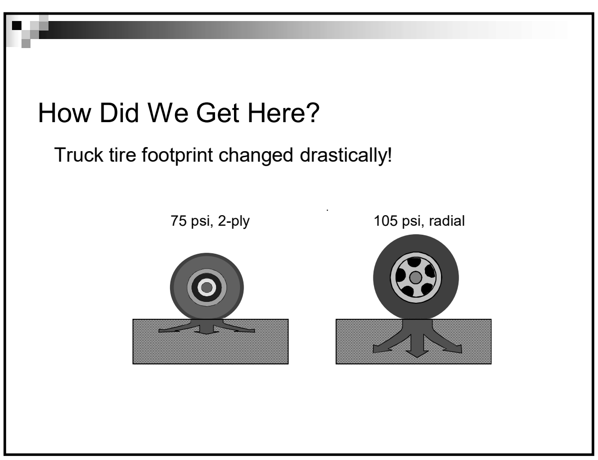
High Type Traffic Solution for high stress and large volumes.

Murphy Pavement Technology

Interstate Traffic


Rutting
How Did We Get Here?
Interstate rutting during late 1970's accelerated. Factors affecting rutting were Weight, Speed & Number of Trucks.
Stresses exceeding HMA *aggregate structure* load capacity typically occurs in top 4" inches of pavement.


600
500
400
300
200
100
0
1970
75
80
85
90
95


How Did We Get Here?
Truck tire footprint changed drastically!
75 psi, 2-ply
105 psi, radial

Heavy, Concentrated Loading

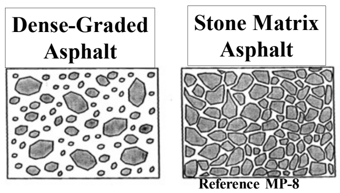
Mix Properties

- Much coarser blend than HMA
- Uses highly modified AC, high dust content and fibers
- Stability from coarse aggregate structure
- Durability from mastic
- Very sensitive to changes in production and placement

Design Issues, General

- ~ 76% of mix is CA,
- Balance is Manufactured Sand and MF,
- Target 2.36mm & 0.075mm in combined blend,
- Fiber introduction,
- High P200.

Design Issues, General



Reference MP-8
PP-41
T19

Stone Matrix Asphalt, Important Design Items

- Voids in the Coarse Aggregates (VCA) is the volume in between the coarse aggregate particles. This volume is filler, fine aggregate, air voids, asphalt binder, and fiber (if used).
- SMA Mortar is the mixture of asphalt binder, filler, and stabilizing additive (fibers).

Stone Matrix Asphalt, VCA

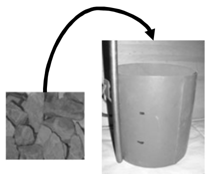
$VCA_{(DRC)}$

- The SMA mixture must have a coarse aggregate skeleton with stone-on-stone contact. The VCA of the CA fraction is determined by compacting the stone with the dry rodded technique according to T19.

Stone Matrix Asphalt, VCA

$VCA_{(DRC)}$ = Voids in the Coarse Aggregate, Dry-Rodded

- Plus #4 material
- 3 equal lifts
- 25 rods
- Strike-off top



Stone Matrix Asphalt, VCA

$VCA_{(DRC)}$

- When the dry rodded density of the stone fraction has been determined, the $VCA_{(DRC)}$ can be calculated using the following equation:

$$VCA_{(DRC)} = \frac{(G_{ca})(\gamma_w) - (\gamma_s)}{(G_{ca})(\gamma_w)}$$

Stone Matrix Asphalt, VCA

$$VCA_{(DRC)} = \frac{(G_{ca})(\gamma_w) - (\gamma_s)}{(G_{ca})(\gamma_w)}$$

G_{ca} : bulk specific gravity (dry) of the coarse aggregate (T85)

γ_w : unit weight of water

γ_s : unit weight of the coarse aggregate fraction in the dry-rodded condition

Stone Matrix Asphalt, VCA

VCA $_{(MIX)}$

- The condition of stone-on-stone contact within an SMA mixture is defined as the point at which the VCA of the compacted mixture is less than the VCA of the coarse aggregate in the dry rodded test.

Stone Matrix Asphalt, VCA

VCA $_{(MIX)}$

- After the trial samples have been compacted and allowed to cool, the VCA $_{(MIX)}$ can be calculated using the following equation:

$$VCA_{(MIX)} = 100 - \left(\frac{G_{mb}}{G_{ca}}\right) * P_{ca}$$

Stone Matrix Asphalt, VCA

$$VCA_{(MIX)} = 100 - \left(\frac{G_{mb}}{G_{ca}}\right) * P_{ca}$$

G_{mb} : bulk specific gravity of the compacted mixture

G_{ca} : bulk specific gravity (dry) of the coarse aggregate fraction

P_{ca} : percent of the coarse aggregate in the total mixture.

Stone Matrix Asphalt, VCA

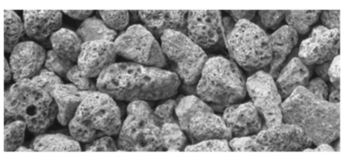
Wanted:
$VCA_{(MIX)} < VCA_{(DRC)}$

If $VCA_{(MIX)} > VCA_{(DRC)}$ then;

- Adjust the mixture gradation,
- This modification is typically accomplished by increasing the percentage of coarse aggregate.

Design Issues, VCA Visual

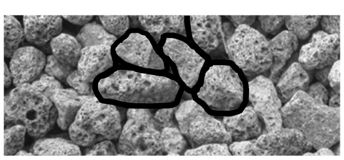
Stone Matrix Asphalt



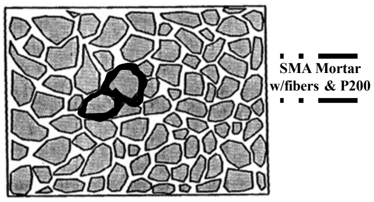
Design Issues, VCA Visual

Stone Matrix Asphalt

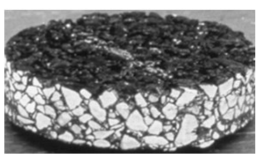
SMA Mortar with fibers & P200



Stone Matrix Asphalt,
$VCA_{(DRC)} < VCA_{(MIX)}$



Stone Matrix Asphalt,
$VCA_{(DRC)} = VCA_{(MIX)}$



Mix Properties Special Provision

Mix Properties, CA

- No individual coarse aggregate gradation is specified.
- The coarse aggregates used shall be capable of being combined with stone sand, slag sand, or steel slag sand meeting the FA/FM20 gradation and mineral filler to meet the approved mix design and the mix requirements noted herein.

Mix Properties, CA

- For surface course, the coarse aggregate shall be Class B Quality crushed aggregate meeting the friction requirement specified in the mixture requirements in the contract plans.
- For binder course, the coarse aggregate shall be Class B Quality crushed aggregate. Steel slag will not be permitted in the binder course.

Mix Properties, CA

- Blending of different coarse aggregate types will not be permitted.
- The coarse aggregate for both courses shall meet the criteria for Flat and Elongated Particles.

Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Mix Properties, CA

- The coarse aggregate for all courses shall have a water absorption ≤ 2.5 %.
- Reclaimed Asphalt Pavement (RAP) will not be permitted.

Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Mix Properties, FA

- Fine aggregate shall be Class B Quality stone sand, slag sand, or steel slag sand meeting the FA/FM20 gradation.

Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Mix Properties, Filler

- Mineral Filler for all courses shall be mineral filler according to the Standard Specifications.
- Mineral filler shall be free from organic impurities and have a PI ≤ 4.
- Additional minus 0.075 mm (No. 200) material required by the mix design shall be mineral filler.

Mix Properties, Fibers

- A stabilizing additive such as cellulose or mineral fiber shall be added to the SMA mixture according to AASHTO MP8.
- Prior to approval and use of fibers, the Contractor shall submit a notarized certification by the producer of these materials, stating they meet these requirements.

Mix Properties, AC

- The asphalt binder (AC) shall be an SBS PG 76-28 when the SMA is used on a full depth asphalt pavement and a SBS PG76-22 when used as an overlay.
- The asphalt binder shall meet the requirements of the Standard Specifications.

Mix Properties, Job-Mix Formula

Mixture Composition (JMF)

Sieve	***Lower***	***Upper***
19.0 mm		100
12.5 mm	90	99
9.5 mm	50	85
4.75 mm	20	40
2.36 mm	16	24*
0.075 mm	8.0	11.0
0.020 mm	3.0	

Mix Properties, Volumetrics

	Steel Slag and Trap Rock (ESAL's > 10 million)	Dolomite (ESAL's ≤ 10 million)
Ndes	80 gyrations	50 gyrations
VMA	17.0%	16.0%
Air Voids	4.0%	4.0%

Mix Properties, Volumetrics

- (*) When establishing the Adjusted Job Mix Formula (AJMF) the 2.36mm sieve shall not be adjusted above 24%.
- When establishing the AJMF the asphalt binder content shall not be adjusted by more than 0.2% from the JMF.

Mix Properties, Stripping

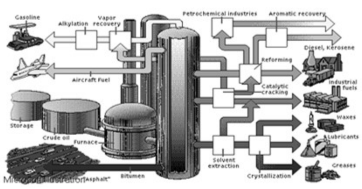
- The mixture shall contain an anti-strip agent consisting of 1.0% hydrated lime. If the minimum TSR of 0.85 is not achieved with hydrated lime alone the Department may require a liquid anti-strip to be used in addition to the hydrated lime.

Voids VMA and VFA: The Building Blocks of Hot Mix Asphalt

Quality Control Items

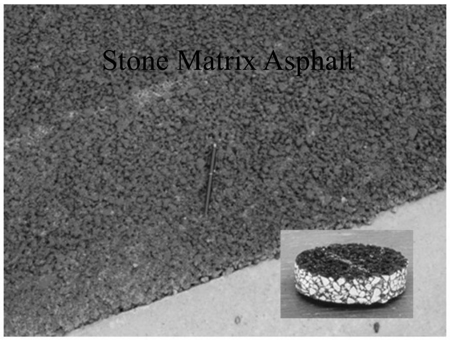
Parameter	Individual Test	Moving Average
9.5 mm (3/8 in.)	± 4%	± 3%
2.36 mm (No. 8)	± 4%	± 2%
Asphalt Binder content	± 0.2%	± 0.1%
Density	94 - 97%	
Air Voids	± 1.2% (of design)	± 1.0% (of design)

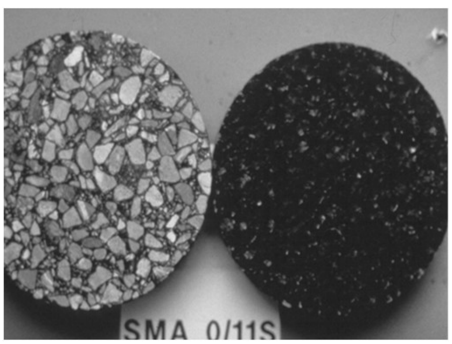
Crude Oil to End Product



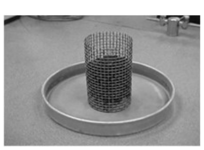
Crude Oil to End Product

Polymers plus Asphalt Binder



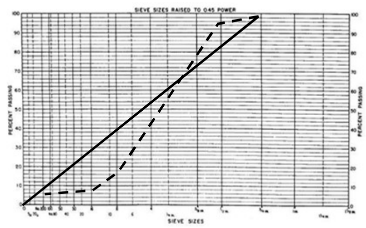


Mix Properties,
NCAT Draindown Method



- Measures draindown of liquid asphalt,
- Deduct stone in draindown,
- Monitor during production,
- Review procedure.

Mix Properties, Gradation



Production Issues

- Know your materials!
- Calibrate plant accurately
- Use multiple cold feeds for CA
- Changes in Asphalt Binder temp can affect pump
- Production rates are generally less
- Remove moisture from the mix
  - increase storage time to help
  - can cause draindown in mix

Production Issues, General

- ~ 76% of mix is CA,
- Balance is Manufactured Sand and MF,
- Target 2.36mm & 0.075mm in combined blend,
- High P200.

Production Issues (Steel Slag SMA)

- G_{sb} variation of +/- 0.04 may result in:
  - 0.03 change in Gmm, +/- 1.0% voids/density!
- G_{sb} of stockpile can change (weathering),
- Self monitoring program exists for absorption and gravity,
- Surface of pile can crust,
- Very high specific gravity and therefore very high G_{mm}.

Fibers

- Cellulose or Mineral required by agency,
- Keep them dry!
- Prevents draindown of Asphalt Binder,
- Stiffens the mix,
- Fills in voids, (y/n)
- Must be added consistently
  - generally added as 0.3-0.4% of aggregate weight (6-8 lbs./ton of mix)

Mix Temperature Consistency

- Highly modified Asphalt Binder, stone sand, fibers and dust creates the **mastic** (glue)
- Stiffness of mastic is **very sensitive** to temperature
- Direct effect on **density** achieved on the road!

Mix Temperature

- High enough for workability
- But….not too high for draindown
- So…….tighter temperature range than normal mixtures

Haul Truck Beds

- Very sticky mix
- Beds must be completely clean and flat
- Lightly spray beds with release agent & drain excess by raising bed

Haul Truck Beds

- Excess release agent will cool mix and cause even more buildup in bed
- Alternative method is a combination of soap detergent powder & stone sand
- Once build up starts…………..

Placement and Compaction Issues

Murphy Pavement Technology

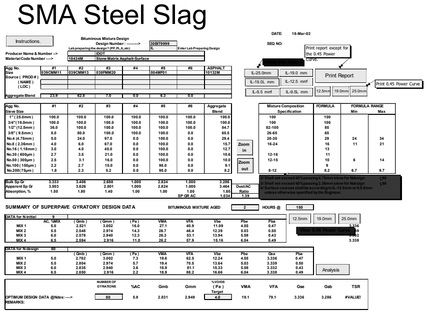
Dolomitic SMA Weight

- Gmm of 2.600 = 162 pcf
- 94% density = 153 pcf
- Pounds/square yard/inch thick = **112**
- 12’ wide mat x 2” thick
  - 1 lineal foot = 300 lbs. (~0.149 tons)
  - 21 tons will go ~ 141 lineal feet
- Optimum P_b 5.5% - 6.0%

Steel Slag SMA Weight

- Gmm of 3.000 = 187 pcf
- 94% density = 176 pcf
- Pounds/square yard/inch thick = **132**
- 12’ wide mat x 2” thick
  - 1 lineal foot = 352 lbs. (~0.176 tons)
  - 21 tons will go ~ 120 lineal feet
- Optimum P_b near 5.9%

SMA Steel Slag



Trap Rock SMA Weight

- Gmm of 2.900 = 181 pcf
- 94% density = 170 pcf
- Pounds/square yard/inch thick = **128**
- 12' wide mat x 2" thick
  - 1 lineal foot = 341 lbs. (~0.171 tons)
  - 21 tons will go ~ 123 lineal feet
- Optimum P_b near 5.6%

Material Transfer Device

- Improves mat temperature uniformity
- Minimizes number of paver stops
- Put first 2-3 loads straight through to heat metal before storing any mix

Paver Issues

- Vibratory Screeds... good or bad??
- Operate at a slow, consistent pace
- Placement rate should be slightly less than production rate
- Don't out-run the breakdown rollers
- Slow down when they need water
- Increase speed slowly to prevent screed rise

Keep Breakdown Rollers Close to Paver

Paver Issues

- Don’t stop the paver
- Increase speed slowly after slowing down
- Keep augers turning
- Preheating of screed off joints critical
- Small fat spots can be fines buildup under screed

Minimize Handwork

- More difficult to work with due to
  - Modified Asphalt Binder
  - Increased dust content
  - Increased Asphalt Binder content
- Perform handwork **before** significant temperature loss
- Keep lutes and shovels clean

Compaction (Breakdown rolling)

- Most important part of compaction process
- Stay as close to paver as possible
- Only static steel wheel (finish type) allowed
- Roller weight is important
- Minimize amount of water on drums
- Soap or fabric softener in water can help

Properly Ballast Rollers

Compaction
Finish Rolling

- Operate as close to breakdown rollers as possible without moving mat
  - Can obtain additional density before mix cools
  - Critical to remove marks before mix cools but marks are generally not an issue
- A few slow, steady passes better than several fast passes for density & smoothness

Compaction (General)

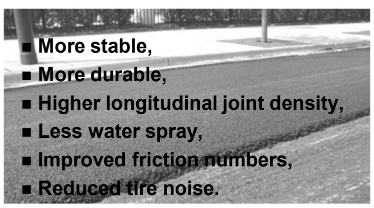
- Weight of roller is significant
- Static steel wheels heavier, but downfalls include:
  - narrower drums require more passes or more rollers for entire lane coverage
  - mat may cool due to increased time for passes
- Pneumatics not good because of pickup

Properly Ballast Rollers

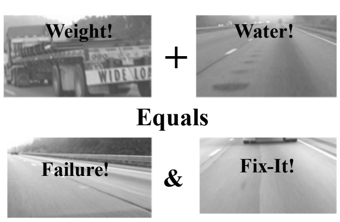
Mat Thickness

- Important for orientation of coarse aggregate
- Critical for achieving density
- Thin lifts cool quicker and will not compact as easily
- Monitor lift thickness constantly!

Benefits of SMA



When Stripping Exists Below!!!



Superpave 4.75-mm
a/k/a Sand Mix Layer (SML)

Presentation compliments of
Abdul Dahhan, P.E.
District One

Murphy Pavement Technology

We'll look at…

- What/Why
- Materials / Volumetric's
- Construction / Density

What is IL-4.75 mm?

- It's a mix with 100% fine aggregate (FA).
- That can be used as a binder.

Visuals are nice…

Why Use IL-4.75 mm?

- Higher in-Place Density & Stability
- Resist reflective cracking
- Waterproof
- Improve ride

Mixture Composition

- Stone Sand / Slag Sand
- Natural Sand
- Mineral Filler
- Polymerized AC

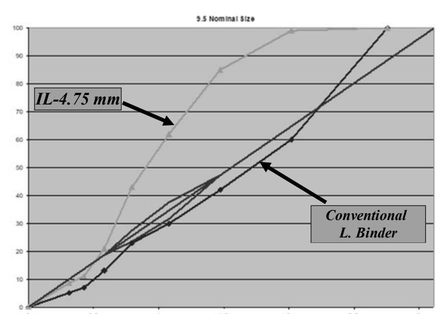
Stability

Flexibility

Waterproofing

Mix Gradation

Sieve	Percent Passing
9.5 mm (3/8 in.)	100
4.75 mm (No. 4)	90 - 100
2.36 mm (No. 8)	70 - 90
1.18 mm (No. 16)	50 - 65
600 µm (No. 30)	35 - 55
300 µm (No. 50)	15 - 30
150 µm (No. 100)	10 - 18
75 µm (No. 200)	7 - 9
AC Content	7% to 9%



Design Criteria

- Air Voids 4.0% @ N50
- VMA 18.5 Min
- VFA 82 – 92
- Dust / AC 1.0
- Drain Down 0.3% Max

Typical IL-4.75 mm Mix Design

Aggregate:

FMM-20	64%	Stone Sand
FMM-02	30%	Natural Sand
Mineral Filler	6%	Manufactured

Asphalt Cement:

SBS PG 76-XX 8%

Mixture Performance

- APA (Small deformation)
- Skid (Research continues)
- TSR (>85%)
- Density (93.5% - 97.4% of G_{mm})

Construction

- Placement
- Temperature
- Compaction

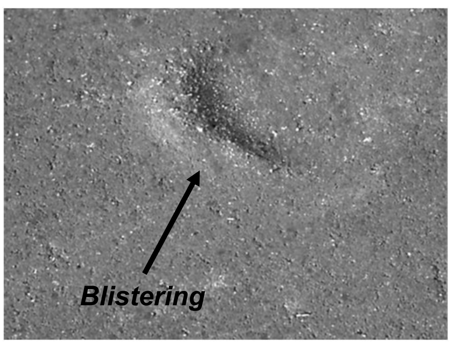
Placement

- Surface can be scarified or smooth
- Surface shall be clean & primed
- Conventional paver

Compaction

- (3) Ballasted Static Rollers
  - Breakdown roller 3 passes
  - Intermediate roller 2 passes
  - Finish roller

Do not use vibratory rollers



IL-9.5 mm
Fine Graded

Mix Gradation

Sieve	Percent Passing
12.5 mm (1/2 in.)	100
9.5 mm (3/8 in.)	90 – 100
4.75 mm (No. 4)	65 – 75 (*80)
2.36 mm (No. 8)	50 – 60 (*65)
1.18 mm (No. 16)	25 – 40
600 μm (No. 30)	15 – 30
300 μm (No. 50)	8 – 15
150 μm (No. 100)	6 – 10
75 μm (No. 200)	4 – 6.5
Asphalt Binder Typically	5% to 7%

* When used as binder

Design Criteria

- Air Voids 4.0% @ N50
- VMA 15.0 Min
- VFA 65 – 78
- Dust / AC 1.0

Typical IL-9.5FG Mix Design

Aggregate:

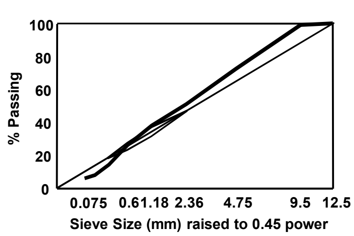
FMM-20	67%	Stone Sand
FMM-02	28%	Natural Sand
Mineral Filler	5%	Manufactured

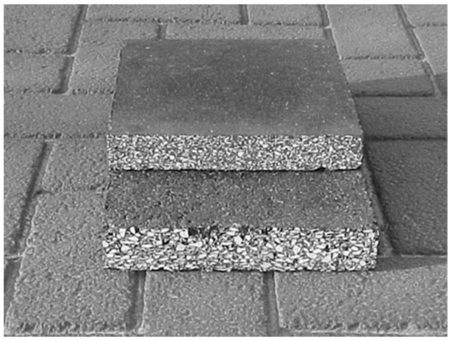
- Asphalt Cement: 6% of PG64-22
- RAP is allowed.
- N_{des} per traffic loading

Low Volume @ N30

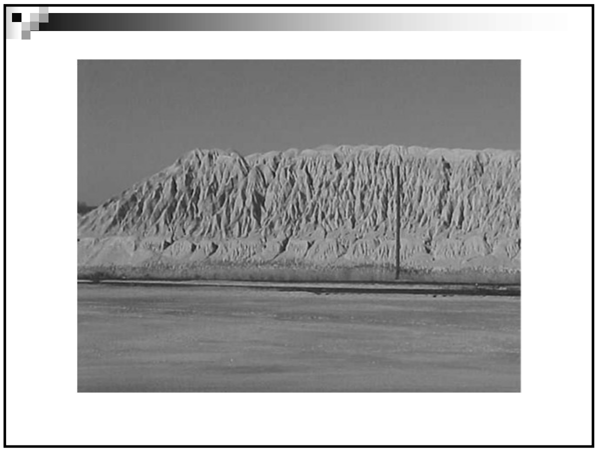
- Developed by Agency/Industry task force,
- Improve performance of low volume pavements,
- Durability more important than rut resistance.

Low Volume @ N30 Gradation





	Low Volume @ N30 Surface Mixture					
MATERIAL:		CA #1	FA #1	FA #2	RAP	Breakdown
SIZE:		3/8"	Man Sand	Nat Sand	RAP	
AGGREGATE						
BLEND:		24.0	15.0	30.0	30.0	1.0
BULK SpG:		2.636	2.718	2.622	2.826	2.750
APPARENT SpG:		2.790	2.765	2.785	2.826	2.850
ABSORPTION:		2.1	1.1	2.2		
	OPTIMUM DATA					
	P_b	Gmb	Gmm	Voids	VMA	VFA
	6.3	2.382	2.457	3.0	15.3	80



□

- Stone Matrix Asphalt
- IL-4.75-mm
- Fine graded surface course, N50

IDOT Lab Verification No.: ---> ____ Ver. 12.10-05.07.18 DATE: 31-Jul-18

Producer Number & Name --> 911-01 Asphalt Anytown, Illinois <--- Plant Location

80BIT9111

Material Code Number ----> 19654R SMA SC N80 12.5 E REC

Plant Bin #	#7	#6	#5	#4	#3	#2	#1	MF	RCY	RCY	RCY	RCY	ASPHALT
Size	0	0	0	0	022CM14	022CM13	038FA20	004MF01	017CM3400	017CM0100	017FM98	Fiber	10131
Source (PROD #)													
(NAME)													
(LOC)													
(ADD. INFO)													PG 76-22
									5.3	3.3	26.0	0.0	< AB in RAP
	Aggregate Blend:											Plan PG Grade >	PG 76-22
	0.0	0.0	0.0	0.0	44.4	25.5	7.1	5.3	14.8	0.0	2.6	0.3	100.0
	Mixture Blend:												Totals: ⇕
	0.0	0.0	0.0	0.0	41.4	23.8	6.6	4.9	14.6	0.0	3.3	0.3	100.0

Agg No. / Sieve Size	#7	#6	#5	#4	#3	#2	#1	MF	RCY	RCY	RCY	RCY	Aggregate Blend	Mixture Comp Spec
1" (25.0mm)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100	
3/4"(19.0mm)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.0	100.0	100.0	100	100
1/2" (12.5mm)	100.0	100.0	100.0	100.0	89.7	96.6	100.0	100.0	100.0	83.0	100.0	100.0	95	90-99
3/8" (9.5mm)	100.0	100.0	100.0	100.0	52.7	82.3	100.0	100.0	100.0	62.0	100.0	100.0	74	50-85
No.4 (4.75mm)	100.0	100.0	100.0	100.0	5.0	25.0	98.8	100.0	77.0	29.0	97.6	100.0	35	20-40
No.8 (2.36mm)	100.0	100.0	100.0	100.0	2.4	4.0	71.1	100.0	51.0	20.0	93.6	100.0	23	16-24
No.16 (1.18mm)	100.0	100.0	100.0	100.0	2.0	1.4	38.7	100.0	36.0	15.0	74.6	100.0	17	
No.30 (600µm)	100.0	100.0	100.0	100.0	1.4	1.0	20.4	100.0	25.0	12.0	48.0	100.0	13	
No.50 (300µm)	100.0	100.0	100.0	100.0	0.8	0.8	11.4	100.0	17.0	9.0	40.2	100.0	11	
No.100 (150µm)	100.0	100.0	100.0	100.0	0.6	0.6	8.2	98.0	12.0	7.0	34.0	100.0	9	
No.200(75µm)	100.0	100.0	100.0	100.0	0.4	0.4	6.4	88.0	9.4	4.9	27.4	100.0	7.8	8.0-11.0
Bulk Sp Gr	1.000	1.000	1.000	1.000	2.663	2.641	2.597	2.800	2.630	2.630	2.500	1.000	2.637	Dust/AB
Absorption, %	1.00	1.00	1.00	1.00	0.30	0.60	2.90	1.00	1.00	1.00	1.00	1.00	0.46	Ratio
												SP GR AB	1.030	1.15

SUMMARY OF SUPERPAVE GYRATORY DESIGN DATA

DATA for N-int.

	AB, %MIX	Gmb	Gmm	Voids (Pa)	VMA	VFA	Vbe	Pbe	Pba
MIX 1	6.2	2.090	2.439	14.3	25.7	44.2	11.36	5.60	0.64
MIX 2	6.7	2.106	2.426	13.2	25.5	48.3	12.29	6.01	0.74
MIX 3	7.2	2.119	2.402	11.8	25.4	53.7	13.64	6.63	0.61
MIX 4	7.7	2.125	2.379	10.7	25.6	58.3	14.94	7.24	0.50

DATA for N-des.

		Gmb	Gmm	Voids (Pa)	VMA	VFA	Vbe	Pbe	Gse	Pba
MIX 1	6.2	2.301	2.439	5.7	18.2	68.8	12.51	5.60	2.681	0.64
MIX 2	6.7	2.321	2.426	4.3	17.9	75.8	13.54	6.01	2.688	0.74
MIX 3	7.2	2.335	2.402	2.8	17.8	84.4	15.03	6.63	2.679	0.61
MIX 4	7.7	2.340	2.379	1.6	18.1	90.9	16.45	7.24	2.671	0.50

Hamburg Wheel Information	
Sample No. Passes	20000
Sample Wheel Depth	-4.06
I-FIT Information	
Flexibility Index	18.8
TSR Information	
Conditioned	108.3
Unconditioned	103.8
TSR	1.04
CA Strip Rating	2
FA Strip Rating	1
Additive Prod #	
Additive Product Name	
Additive %	

OPTIMUM DESIGN DATA @ Ndes

GYRATIONS	AB	Gmb	Gmm	%VOIDS (Pa)	VMA	VFA	Gse	Gsb	TSR	RCY AB	Virgin AB	ABR
	6.81			Target								
	6.8	2.324	2.421	4.0	17.9	77.6	2.686	2.637	1.04	1.62	5.19	23.8

REMARKS LINE 1 ____

REMARKS LINE 2 ____

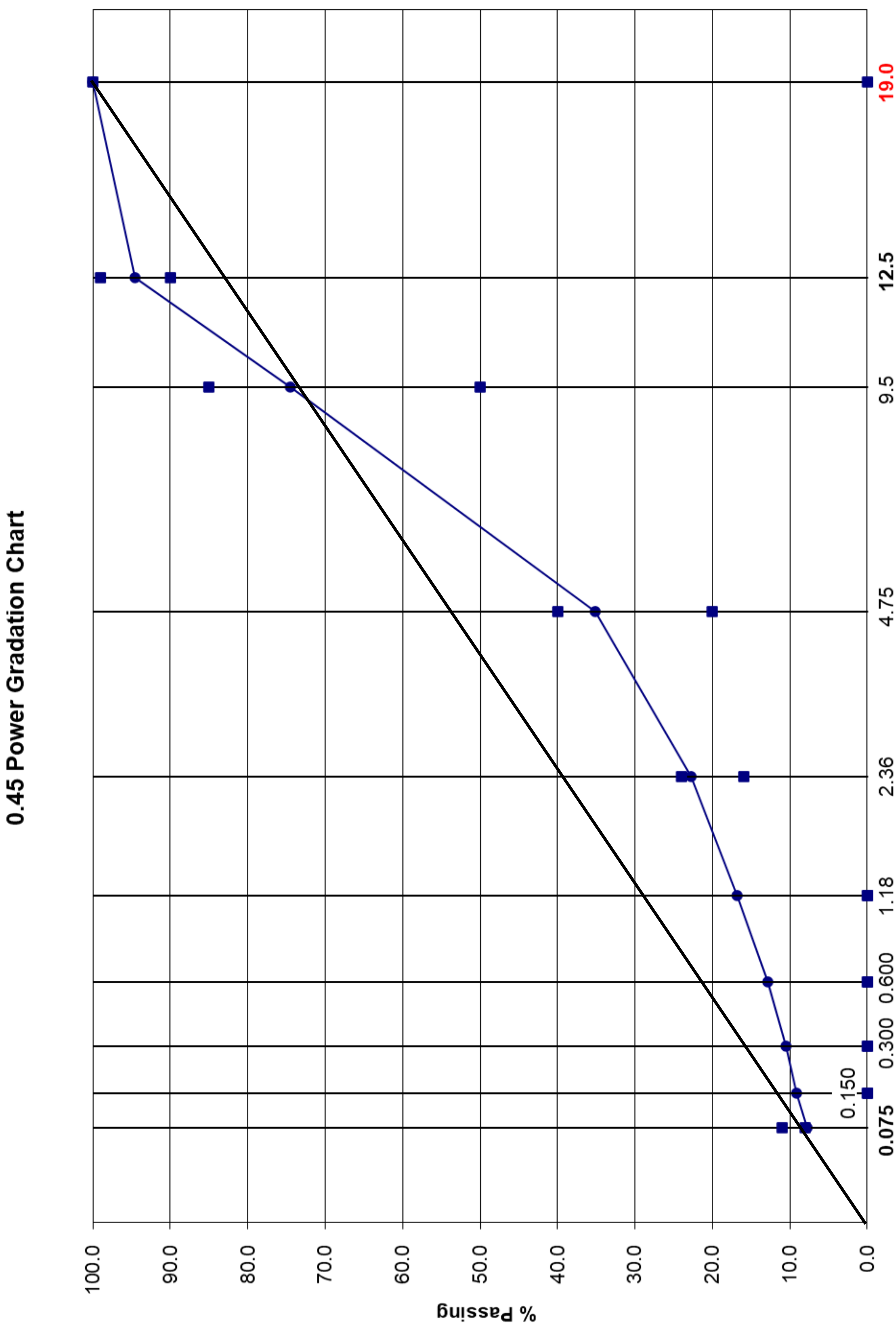
BITUMINOUS MIXTURE AGED 1 HOURS @ 146

80BIT9111

Lab Preparing Design ____
Designing Lab Mix# ____
Designing Lab Name ____

Tested by : ____ Verified by: ____

Reviewed by : ____ Final Approval : ____


0.45 Power Gradation Chart
% Passing
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
19.0
12.5
9.5
4.75
2.36
1.18
0.600
0.300
0.150
0.075

Illinois Department of Transportation

Procedure when using Fibers in Bituminous Mixture Designs

Effective Date: August 25, 2004

1.0 GENERAL

When designing and producing bituminous mixtures with high asphalt contents and/or open-graded aggregate structure, a stabilizing agent such as fibers is used to hold the asphalt binder on the coarse aggregates during hauling and placement.

2.0 MATERIALS

A. The fibers are organic (cellulose fibers) or mineral fibers.
   1. Cellulose fibers are typically added at a rate of 0.3% (by weight of total mixture).
   2. Mineral fibers are typically added at a rate of 0.4% (by weight of total mixture).

B. During the mix design phase, the fibers are considered part of the aggregate blend. As a result, each aggregate weight is adjusted to account for the weight of the fibers that is added.

C. The fibers must meet all physical and chemical property requirements as stated in applicable specifications.

3.0 DRAINDOWN TEST

A. All mixtures containing fibers must pass a draindown test according to IL-modified AASHTO T 305, “Determination of Draindown Characteristics of Uncompacted Asphalt Mixtures”, to determine the mixture’s susceptibility to draindown of the asphalt binder. The test shall be conducted at two temperatures. One of the temperatures shall be the lab mixing temperature while the second shall be 15°C (27°F) higher than the lab mixing temperature.

B. The draindown shall be a maximum of 0.30% or less. If the mixture fails to meet this requirement, then the amount of fibers should be increased by 0.1% to reduce the draindown to an acceptable level.

4.0 SPECIMEN PREPARATION

A. The aggregates shall be dried to constant mass and separated into the appropriate size fractions as stated in IL-modified AASHTO T 245.

B. Determine the mixing temperature for the mix.

C. Weigh the correct amount of each size fraction for each batch and blend the weighed aggregate for each batch in a separate pan.

D. Place the aggregate samples in the oven set to the mixing temperature.

E. Heat the asphalt to the mixing temperature.

F. Place the heated aggregate in a mixing bowl.

G. Form a crater in the heated aggregate blend and add the measured amount of fibers.

H. Mix until the fibers are uniformly dispersed (5 to 15 seconds).

I. Form a crater in the heated aggregate and add the correct amount of heated asphalt.

J. Mix the heated aggregate with fibers and the heated asphalt until the aggregate is thoroughly coated.

Designing With Fibers

F = % Fibers in the Mix
AC = Percent of Asphalt Binder in the Mix
X = % Aggregate in the Mix
M = Weight of the Mix (grams)
P_1, P_2, P_3, … P_n = % Weight of an Individual Aggregates
W_1, W_2, W_3, … W_n = Adjusted Weight of an Individual Aggregate (grams) (to account for Fibers)
W_f = Weight of Fibers (grams)
W_{ac} = Weight of Asphalt (grams)
T = Total Adjusted Weight of Individual Aggregates (grams) (to account for Fiber Addition)
T_{af} = Total Adjusted Weight of Individual Aggregates and Fibers (grams)
T_m = Total Weight of Mix (grams)

Eq. 1	T = [{(X - F) / 100} x M]

T =	**9410.0**

Eq. 2	W = T x (P / 100)

Eq. 3	$T = W_1 + W_2 + W_3 + \ldots + W_n$

Check	**T =**	**9410.0**

Eq. 4	$T_{af} = T + W_f$

T_{af} =	**9440.0**

F =	0.3	**P_1** =	25.0	**W_1** =	2352.5
X =	94.4	**P_2** =	20.0	**W_2** =	1882.0
M =	10000.0	**P_3** =	16.0	**W_3** =	1505.6
AC =	5.6	**P_4** =	14.0	**W_4** =	1317.4
W_{ac} =	560.0	**P_5 =**	10.0	**W_5 =**	941.0
T_m =	10000.0	**P_6 =**	9.0	**W_6 =**	846.9
Check - Should = M		**P_7 =**	4.0	**W_7 =**	376.4
		P_8 =	2.0	**W_8 =**	188.2
		P_9 =		**W_9 =**	
		P_{10} =		**W_{10} =**	
	Should equal 100%	**Total %**	100.0	**W_f =**	30.0

EXAMPLE

Assume:

The weight of mix = 10000 grams
The percent of asphalt = 5.6
The percent of fibers = 0.3
The percent of aggregate #1 = 61.0
The percent of aggregate #2 = 20.0
The percent of aggregate #3 = 16.0
The percent of aggregate #4 = 3.0

Calculate the total adjusted weight of the individual aggregates.

Eq. 1	T = [{(X - F) / 100} x M]

T = [{(94.4 - 0.3) / 100} x 10000} = 9410.0

Calculate the adjusted weight of the individual aggregates.

Eq. 2	W = T x (P / 100)

W_{aggr1} = 9410 x (61.0 / 100) = 5740.1

W_{aggr2} = 9410 x (20.0 / 100) = 1882.0

W_{aggr3} = 9410 x (16.0 / 100) = 1505.6

W_{aggr4} = 9410 x (3.0 / 100) = 282.3

Calculate the weight of fibers

$W_f = M \times (F / 100)$

W_f = 10000 x (0.3 / 100) = 30.0

Calculate the total adjusted weight of aggregate and fibers

Eq. 4	$T_{af} = T + W_f$

T_{af} = 5740.1 + 1882.0 + 1505.6 + 282.3 + 30.0 = 9440

Calculate the weight of asphalt binder

$W_{ac} = M \times (AC / 100)$

W_{ac} = 10000 x (5.6 / 100) = 560

Check the total weight of mix

$T_m = T_{af} + W_{ac}$

T_m = 9440.0 + 560.0 = 10000 **Checks, equals "M"**

Illinois Modified Test Procedure
Effective Date: December 1, 2021

Standard Method of Test
for
Bulk Density ("Unit Weight") and Voids in Aggregate

Reference AASHTO T 19 / T 19M-14 (2018)

AASHTO Section	***Illinois Modification***
1.2	Revise "AASHTO M 92" to read "AASHTO M 92 (Illinois Modified)".
2.1	Revise the individual Standards as follows: AASHTO M 92 (Illinois Modified) AASHTO R 90 (Illinois Modified) AASHTO T 84 (Illinois Modified) AASHTO T 85 (Illinois Modified) AASHTO T 121 (Illinois Modified) AASHTO R 76 (Illinois Modified) Illinois Specification 201
3.2.1.1	Revise "AASHTO T 19/T 19M" to read "AASHTO T 19/T 19M (Illinois Modified".
5.2	Revise as follows: *Tamping Rod*—A round, straight steel rod, 16 mm (5/8 inch) in diameter and a minimum of 584 mm (23 inches) long, having one end rounded to a hemispherical tip of the same diameter as the rod.
5.3.1	Revise "AASHTO T 121" to read "AASHTO T 121 (Illinois Modified)".
5.6 New Section	*Source of Heat*—An oven of sufficient size, specifically built for drying, capable of maintaining a uniform temperature of 110 ± 5 °C (230 ± 9 °F) shall be used for drying. In addition, a gas burner or electric hot plate may be used. Microwave ovens are not permitted for drying unit weight or voids test samples.
6.1	Replace with the following: Field samples of aggregate shall be taken according to AASHTO R 90 (Illinois Modified). Field sample size shall conform to the minimum requirements in the Illinois Specification 201. Reduction of field samples shall be according to AASHTO R 76 (Illinois Modified).
7.1	Replace the second sentence with the following: The test sample shall be dried to constant mass in an oven, specifically built for drying, set at and capable of maintaining a uniform temperature of 110 ± 5 °C (230 ± 9 °F). Constant mass is defined as the sample mass at which there has not been more than a 0.5-gram loss during 1 hour of drying. This should be verified occasionally.

Illinois Modified Test Procedure
Effective Date: December 1, 2021

Standard Method of Test
for
Bulk Density ("Unit Weight") and Voids in Aggregate

Reference AASHTO T 19 / T 19M-14 (2018)

AASHTO Section	***Illinois Modification***
7.1 (cont.)	The sample may also be dried to constant mass in a pan on an electric hot plate or gas burner. The technician shall continually attend the sample when drying on the electric hot plate or gas burner. Microwave ovens are not permitted for drying unit weight or voids test samples. The electric hot plate or gas burner should be operated on a low-as-needed heat to prevent popping, crackling, and/or sizzling noise from the aggregate during drying. If these noises occur, the heat must be turned down and/or the sample must be constantly stirred during drying to prevent potential aggregate particle breakdown.
7.1	Add the following: When more than one size of coarse aggregate is to be used in IDOT's mortar-voids design method for portland cement concrete mixtures, the void content shall be determined from a sample consisting of the coarse aggregate combination.
9.1	Replace with the following: The compact bulk density shall be determined by the rodding procedure for aggregates having a nominal maximum size of 37.5mm (1 ½ in.) or less, or by the jigging procedure for aggregates have a nominal maximum size greater than 37.5mm (1 ½ in.) and not exceeding 125mm (5 in.).
10.1	Add the following: The tamping rod may be used as a straightedge.
12.1	Delete.
12.2	Delete.
13.1	Revise the first sentence as follows: *Unit Weight*—Calculate the unit weight for the rodding or jigging procedure as follows:
13.1.1	Revise "AASHTO T 84" to read "AASHTO T 84 (Illinois Modified)" and "AASHTO T 85" to read "AASHTO T 85 (Illinois Modified)".
13.2	Revise the first sentence as follows: *Void Content*—Calculate the void content in the aggregate using the unit weight determined by either the rodding or jigging procedure as follows:

Illinois Modified Test Procedure
Effective Date: December 1, 2021

Standard Method of Test
for
Bulk Density ("Unit Weight") and Voids in Aggregate

Reference AASHTO T 19 / T 19M-14 (2018)

AASHTO Section	***Illinois Modification***
13.2	Revise "AASHTO T 84" to read "AASHTO T 84 (Illinois Modified)" and "AASHTO T 85" to read "AASHTO T 85 (Illinois Modified)".
13.3 New Section	When more than one size of coarse aggregate is used in IDOT's mortar-voids design method for concrete mixtures, the void content is determined from a sample consisting of the coarse aggregate combination. To perform the calculation in Section 13.2, the bulk specific gravity (dry basis) shall be a weighted average of the coarse aggregate combination. Example: A Aggregate = 2.601 specific gravity / 40% blend B Aggregate = 2.676 specific gravity / 60% blend Blend Specific Gravity = (2.601 x 0.4) + (2.676 x 0.6) = 2.646
14.1	Revise as follows: Report the results for unit weight to the nearest 1 kg/m^3 (1 lb/ft^3).
14.1	Add the following: All rounding shall be according to ASTM E 29 (Illinois Modified).
14.1.3	Delete.
14.2.3	Delete.
15.4	Revise "AASHTO T 84" to read "AASHTO T 84 (Illinois Modified)" and "AASHTO T 85" to read "AASHTO T 85 (Illinois Modified)".

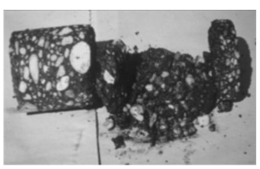
Stripping of Hot Mix Asphalt

- Definition and Explanation of Stripping
- Method for Introducing Anti-strip Additives in the Lab
  - Liquid Anti-strip
  - Hydrated Lime
- Tests to Identify Stripping
  - AASHTO T-283
  - Visual Identification of Stripping

Timothy R. Murphy, P.E.
President
Murphy Pavement Technology

Stripping Definition

Simply stated, stripping is the breaking of the adhesive bond between the aggregate surface and the asphalt binder.



Adhesion Definition

Adhesion is defined as the force of attraction between unlike molecules that makes bodies stick together.

The Cause of Stripping

There is only one cause of stripping - water getting between an asphalt film and and aggregate surface and replacing the asphalt as the aggregate's coating.

Problems Caused by Stripping

- Stripping Contributes to Pavement Distresses including:
  - Rutting,
  - Raveling, and
  - Cracking.

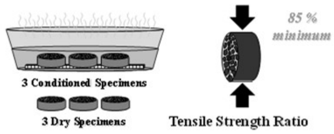
Tests to Evaluate Stripping

- AASHTO T-283
- Visual Stripping Evaluation

Testing Protocol

Moisture Sensitivity
Modified AASHTO T 283

- Measured on Proposed Aggregate Blend and Asphalt Binder Content



Specimen Preparation

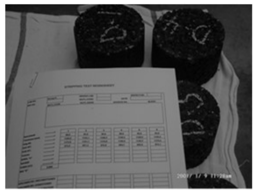
Illinois uses 6-inch (150mm) specimens, compacted using the Gyratory compactor.

Specimen Preparation

Compact pilot specimens (at optimum AC) to a void level of 7% +/- 1.0%. This procedure follows the compaction and bulk specific gravity (G_{mb}) process using the Gyratory Compactor.

Specimen Preparation

Six test specimens are compacted to 7% +/- 1.0% voids.

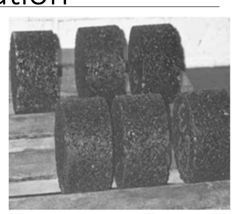


Specimen Preparation

- Determine the height of each of the six bricks as previously discussed.
- Determine the bulk specific gravity (G_{mb}) of all six bricks and, by using the maximum theoretical specific gravity (G_{mm}) from the mix design, calculate the void percent of each brick.
- Calculate the volume of air voids (cc) of all six bricks.

Specimen Preparation

- Divide the six bricks into conditioned and unconditioned sets, each containing three bricks so that the average bulk specific gravity (G_{mb}) of each group is approximately equal.
- Store the unconditioned bricks at room temperature until test time and the conditioned bricks in the 25° ± 1° C (77° ± 1.8° F) bath.



Specimen Preparation

- Check the conditioned bricks to determine if the 70% to 80% saturation level has been achieved in the bath. If not, proceed to vacuum-saturate according to the method described in prior training.

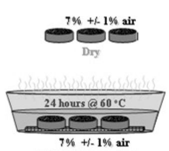
Specimen Preparation

- Once the saturation level is attained, place the conditioned bricks in a 60° ± 1° C (140° ± 1.8° F) bath for 24 hours for a moisture conditioning cycle.
- After the conditioning cycle is complete, place both the conditioned and the unconditioned bricks in a 25° ± 1° C (77° ± 1.8° F) bath for 2 hours to bring to a constant temperature.

Testing Protocol

Modified AASHTO T 283 Conditioning

- Unconditioned "Dry" Set
  - 2 hrs @ 25°C before testing
- Conditioned "Wet" Set
  - 24 hrs @ 60°C
  - 2 hrs @ 25°C before testing

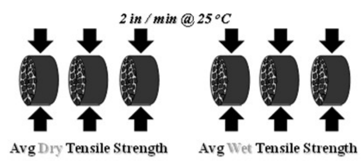


Specimen Preparation

- Determine the split tensile strength of both sets of bricks.
- Proceed with calculations to determine the tensile strength ratio (TSR). If the TSR is above 0.85, it passes. If below 0.85, an additive or variation in additives must be used.

Testing Protocol

AASHTO T 283 Test Procedure



$$TSR = \frac{Wet}{Dry} \geq 85\ \%$$

Specimen Preparation

- If the ratios of the tensile strengths are equal to or above the 0.85 criteria, no anti-strip additive is required (unless determined by the Engineer). If the ratio is less than 0.85, the mixture exhibits a tendency to strip and an anti-strip is required.

Specimen Preparation

- This procedure is then repeated on the mixture in which an anti-strip has been added; typically 0.5% liquid anti-strip and / or 1.0% hydrated lime by weight. Hydrated lime may be added in either the dry or slurry form.
- A current list of approved anti-strip agents is no longer maintained by the Department.

Modifications to Minimize Stripping Potential

- If the mixture fails to meet these test criteria, the designer can modify the mixture is several ways.

Modifications to Minimize Stripping Potential

Some of those changes are as follows:

- Increase the asphalt binder content.
- Use a higher viscosity (heavier) grade of asphalt.
- Provide a cleaner or different aggregate source.
- Add hydrated lime or add liquid anti-strip additive to mix (if benefit is shown in laboratory testing).
- Possibly blend aggregates to improve gradation and density.

Engineering Judgment & Field Observations

- Historically all the test procedures for stripping have been shown occasionally to provide inaccurate results when compared to actual performance;
- Therefore, the indications from these tests should not be considered as ultimate proof of the presence of stripping or the degree of stripping.

Anti-Strip Agents and Hydrated Lime

- Procedure for introducing into the mixture.
- Calculating quantity.

Procedure for Introducing Liquid Anti-Strip

When a liquid anti-strip is used, sufficient asphalt binder for one batch shall be heated in a loosely covered 1-liter (1-quart) can, in an oven, to the recommended temperature.

Procedure for Introducing Liquid Anti-Strip

The required quantity of additive shall be added to the asphalt and mixed immediately with a mechanical stirrer approximately 25 mm (1 inch) from the bottom of the container for approximately 2 minutes.

Procedure for Introducing Liquid Anti-Strip

If the treated asphalt binder is not used on the same day in which it is prepared, or if it is allowed to cool so that it would require reheating, it shall be discarded.

Calculating Quantity of Liquid Anti-Strip

$$\frac{\text{Mass of AC in Container}}{(100 - \text{Additive\%}) / 100} = \frac{\_\_\_\_\_\_\_\_ \text{ g}}{\text{Total Liquid}}$$

Calculating Quantity of Liquid Anti-Strip

$$\frac{\text{Mass of AC in Container}}{(100 - \text{Additive\%}) / 100} = \underset{\text{Total Liquid}}{\underline{\hspace{3em}}}\ g$$

$$\frac{5000}{}$$

Calculating Quantity of Liquid Anti-Strip

$$\frac{\text{Mass of AC in Container}}{(100 - \text{Additive\%}) / 100} = \underset{\text{Total Liquid}}{\underline{\hspace{3em}}}\ g$$

$$\frac{5000}{(100 - 0.5\%) / 100}$$

Calculating Quantity of Liquid Anti-Strip

$$\frac{\text{Mass of AC in Container}}{(100 - \text{Additive\%}) / 100} = \underset{\text{Total Liquid}}{\underline{\hspace{3em}}}\ g$$

$$\frac{5000}{(100 - 0.5\%) / 100} = \frac{5000}{0.995}$$

Calculating Quantity of Liquid Anti-Strip

$$\frac{\text{Mass of AC in Container}}{(100 - \text{Additive\%}) / 100} = \frac{\_\_\_\_\_\_ \text{ g}}{\text{Total Liquid}}$$

$$\frac{5000}{(100 - 0.5\%) / 100} = \frac{5000}{0.995} = \text{5025 g Total Liquid}$$

Calculating Quantity of Liquid Anti-Strip

$$\frac{\text{Mass of AC in Container}}{(100 - \text{Additive\%}) / 100} = \frac{\_\_\_\_\_\_ \text{ g}}{\text{Total Liquid}}$$

$$\frac{5000}{(100 - 0.5\%) / 100} = \frac{5000}{0.995} = \text{5025 g Total Liquid}$$

Total Liquid in Container - Mass of AC in Container = Mass of Additive

Calculating Quantity of Liquid Anti-Strip

$$\frac{\text{Mass of AC in Container}}{(100 - \text{Additive\%}) / 100} = \frac{\_\_\_\_\_\_ \text{ g}}{\text{Total Liquid}}$$

$$\frac{5000}{(100 - 0.5\%) / 100} = \frac{5000}{0.995} = \text{5025 g Total Liquid}$$

Total Liquid in Container - Mass of AC in Container = Mass of Additive

5025 g - 5000g = 25 g

Procedure for Introducing Hydrated Lime

- Dry the aggregates at 230±9°F.
- Fractionalize the aggregates.
- Blend the aggregates into the correct batch size.
- Determine the correct mass of hydrated lime (1.0% by weight of aggregates).

Procedure for Hydrated Lime: Dry Method

- Heat Asphalt Binder and aggregates to Mixing Temperature
  - 295±5°F for neat asphalt
  - 325±5°F for polymer-modified asphalt
- Make a crater in the top of aggregates
- Add dry lime in crater

Procedure for Hydrated Lime: Dry Method

- Mix lime and aggregates (approx. 10 to 15 seconds)
- Make crater in aggregates and add AC to aggregates and lime
- Mix Asphalt Binder with blend of aggregates and lime

Procedure for Hydrated Lime: Slurry Method

- Add the amount of water that is equal to the absorption capacity of the aggregate to the cooled and blended aggregates
- Mix 1.0% dry lime and 3.0% water together to form a slurry.

Add the slurry to the dry aggregates

Procedure for Hydrated Lime: Slurry Method

- Mix until the aggregates and slurry make a homogeneous mixture.
- Dry the coated aggregates in a 230±9°F oven.

Procedure for Hydrated Lime: Slurry Method

- Heat the aggregates and Asphalt Binder to the mixing temperature.
  - 295±5°F for neat asphalt
  - 325±5°F for polymer-modified asphalt
- Make a crater in the aggregates and add the correct amount of asphalt to the blend.

Procedure for Hydrated Lime: Slurry Method

- Mix the asphalt with the aggregate and lime blend until the aggregates are completely coated.

Calculating Quantity of Hydrated Lime

Mass of Aggregate Batch = ____________ g *
(100 – Lime %) / 100 (Total Mass of Solid Material)

Mass of Solid Material, g ____________
minus Mass of Aggregate Batch, g ____________
equals Mass of Lime to introduce, g ____________

**** Adjust AC Mass***

Calculating Quantity of Hydrated Lime

Mass of Aggregate Batch = 6060 g *
(100 – Lime %) / 100 (Total Mass of Solid Material)

Mass of Solid Material, g ____________
minus Mass of Aggregate Batch, g ____________
equals Mass of Lime to introduce, g ____________

**** Adjust AC Mass***

Calculating Quantity of Hydrated Lime

Mass of Aggregate Batch / (100 – Lime %) / 100	=	6060 g * (Total Mass of Solid Material)

Mass of Solid Material, g	6060
minus Mass of Aggregate Batch, g	6000
equals Mass of Lime to introduce, g	60

***Adjust AC Mass**

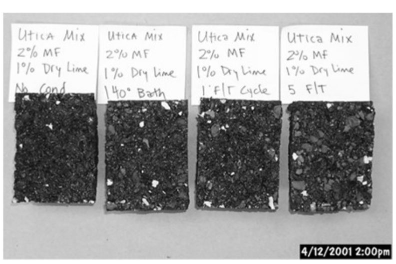
Stripping of HMA Mixtures

Visual Identification & Classification

INSTRUCTIONS

PROCEDURES

Stripping:
Visual Identification and Classification



Visual Identification of Stripping Procedure

The following instructions describe the method to be used for visually identifying and classifying the effect of moisture damage on the adhesion of asphalt binder to the aggregate in bituminous mixtures. This procedure provides the means to rate this phenomena in numerical terms and by assigning an adjective description. This procedure is applicable to both pavement cores[1] and freshly compacted laboratory specimens.

(Reference document at back of chapter.)

Visual Identification of Stripping Procedure

- Obtain a freshly split face through the split tensile test or some other means.

Visual Identification of Stripping Procedure

- Observe the coarse aggregate of the split face with the naked eye. Pay special attention to the coarse aggregate that is broken, fractured, or merely dull. These particles are not stripped.

Visual Identification of Stripping Procedure

- Based on the following descriptions, assign a strip rating to the coarse aggregate of the split face:
  - 1 - less than 10% of the entire area of all the coarse aggregate particles is stripped
  - 2 - between 10% and 40% of the entire area of all the coarse aggregate particles is stripped
  - 3 - more than 40% of the entire area of all the coarse aggregate particles is stripped

Visual Identification of Stripping Procedure

- Observe the fine aggregate particles and rate the particles for percent of the area showing moisture damage. A microscope or magnifying glass with a total magnification of 10X should be used to aid in viewing the samples.
- Observe the fine aggregate particles and mentally rate the particles present in the field of view. Move the sample to a new field of view and rate the particles present.
- Repeat this process once more, ensuring a new field of view is chosen. Average the three (3) observations.

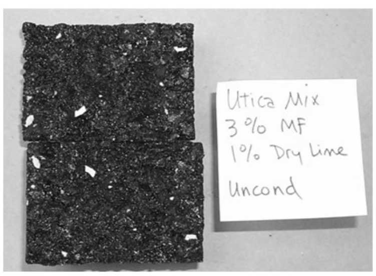
Visual Identification of Stripping Procedure

- Assign a strip rating to the fine aggregate of the split face based on the following descriptions:
  - 1 - less than 10% of the entire area of all the fine aggregate particles viewed is stripped
  - 2 - between 10% and 25% of the entire area of all the fine aggregate particles viewed is stripped
  - 3 - more than 25% of the entire area of all the fine aggregate particles viewed is stripped

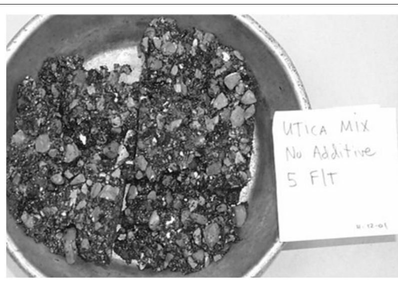
Visual Identification of Stripping Procedure

- Report the individual strip ratings for coarse and fine aggregate, the composite strip rating, and the description on the strip rating form.
- Include any comments or special notes about the observations from that sample.

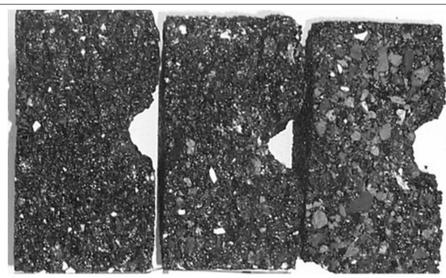
Visual Strip Rating: Coarse & Fines = 1.0



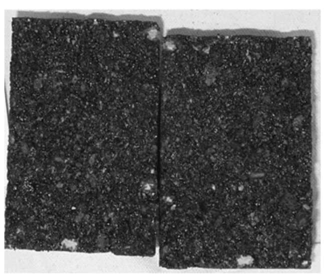
Visual Strip Rating: Coarse = 3.0



Visual Strip Rating:
Coarse = 1.0, 2.0, & 3.0

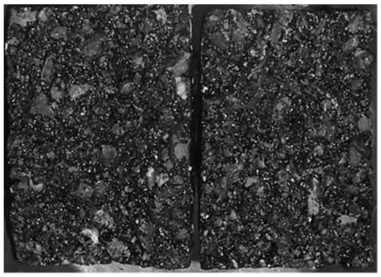


Visual Strip Rating:
Fines = 3.0



Visual Strip Rating:
Fines = 2.0

Visual Strip Rating: Coarse & Fines = 2.0



Visual Strip Rating: Coarse & Fines = 2.0

Summary

- Definition and Explanation of Stripping
- Method for Introducing Anti-strip Additives in the Lab
  - Liquid Anti-strip
  - Hydrated Lime
- Tests to Identify Stripping
  - AASHTO T-283
  - Visual Identification of Stripping

ADDITIONAL CRITERIA FOR AN APPROVED MIX DESIGN

There are two additional criteria which the designer must consider in an attempt to produce an approved mix design for use on IDOT projects: (1) a Moisture Susceptibility Analysis (TSR) which is performed in the lab and (2) designing a mix which is reproducible in the field. This means all criteria in the lab should be achievable in the field with minor modifications. The second criterion will be evaluated during the start-up and first day of paving with a decision being made as to continue paving with or without changes or require a new mix design. A few suggestions were made in prior discussions to aid in achieving a reproducible mix, so the rest of this section will focus on the TSR analysis.

A. General

On occasion a properly designed HMA mixture may not perform as expected. The reasons for this lack of good performance may be related to material durability or compatibility. Durability tests may be divided into two categories: aggregates and mixtures. Standard durability tests for the physical properties of the aggregate has already been discussed and evaluated by IDOT during their quality tests.

Once the aggregate is acceptable based on these tests, a mixture is then designed in accordance with procedures as outlined earlier. The other category of durability tests is concerned with how that aggregate reacts with the asphalt and how the properties of the finished mix design react in the presence of water.

B. Aggregate/Asphalt Compatibility

The property of adhesion between asphalt and aggregates in HMA is very complex and not clearly understood. The loss of bond (stripping) due to the presence of moisture between the asphalt and the aggregate is a problem in some areas of the country and can be severe in some cases. Research has identified five different mechanisms by which stripping may occur. These mechanisms are detachment, displacement, spontaneous emulsification, pore pressure, and hydraulic scouring. These may act individually or together to cause an adhesion failure.

The stripping behavior is complicated by many factors such as type and use of the asphalt-aggregate mix, asphalt characteristics, aggregate characteristics, environment, traffic, construction practice, drainage, and the use of various anti-strip additives. Hydrophobic (water-hating) aggregates (such as limestone) that have porous, slightly rough surfaces, and surfaces that are clean, dry, and have been aged for a period of time to acquire an organic contamination, will generally provide better stripping resistance.

The capacity for water getting into and draining out of a pavement has also been shown to be a critical factor. Stripped wet mixtures can be much weaker than dry mixtures. However, the effects may be reversible if the asphalt is not completely washed away from the layer. It has also been shown that an existing stripping problem can be mitigated by changing the asphalt or aggregate, or by adding hydrated lime or a proven additive based on the results of a laboratory strength test. The compatibility of all the actual mix components needs to be checked as a part of the mix design.

IDOT has developed a test procedure to be used to determine the moisture susceptibility of asphalt paving mixtures and to evaluate the potential of certain additive or mix changes. The actual test procedure has been taught in Level I and again performed in this class.

It has been documented in previous research at the Asphalt Institute and by others that the stripping behavior of various mixes is affected by the amount of asphalt binder surrounding the aggregates and the percentage of air voids through which the moisture must travel. If the mixture fails to meet these test criteria, the designer can modify the mixture is several ways. Some of those changes are as follows:

1. Increase the asphalt binder content.
2. Use a higher viscosity (heavier) grade of asphalt.
3. Provide a cleaner or different aggregate source.
4. Add hydrated lime as a mineral filler or add liquid anti-stripping additive to mix (if benefit is shown in laboratory testing).
5. Possibly blend aggregates to improve gradation and density.

A good deal of judgment is still required; eliminating cheaper local materials based on the results of an overly demanding test would be extremely regrettable. In summary, all the test procedures have been shown occasionally to provide incorrect results when compared to actual performance; therefore, the indications from these tests should not be considered as ultimate proof of compatibility.

C. Tensile Strength Ratio (TSR)

IDOT requires a minimum TSR value of 0.85 for a passing design. This test shall be conducted according to Illinois' test procedures at the optimum Asphalt Binder content selected for the design. Typically, the HMA design procedure requires two to three days to determine optimum Asphalt Binder and to verify that it meets all the remaining criteria. Once the optimum Asphalt Binder is determined, gyratory cylinders can be made for TSR testing. To expedite the TSR, multiple testing can be run simultaneously. Testing of the mix with no additive as well as testing with different additives or dosage rates is a means to complete this phase with a better probability of achieving the minimum TSR in the shortest time frame - three days.

D. Additives

The contractor has the option of using hydrated lime, in slurry or dry form, or a liquid anti-strip.

1. Anti-Strip

(a) Procedure for Introducing into Mixture

When a liquid anti-strip is used, sufficient asphalt binder for one batch shall be heated in a loosely covered 1-liter (1-quart) can, in an oven, to the recommended temperature. The required quantity of additive shall be added to the asphalt and mixed immediately with a mechanical stirrer approximately 25 mm (1 inch) from the bottom of the container for approximately 2 minutes. If the treated asphalt binder is not used on the same day in which it is prepared, or if it is allowed to cool so that it would require reheating, it shall be discarded.

(b) Calculating Quantity

The usual dosage rate of liquid additive is between 0.25% and 1% by weight of liquid AC.

See Figure 13.1

It should be noted that the batch weight calculated for virgin Asphalt Binder shall remain the same quantity. This quantity shall be comprised of liquid Asphalt Binder and liquid anti-strip.

2. Hydrated Lime

(a) Procedure for Introducing into Mixture

When hydrated lime is used, the procedure shall simulate the procedure expected in the field. One of the two procedures specified below should be used.

(1) Dry Form. When hydrated lime is added to damp aggregate, the damp mineral shall be batched, and the moisture content of the combined aggregate shall be adjusted to the required field moisture level. The required quantity of lime shall be added to the damp aggregate, and the entire mass shall be thoroughly mixed until a uniform distribution of additive has been achieved. Care shall be taken to minimize loss of additive to the atmosphere in the form of dust. After mixing, the treated aggregate shall be dried, heated to the temperature required for mixing, and maintained at that temperature until it is used.

(2) Slurry Form. When a slurry is used, the required quantity of lime shall be added to the water using the lime-to-water ratio expected in the field. Care shall be taken to minimize the loss of additive to the atmosphere in the form of dust. The resulting slurry shall be mixed continuously until it is used, to prevent settling.

The dry mineral aggregate shall be batched, the required quantity of slurry shall be added, and the entire mass shall be thoroughly mixed until a uniform distribution of slurry has been achieved. After mixing, the treated aggregate shall be redried, heated to the temperature required for mixing, and maintained at that temperature until it is used.

(b) Calculating Quantity

The required application rate is 1.0% to 1.5% by weight of total aggregate. The aggregate batch weight stays the same, and the required lime is added to the batch weight. This requires the Asphalt Binder weight to be corrected.

See Figure 13.2
Figure 13.3,
and Figure 13.4

The Page Is Reserved

INTRODUCTION OF STRIP RATING

01/07/04

As part of the IDOT Bituminous QC/QA Technical Working Group meeting in April 2003, Visual Strip Rating was discussed. Some of the district representatives requested a Visual Strip Rating Guide to aid them when evaluating moisture susceptibility.

This CD contains a DRAFT Strip Rating Guide. Ten files are included on the CD in addition to this introduction. The Guide begins with the file, “B. Stripping Procedure 11-20-03.doc” which is a copy of the "Stripping of Bituminous Mixtures Visual Identification and Classification" procedure. The file “C. Sample Strip Rating Form.xls” contains a strip rating worksheet.

In “D. Visual Strip Rating Guide.xls”, the first worksheet tab gives a brief description of the visual strip rating procedure and its value. The other worksheets each show a picture of a bituminous mix specimen and the rating (1, 2, or 3) that was given to it for either the coarse or fine aggregates in that specimen.

The remaining files contain additional pictures of the split face of bituminous specimens, with each file showing a different rating for coarse and fine stripping.

The intent of this Strip Rating Guide is (1) to be a supplemental tool for evaluating moisture susceptibility and (2) to promote a consistent rating system for evaluating moisture susceptibility. Remember, that visual strip rating is a subjective procedure! Primarily, it is a tool to help determine if a given bituminous mixture has a tendency to be susceptible to moisture damage and to try to assign a numerical value to that tendency. The Visual Strip Rating is intended to be used in addition to Illinois-modified AASHTO T-283 and other tests to determine if an anti-strip additive is required in specific asphalt mixes or to be used to evaluate an existing hot mix asphalt pavement.

Please try to perform Strip Rating Evaluations according to the Guide. Hopefully, the information will be useful. However, it is still a DRAFT and can be improved. Your suggestions for improving this Guide are welcome.

Thank You!

Tom Zehr
IDOT BMPR
(217) 524-7268

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Illinois Department of Transportation

Stripping of Hot-Mix Asphalt Mixtures
Visual Identification and Classification
Appendix B.16

Effective: November 20, 2003
Revised: January 1, 2014

The following instructions describe the method to be used for visually identifying and classifying the effect of moisture damage on the adhesion of asphalt binder to the aggregate in Hot-Mix Asphalt (HMA) mixtures. This procedure provides the means to rate this phenomenon in numerical terms. This procedure is applicable to both laboratory compacted specimens and pavement cores[1].

INSTRUCTIONS

1. This procedure shall only be applied to freshly split specimen faces, such as those obtained from split tensile testing. The observation of cored, sawed, or chiseled faces shall be avoided, as the true condition of the stripping will be obscured.

2. The rating shall be completed within 10 minutes of splitting for maximum clarity. When the specimens dry out, they may look considerably different. The aggregate surfaces shall be examined carefully to determine if the asphalt binder was stripped from the aggregate as a result of being “washed” by water before the specimen was split or if the asphalt binder was “ripped apart” near the asphalt/aggregate interface during the split tensile test. Also, aggregate surfaces with small, relatively isolated, globules of asphalt binder are quite likely not stripped.

3. Special attention shall be given to fractured and broken aggregates. Fractured aggregates are those that were cracked during compaction. These fractured aggregates will have a distinct face with a dull or discolored surface. Broken aggregates are those that were broken during the split tensile test. Broken aggregates often occur near the outside surface of the specimen where the compressive forces are greatest. These broken aggregates will also have a distinct broken face, but will have a bright, uncoated surface. The broken aggregates may be a continuation of a crack that was started during compaction. There is no evidence that a broken aggregate was broken entirely under the compressive force of the split tensile test.

4. Coarse aggregate particles shall be defined as those particles retained on the #8 sieve. Fine aggregate particles shall be defined as those particles that will pass through a #8 sieve.

5. When examining the split face, use the entire face area of all the fine particles separately from all the coarse particles on the split face to determine the percentage of the total area that is stripped. Do not use the percent of the area of each individual stone that is stripped to collectively determine the percentage of stripped aggregate particles on the entire split face of the specimen. Also, do not estimate the percentage of aggregate particles that are

---

[1] Pavement cores taken from the field shall be sealed in plastic bags immediately after coring in order to retain their in-situ moisture. Pavement cores shall be split and visually rated as soon as possible after coring to avoid any “healing” of the asphalt to the aggregate surfaces.

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Stripping of Hot-Mix Asphalt Mixtures
Visual Identification and Classification
Appendix B.16
(continued)
Effective: November 20, 2003
Revised: January 1, 2014

stripped based on the total number of aggregate particles. (i.e., a small stripped aggregate particle does not affect the entire specimen the same as a large stripped aggregate particle.)

PROCEDURE

1. Obtain a freshly split face through the split tensile test.

2. Observe the coarse aggregate of the split face with the naked eye. Pay special attention to the coarse aggregate that is broken or fractured. These particles are not stripped.

3. Assign a strip rating to the coarse aggregate of the split face based on the following descriptions:

    1 - Less than 10% of the entire area of all the coarse aggregate particles is stripped (no stripping to slight stripping).

    2 - Between 10% and 40% of the entire area of all the coarse aggregate particles is stripped (moderate stripping).

    3 - More than 40% of the entire area of all the coarse aggregate particles is stripped (severe stripping).

4. Observe the fine aggregate particles and rate the particles for percent of the area showing moisture damage. A microscope or magnifying glass with a total magnification of 10X shall be used to aid in viewing the specimens. Observe the fine aggregate particles and mentally rate the particles present in the field of view. Move the specimen to a new field of view and rate the particles present. Repeat this process once more, ensuring a new field of view is chosen. Average the three observations.

5. Assign a strip rating to the fine aggregate of the split face based on the following descriptions:

    1 - Less than 10% of the entire area of all the fine aggregate particles viewed is stripped (no stripping to slight stripping).

    2 - Between 10% and 25% of the entire area of all the fine aggregate particles viewed is stripped (moderate stripping).

    3 - More than 25% of the entire area of all the fine aggregate particles viewed is stripped (severe stripping).

6. Report the individual strip ratings for both the coarse and fine aggregate on the strip rating form. Include any comments or special notes about the observations from that specimen.

Illinois Department of Transportation

Stripping of Hot-Mix Asphalt Mixtures
Visual Identification and Classification
Appendix B.16
(continued)
Effective: November 20, 2003
Revised: January 1, 2014

7. Average all the individual strip ratings for the conditioned specimens (typically 3) for a given test sample. Calculate a separate average for both coarse and fine aggregates. The average coarse and fine strip ratings for the unconditioned specimens (typically 3) may also be calculated for a given test sample. These average ratings give a quick overall appraisal of the moisture susceptibility of the sample. Note that the averaged ratings may not be simple whole numbers.

STRIP RATING FORM

PROJECT ______________________________ DATE ____________

GENERAL COMMENTS ______________________________________

SPECIMEN NO.	TYPE OF CONDITIONING	COARSE RATING	FINE RATING	COMMENTS

Illinois Department of Transportation

Procedure for Introducing Additives to Hot Mix Asphalt Mixtures and Testing in the Lab Appendix B.17

Effective Date: March 7, 2005
Revised: December 1, 2020

1.0 GENERAL

Moisture damage or stripping is considered to be one of the main reasons for an asphalt pavement (especially full depth asphalt pavement) not lasting indefinitely. Stripping is the weakening and loss of the adhesive bond between aggregates and asphalt binder, in the presence of moisture. Various additives can be used to help reduce the stripping potential of an aggregate. In Illinois, liquid anti-strip additives are used almost exclusively. However, other states use or require adding hydrated lime in HMA. Hydrated Lime is considered, by many, as a superior additive for moisture damage control and prevention. It typically is added to the aggregate and asphalt mixture by one of three methods, the dry, the wet, or the slurry method.

Different levels of conditioning can be used in lab-prepared specimens to simulate the effect of the actual moisture conditions in the field. Four levels are described in this document. The level of conditioning actually used will be as specified in contract documents or as determined in the workplan for research.

2.0 PURPOSE

A. This procedure applies to using additives in hot mix asphalt (HMA) mixtures and testing those mixtures in the lab. This procedure includes the dry method of hydrated lime addition as well as the wet method and the slurry method. Also, this procedure includes specimens containing no additive, liquid anti-strip, polymer-modified asphalt, and polymer-modified asphalt with hydrated lime or liquid anti-strip.

B. Four levels of conditioning are included in this procedure and are used when specified. These four levels are no conditioning (or control), submerging in a hot water bath, one cycle of freezing followed by submerging in the hot water bath, and five freeze and hot water bath cycles. The conditioned samples are all partially saturated with water before the freeze and hot water bath cycles begin.

C. Illinois-modified AASHTO T-283 and T-324 are the standard specifications in Illinois that are required and used to test all HMA mixtures for moisture susceptibility. Only specimens with no conditioning and specimens conditioned in the hot water bath shall be tested according to Illinois-modified AASHTO T-283.

In addition to the conditioning and testing specified in Illinois-modified AASHTO T-283 and T-324, this procedure also contains guidelines for conditioning and testing specimens using freeze/thaw conditioning cycles. Freeze/thaw cycles shall be used if specified and also may be used for research projects. Utilizing five freeze/thaw cycles is harsher than the other conditioning methods in this procedure and is considered to more effectively predict the long-term susceptibility to moisture damage of specific materials and mixtures.

D. Tensile strengths are determined and the tensile strength ratio (TSR) is calculated. The tensile strength of the unconditioned specimens is compared with the tensile strength of the specimens from each of the applicable levels of conditioning to determine the TSR. The TSR is a measure of the relative effect that each additive type and conditioning method has on the moisture susceptibility of the samples. The results are used to compare the various additives and their effect on the stripping potential of each mix and to determine the best additive to be used for a specific mixture containing a specific blend of materials.

3.0 MATERIALS

A. The hydrated lime shall conform to Section 1012.01 of the Standard Specifications for Road and Bridge Construction. Illinois Test Procedure 27 shall be used to determine the maximum percent of the hydrated lime retained on specified sieves.

The HMA Mix Design shall be performed using the hydrated lime addition method and / or the liquid anti-strip type that will be used during actual production in the field.

B. The liquid anti-strip and / or hydrated lime method used must result in:
1) A conditioned tensile strength that is equal to, or greater than, the original conditioned tensile strength for the same mixture without the additive,
2) A TSR value that is equal to, or greater than, 0.85 for 6-inch (150 mm) diameter specimens, and
3) Hamburg Wheel test results for rut depth and number of wheel passes according to Illinois modified AASHTO T-324.

4.0 SAMPLE PREPARATION

A. Dry Aggregates:

Dry the aggregate samples in a 230 ± 9 °F (110 ± 5 °C) oven so that the batch weights and additive amounts can be accurately determined.

B. Split Aggregates:

The aggregate samples will then be split according to Illinois Test Procedure 248.

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Procedure for Introducing Additives to
Hot Mix Asphalt Mixtures and Testing in the Lab
Appendix B.17

Effective Date: March 7, 2005
Revised: December 1, 2020

C. Blend Aggregates:

The aggregates will be blended into the correct batch size. Because of the large size of the gyratory specimens, each batch will contain enough material for two gyratory specimens (approximately 8000 - 8500 grams for tensile strength and TSR and approximately 5000 – 5500 grams for the Hamburg Wheel test). Several batches will need to be prepared to produce the required number of gyratory specimens (six for strength and TSR and four for Hamburg Wheel testing as well as pilot specimens). Also, include sufficient material in one of the batches for a maximum specific gravity (Gmm) test run according to Illinois-modified AASHTO T-209 (approximately 2000 grams).

D. Mix Samples:

1. With No Additive:

   a. Heat the asphalt binder and the dry aggregate blend to a mixing temperature of 295 ± 5 °F (146 ± 2.8°C) for neat asphalt.
   b. Remove the blend from the oven and make a small crater in the top of the hot, dry aggregates.
   c. Add the correct amount of asphalt binder to the batch.
   d. Mix the aggregates and asphalt binder.

2. Hydrated Lime – Dry Method:

   a. List the hydrated lime in its own column on the Aggregate Blending Sheet and enter the percent passing each sieve in the corresponding line on the form.
   b. 1.0% hydrated lime is added to the mix. The 1.0% hydrated lime is based on the total dry weight of aggregate in the mix and is added in addition to the mineral filler specified in the mix design.

   NOTE: Theoretically when hydrated lime is added by the dry method, it is assumed that half of the hydrated lime (0.5%) adheres to the aggregate and that the other half (0.5%) of the hydrated lime acts like mineral filler and becomes part of the asphalt binder in the HMA mix. However, for design purposes (and to adapt to existing design software), the hydrated lime is all considered as a separate aggregate, similar to mineral filler, and the gradation of all of the hydrated lime contributes to the overall blend gradation.

c. When hydrated lime is used in a mix design, it is important to include sufficient added mineral filler in the design. During plant production some of this mineral filler may need to be removed to compensate for the fines that are generated during production.

d. Calculate the dust correction factor (DCF) according to the "Hot-Mix Asphalt Mix Design Procedure for Dust Correction Factor Determination", on each mix design with hydrated lime added. Include the hydrated lime in both the job mix formula (JMF) gradation and the washed gradation on the aggregate combined blend. The DCF procedure is performed to account for additional minus 75-µm (minus No. 200) material present as a result of batching with unwashed aggregates. Refer to the attached sheet which shows an example calculation of the DCF.

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Procedure for Introducing Additives to Hot Mix Asphalt Mixtures and Testing in the Lab Appendix B.17

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Revised: December 1, 2020

DCF Example

Bituminous Mixture Design

Design Number →	50BITEXPL
Lab preparing the design?(PP,PL,IL,etc.)	IDOT
Producer, Name & Number →	1111-01 Example Company Inc Somewhere 1, IL
Material Code Number →	17552 BITCONC BCS 1 B TONS

Agg No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	032CMM11	032CMM16	038FAM20	037FAM01	004MFM01	003FA00	10124M
Source (PROD#)	51972-02	51972-02	51230-06	51790-04	51052-04	50315-07	2260-01
(NAME)	MAT SER	MAT SER	MIDWEST	CONICK	LIVINGSTON	MARBLEHD	BMLS COAT
(LOC)							
Aggregate Blend	37.5	35.0	14.0	10.0	2.5	1.0	100.0

Agg No Sieve Size	#1	#2	#3	#4	#5	#6	Blend
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
3/4	88.0	100.0	100.0	100.0	100.0	100.0	95.5
1/2	45.0	100.0	100.0	100.0	100.0	100.0	79.4
3/8	19.0	97.0	100.0	100.0	100.0	100.0	68.6
#4	6.0	29.0	97.0	97.0	100.0	100.0	39.2
#8	2.0	7.0	80.0	85.0	100.0	100.0	26.4
#16	2.0	4.0	50.0	65.0	100.0	100.0	19.2
#30	1.8	3.0	35.0	43.0	100.0	100.0	14.4
#50	1.7	3.0	19.0	16.0	100.0	99.0	9.4
#100	1.5	3.0	10.0	5.0	90.0	99.0	6.8
#200	1.3	1.3	4.0	2.5	88.0	96.3	4.9

Step 1. Batch a combined aggregate sample meeting the JMF. Illinois Specification 201 requires a 5000-gram sample when CM-11 is present. Include the hydrated Lime in the Blend.

Step 2. Run a washed test using AASHTO T-11

Step 3. Determine the Dust Correction Factor (DCF). The DCF is the difference in the percent passing the 75-µm (no. 200) sieve between the washed test and the JMF.

	JMF	Washed Test	DCF
75-µm (no. 200)	4.9%	6.0%	1.1%

Step 4. Determine the Mineral Filler Reduction (MFR) by dividing the DCF (%) by the percent (in decimal form) mineral filler gradation passing the 75-µm (No. 200) sieve:

MFR (%) = 1.1 / 0.88 = 1.25%

Step 5. Determine the adjusted mineral filler blend percentage by subtracting the MFR (%) from the blend percentage of mineral filler.

2.5% - 1.25% = 1.25%

Step 6. Adjust the remaining blend percentages, of the coarse and fine aggregates, to sum 100 by dividing each by the quantity [1 - MFR (in decimal form)]. Do not adjust the hydrated lime blend percentage of 1.0%.

	Blend Percentage	Adjusted Blend Percentage
032CMM11	37.5	38.0
032CMM16	35.0	35.4
038FAM20	14.0	14.2
037FAM01	10.0	10.1
004MFM01	2.5	1.3
003FA00	1.0	1.0
	100.0	100.0

Note: It is important to note the Adjusted Blend Percentages are temporary percentages used during laboratory batching only. The original Blend Percentages on the "Design Summary Sheet" remain unchanged. Also, the Total Adjusted Blend Percentage may equal 100 as a result of rounding during calculation.

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Procedure for Introducing Additives to Hot Mix Asphalt Mixtures and Testing in the Lab Appendix B.17

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e. Heat the asphalt binder and the dry aggregates (not including mineral filler) to a mixing temperature of 295 ± 5 °F (146 ± 2.8°C) for neat asphalt or 325 ± 5 °F (163 ± 2.8°C) for polymer modified asphalt.

f. Make a small crater in the top of the hot, dry aggregates.

g. Add the correct amount of dry hydrated lime to the crater in the aggregates.

h. Mix the hydrated lime and aggregates until the aggregates are completely coated (approximately 10 to 15 seconds).

i. If the blend of aggregates and hydrated lime cools below the mixing temperature, place the blend back in the oven until the blend is returned to the mixing temperature (approximately 10 minutes).

j. Remove the blend from the oven and make a small crater in the top of the hot, dry aggregates and hydrated lime.

k. Add the correct amount of mineral filler, (if required in the mix design), to the crater in the aggregates.

l. Mix the mineral filler with the aggregates and hydrated lime until the mineral filler is uniformly dispersed in the blend (approximately 10 to 15 seconds).

m. If the blend of aggregates, hydrated lime, and mineral filler cools below the mixing temperature, place the blend back in the oven until the blend is returned to the mixing temperature (approximately 10 minutes).

n. Make a crater in the aggregates and add the correct amount of asphalt binder to aggregates, hydrated lime, and mineral filler.

o. Mix the asphalt binder with the blend of aggregates, hydrated lime, and mineral filler.

3. Hydrated Lime – Wet Method:

   a. List the hydrated lime in its own column on the Aggregate Blending Sheet and enter the percent passing each sieve in the corresponding line on the form.

   b. 1.0% hydrated lime is added to the mix. The 1.0% hydrated lime is based on the total dry weight of aggregate in the mix and is added in addition to the mineral filler specified in the mix design.

NOTE: Theoretically when hydrated lime is added by the wet method, it is assumed that all of the hydrated lime (1.0%) adheres to the aggregate and does not function like mineral filler which becomes mixed with the asphalt binder in the HMA mix. Accordingly, the lime is added in addition to the mineral filler specified in the mix design. For design purposes (and to adapt to existing design software), the hydrated lime is all considered as a separate aggregate, similar to mineral filler, and the gradation of all of the hydrated lime contributes to the overall blend gradation.

c. When hydrated lime is used in a mix design, it is important to include sufficient added mineral filler in the design. During plant production some of this mineral filler may need to be removed to compensate for the fines that are generated during production.
d. Calculate the dust correction factor (DCF) according to the "Hot-Mix Asphalt Mix Design Procedure for Dust Correction Factor Determination", on each mix design with hydrated lime added to wet aggregates. Include the hydrated lime in both the job mix formula (JMF) gradation and the washed gradation on the aggregate combined blend. The DCF procedure is performed to account for additional minus 75-µm (minus No. 200) material present as a result of batching with unwashed aggregates. Perform the washed gradation on the combined aggregate blend containing the hydrated lime after it has been allowed to dry on the aggregates (step h.). Refer to the previously attached sheet which shows an example calculation of the DCF.
e. Add the amount of water that is equal to the aggregate's water absorption capacity to the cooled and blended, oven-dried aggregates. The aggregates should be in their saturated surface dry (SSD) condition.
f. Add an additional three percent of water, based on the total dry weight of aggregates, to the aggregates in the SSD condition. Stir the aggregates and the additional water to ensure that the water is evenly mixed with the aggregates.
g. Add one percent dry hydrated lime to the wet aggregates, based on the total dry weight of the aggregates. Stir and mix until the hydrated lime coats the aggregates and the aggregates and hydrated lime make up a homogeneous mixture.
h. Dry the aggregates coated with the hydrated lime in a 230 ± 9 °F (110 ± 5°C) oven to constant mass, as defined in Illinois-modified AASHTO T-166.
i. Heat the hydrated lime-coated aggregates and the asphalt binder each to a mixing temperature of 295 ± 5 °F (146 ± 2.8°C) for neat asphalt or 325 ± 5 °F (163 ± 2.8°C) for polymer modified asphalt.
j. Remove the blend from the oven and make a small crater in the top of the hot, dry, hydrated lime-covered aggregates.
k. Add the correct amount of mineral filler, (if required in the mix design), to the crater in the aggregates.

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l. Mix the mineral filler with the hydrated lime-covered aggregates until the mineral filler is uniformly dispersed in the blend (approximately 10 to 15 seconds).

m. If the blend of hydrated lime-coated aggregates and mineral filler cools below the mixing temperature, place the blend back in the oven until the blend is returned to the mixing temperature (approximately 10 minutes).

n. Make a crater in the aggregates and add the correct amount of asphalt binder to the mixture of hydrated lime-covered aggregates and mineral filler.

o. Mix the hydrated lime-coated aggregates, mineral filler, and asphalt binder together until the aggregates are completely coated with the asphalt binder.

4. Hydrated Lime – Slurry Method:

a. List the hydrated lime in its own column on the Aggregate Blending Sheet and enter the percent passing each sieve in the corresponding line on the form.

b. 1.0% hydrated lime is added to the mix. The 1.0% hydrated lime is based on the total dry weight of aggregate in the mix and is added in addition to the mineral filler specified in the mix design.

NOTE: Theoretically when hydrated lime is added by the slurry method, it is assumed that all of the hydrated lime (1.0%) adheres to the aggregate and does not function like mineral filler which becomes mixed with the asphalt binder in the HMA mix. Accordingly, the lime is added in addition to the mineral filler specified in the mix design. For design purposes (and to adapt to existing design software), the hydrated lime is all considered as a separate aggregate, similar to mineral filler, and the gradation of all of the hydrated lime contributes to the overall blend gradation.

c. When hydrated lime is used in a mix design, it is important to include sufficient added mineral filler in the design. During plant production some of this mineral filler may need to be removed to compensate for the fines that are generated during production.

d. Calculate the dust correction factor (DCF) according to the "Hot-Mix Asphalt Mix Design Procedure for Dust Correction Factor Determination", on each mix design with hydrated lime slurry added. Include the hydrated lime in both the job mix formula (JMF) gradation and the washed gradation on the aggregate combined blend. The DCF procedure is performed to account for additional minus 75-µm (minus No. 200) material present as a result of batching with unwashed aggregates. Perform the washed gradation on the combined aggregate blend containing the hydrated lime slurry after it has been allowed to dry on the aggregates (step h.). Refer to the previously attached sheet which shows an example calculation of the DCF.

e. Add the amount of water that is equal to the aggregate's water absorption capacity to the cooled and blended, oven-dried aggregates. The aggregates should be in their saturated surface dry (SSD) condition.
f. Mix one percent dry hydrated lime and three percent water together, each based on the total weight of aggregates, to form a slurry.
g. Add the slurry to the aggregates. Stir and mix until the aggregates and hydrated lime slurry make up a homogeneous mixture.
h. Dry the aggregates coated with the hydrated lime slurry in a 230 ± 9 °F (110 ± 5°C) oven to constant mass, as defined in Illinois-modified AASHTO T-166.
i. Heat the hydrated lime-coated aggregates and the asphalt binder each to a mixing temperature of 295 ± 5 °F (146 ± 2.8°C) for neat asphalt or 325 ± 5 °F (163 ± 2.8°C) for polymer modified asphalt.
j. Remove the blend from the oven and make a small crater in the top of the hot, dry, hydrated lime-covered aggregates.
k. Add the correct amount of mineral filler, (if required in the mix design), to the crater in the aggregates.
l. Mix the mineral filler with the hydrated lime-covered aggregates until the mineral filler is uniformly dispersed in the blend (approximately 10 to 15 seconds).
m. If the blend of hydrated lime-coated aggregates and mineral filler cools below the mixing temperature, place the blend back in the oven until the blend is returned to the mixing temperature (approximately 10 minutes).
n. Make a crater in the aggregates and add the correct amount of asphalt binder to the mixture of hydrated lime-covered aggregates and mineral filler.
o. Mix the hydrated lime-coated aggregates, mineral filler, and asphalt binder together until the aggregates are completely coated with the asphalt binder.

5. Liquid Anti-strip

   a. Add 0.5% of liquid anti-strip (by weight of asphalt) to the asphalt binder and mix together until the liquid anti-strip is distributed thoroughly in the asphalt binder.

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b. Heat the aggregates and asphalt binder each to a mixing temperature of 295 ± 5 °F (146 ± 2.8°C) for neat asphalt or 325 ± 5 °F (163 ± 2.8°C) for polymer modified asphalt.
c. Remove the aggregate blend from the oven and make a small crater in the top of the hot, dry aggregates.
d. Add the asphalt binder with liquid anti-strip to the dried aggregates.
e. Mix the aggregates and the asphalt binder.

6. Polymer

a. Heat the aggregates and asphalt binder each to a mixing temperature of 325 ± 5 °F (163 ± 2.8°C).
b. Remove the aggregate blend from the oven and make a small crater in the top of the hot, dry aggregates.
c. Add the correct amount of polymer-modified asphalt binder to aggregate blend.
d. Mix the aggregate blend and the polymer-modified asphalt binder.

7. Polymer with Hydrated Lime

a. Heat the polymer-modified asphalt binder to a mixing temperature of 325 ± 5 °F (163 ± 2.8°C).
b. Add the correct amount of hydrated lime to the dry aggregates. (1% based on the total weight of aggregates). Follow the instructions for adding hydrated lime dry method (section 2), hydrated lime wet method (section 3), or hydrated lime slurry method (section 4) above.
c. Heat the aggregates a mixing temperature of 325 ± 5 °F (163 ± 2.8°C).
d. Remove the blend from the oven and make a small crater in the top of the hot, dry aggregates and hydrated lime.
e. Add the correct amount of mineral filler (if required in the mix design) to the crater in the aggregates.
f. Mix the mineral filler with the aggregates and hydrated lime until the mineral filler is uniformly dispersed in the blend (approximately 10 to 15 seconds).
g. If the blend of aggregates, hydrated lime, and mineral filler cools below the mixing temperature, place the blend back in the oven until the blend is returned to the mixing temperature (approximately 10 minutes).
h. Make a crater in the aggregates and add the correct amount of polymer-modified asphalt binder to aggregates, hydrated lime, and mineral filler.

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i. Mix the hydrated lime-coated aggregates and the polymer-modified asphalt binder.

E. Split Samples:

Split the batches into the correct sample size which will make a gyratory specimen 3 ¾ in. (95 mm) high (approximately 4200 grams).

F. Compact Samples:

1. Run a maximum specific gravity (Gmm) for each of the additive mix types being evaluated.
2. Heat the mixture to a compaction temperature of 295 ± 5 °F (146 ± 2.8°C) for neat asphalt or 305 ± 5 °F (152 ± 2.8°C) for polymer-modified asphalt.
3. Pilot bricks from the mixes for each type of additives being evaluated will be made to determine the correct compaction level to achieve 7.0 ± 1.0% air voids.
4. Run a bulk specific gravity (Gmb), according to Illinois-modified AASHTO T-166, for each pilot brick to determine the air void content.
5. Compact samples to 7.0 ± 1.0% air voids for each mix additive type using the number of gyrations determined above.
6. A total of 12 individual samples will be compacted for each additive mix type for each complete round of testing.
7. Run a Gmb on each sample to verify that the air voids are within the range of 7.0 ± 1.0%.

5.0 TESTING

Illinois Modified AASHTO T-283

For each set of samples for each additive type:

A. Control Sample Set – (Always use unless otherwise specified):

1. Three bricks will be tested with no conditioning.

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2. The samples will be:

   a. Placed in a 77°F (25°C) water bath for a minimum of two hours to bring the sample to room temperature.
   b. Placed between the loading heads and loaded at 2 in. (50 mm) per minute until failure.

3. The corresponding load will be recorded.

4. The indirect tensile strength (ITS) will be calculated using the equation:

$$ITS = \frac{2 \times P}{\pi \times t \times d}$$

where:
P = Load (pounds)
π = 3.1416
t = Sample Thickness (inches)
d = Sample Diameter (inches)

5. Within 10 minutes after breaking the sample in the indirect tensile tester, the split samples will be inspected visually to evaluate the amount and degree of moisture damage. This will be done according to the IDOT procedure, “Stripping of Hot Mix Asphalt Mixtures - Visual Identification and Classification”.

B. Illinois-Modified AASHTO T-283 Sample Set – (Always use unless otherwise specified):

1. Three bricks will be tested according to IL-modified AASHTO T-283.

2. The samples will be:

   a. Vacuum saturated to 70 - 80%. Use a vacuum of approximately 0.8 to 1.0 in. (20 to 25 mm) of mercury (Hg) for one minute. Start with 0.8 in. (20 mm) Hg for one minute, and then weigh the specimen. Increase the vacuum until the saturation is 70 - 80%.
   b. Soaked in a 140°F (60°C) water bath for 24 ± 1 hours, and
   c. Tested as above in “Testing; A; 2, 3, 4, & 5.”

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C. AASHTO T-283 Sample Set (with one freeze-thaw cycle) – (Only use when specified):

1. Three bricks will be tested according to AASHTO T-283.

2. Each sample will be:

   a. Vacuum saturated to 70 - 80%. Use a vacuum of approximately 0.8 to 1.0 in. (20 to 25 mm) of mercury (Hg) for one minute. Start with 0.8 in. (20 mm) Hg for one minute, and then weigh the specimen. Increase the vacuum until the saturation is 70 - 80%.
   b. Wrapped in plastic wrap (Saran Wrap) placed in a plastic bag with 10 mL of water and sealed in a plastic bag.
   c. Placed in a 0 ± 5°F (-18 ± 2.8°C) freezer for a minimum of 16 hours. (The exact time greater than 16 hours should be determined so that the testing can be done at approximately the same time each day).
   d. After removal from the freezer, the samples will be placed in a 140°F (60°C) water bath and soaked for 24 ± 1 hours, with the plastic bag and plastic wrap removed as soon as possible after being placed in the bath.
   e. After the freeze – thaw cycle is complete, follow the steps above in "Testing; A; 2, 3, 4, & 5."

D. AASHTO T-283 Sample Set (with five freeze-thaw cycles) – (Only use when specified):

1. Three bricks will be tested as in "Testing; C" above except that five complete freeze – thaw cycles will be completed instead of only one.

2. The plastic bag and plastic wrap should stay on the sample throughout the test and should not be removed until the beginning of the final thaw cycle in the 140°F (60°C) bath. If the plastic bag tears or if the plastic wrap comes loose, replace them prior to the next freeze cycle and add 10 mL of water.

3. After the final thaw cycle is complete, follow the steps above in "Testing; A; 2, 3, 4, & 5."

Illinois Modified AASHTO T-324: Perform a Loaded Wheel test according to Illinois modified AASHTO T-324.

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6.0 DATA COLLECTION AND EVALUATION

A. All the data from testing will be collected and will/may include:

1. Gmm
2. Gmb
3. Voids
4. Indirect Tensile Strength
   a. Unconditioned
   b. Conditioned
      i. 140°F (60°C) water bath
      ii. One freeze / thaw cycle
      iii. Five freeze / thaw cycles
5. The standard TSR, for each additive type (calculated with the unconditioned strength in the denominator and with the conditioned strength in the numerator). For each additive type the TSR is calculated separately for each level of conditioning.
6. The combined TSR, which is similar to the standard TSR except that it is calculated by always using the unconditioned strength from samples with no additive in the denominator, regardless of the additive type used.
7. Visual strip rating of each sample.
8. Rut depth and number of wheel passes.

B. Evaluate the strengths, TSRs, rut depths, and wheel passes for each additive type, for each aggregate type tested, to determine if:

1. An anti-strip additive is needed and improves the performance of the mix.
2. One of the additive types consistently gives higher strengths, TSR ratings, rut depths, and wheel passes.

Figure 13.1

CALCULATION TO BLEND
LIQUID ADDITIVE

$$\frac{\text{Mass of AC in Container}}{(100 - \text{Additive \%}) / 100} = \underline{\qquad\qquad\qquad} \text{ g}$$

(Total Liquid)

$\underline{\qquad\qquad}$ Total Liquid, g – Mass of AC, g = $\underline{\qquad\qquad}$ g

(Mass of Additive
to introduce)

Figure 13.2

CALCULATION TO BLEND LIME

Mass of Aggregate Batch = ______________ g *
(100 – Lime %) / 100 (Total Mass of Solid Material)

Mass of Solid Material, g ______________
minus Mass of Aggregate Batch, g ______________
equals Mass of Lime to introduce, g ______________

**** Adjust AC Mass***

Figure 13.3

BATCHING SOURCES

Design No. 001 Bit 01 Dist 0 Date ______

Contractor Jim's Paving Sheet 1 of 4

Mix Type HMA D Surface, N70

Lab. No.	Ingredient Materials		Proportioning	
P/S#	**Source Name**	**Material Code**	**% Weight**	**Weight Grams**
001	Big Rock	CM13		
002	Natural Sand	FA01		
003	Manufactured Sand	FM20		
004				
005				
006				
007				
TOTAL				12,000
008	Glue, Inc.	PG64-22	5.0	
009	Lime		1.0	

Remarks:

Figure 13.4

BATCHING WORKSHEET

Batch Size	12,000

Design No. 001 Bit 01 Dist 0 Date ______________

Contractor Jim's Paving Sheet 1 of 1

Mix Type HMA Surface, Mix D, N70

AGG. #1->				AGG. #4->			
MATERIAL	PERCENT	WEIGHTS	ACCUMULATIVE WEIGHTS	MATERIAL	PERCENT	WEIGHTS	ACCUMULATIVE WEIGHTS
TOTAL				TOTAL			
AGG. #2->				AGG. #5->	Lime		
				-#8	100		
TOTAL				TOTAL			
AGG. #3->				ASPHALT:	Glue Inc. PG64-22		
				ADDITIVE:	Lime @ 1.0%		
					5.0		
TOTAL							

NOTES: ____

Classical HMA Mix Design Verification Procedure

Timothy R. Murphy, P.E.
President

Murphy Pavement Technology

HMA Mix Design Verification

Contractor HMA Mix Design

- **Sign off by Level III**
  Lab Work by min Level I
- **Mix Formula: Gradation**
  Optimum AB

HMA Mix Design Verification

Contractor Mix Design

Component Materials
- **Material Name**
- **Material Code Number**
- **Source Name**
- **Source Number/Location**

{ **Aggregates**, **AB**, **Anti-strip** }

HMA Mix Design Verification

Mix Formula: Gradation
Optimum AB

Aggregates
- **Blend %'s**
- **Plant Stockpile Ave. (5 samples)**
- **0.45 Power Chart**
- **Dust Factor**
- **Current G_{sb}**
- **RAP Details**

Optimum AB Bracketed

HMA Test Data

- **Cover Page / Summary**
- **Worksheets**
  - **HMA Compaction Log**
  - **Actual G_{mb} and G_{mm}**
  - **Batching Sources**
  - **Dust Correction Factor**
  - **Stripping**
- **Recalculations/Retests/Address Flyers**
- **Mix Design Graphs**
- **Performance Test (TSR, Hamburg,I-Fit)**

HMA Test Data

Mix Design Graphs

- **Gradation (0.45 power chart)**
- **AB vs. Voids**
- **AB vs. VMA**
- **AB vs. VFA**
- **AB vs. G_{mm}/G_{mb}**

} **Optimum Design Data Bracketed**

Samples to Agency

Ready to Blend Components

Blended aggregates
- 2 - 12,000g samples
- Airtight bags
- Identify as before
- Sample date
- Sample location

AB
- min. 4 quarts
- Identify as before
- Sample date/location

Additives
- Brand Name, MSDS, Dosage Rate

Samples to Agency

Compacted Gyratory Cylinders

Binders
- 6 @ 95 mm – TSR's
- 2 @ 160mm or 4 @ 115 mm for Hamburg
- 1 @ 160 mm or 2 @ 115 mm for I-FIT

Surface
- 6 @ 95 mm – TSR's
- 2 @ 160mm or 4 @ 115 mm - Hamburg
- 1 @ 160 mm or 2 @ 115 mm - I-FIT
- 1 @ 160 mm or 2 @ 115 mm - I-FIT (Long-Term Aging)

Ready to Blend Components

Agency Verification

- Review Design Data
- Mix & Test Components at Optimum AB Content
- Test Compacted Gyratory Samples

Comparison of Test Results

G_{se}	± 0.014
G_{mb}	± 0.020
G_{mm}	± 0.014
Air Voids	± 0.5
12.5 mm	± 3.0
4.75 mm	± 2.0
2.36 mm	± 2.0
600 µm	± 1.0
75 µm	± 0.5
P_b	± 0.15

Performance Test Shall meet the Minimum required in Current Standard Specifications 1030.05(d)

Mix Design Verification

- Agency 5 to 30-Day Turnaround
- Contractor Certification of Materials
- Design must be reproducible at the plant
- Previously Submitted Designs
  1. Resubmit Design Paperwork
  2. Re-verification based on Successful Production

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Hot-Mix Asphalt Mixture Design Verification Procedure
Appendix B.9

Effective Date: January 1, 2002
Revised Date: December 1, 2022

1.1 GENERAL

Contractors shall provide all hot-mix asphalt (HMA) mix designs for use on Department contracts. Mix designs shall be the proprietary property of the Contractor. Mix designs must result in mixtures meeting Department criteria. The Department will provide current aggregate bulk specific gravities.

Note. The values stated in SI units are to be regarded as the standard. The English units are shown in parentheses and may not be exact equivalents.

2.1 PURPOSE

To establish a verification procedure to evaluate Contractor mix designs for use on Department contracts. This procedure also allows for comparison of test accuracy and precision between laboratories.

3.1 REQUIRED DESIGN DATA/MATERIAL SAMPLES

3.2 The Contractor shall provide a mix design prepared by a Hot-Mix Asphalt Level III Technician in accordance with the Department's "Hot-Mix Asphalt Design Procedure" in the current *Hot-Mix Asphalt Level III Technician Course* manual. All testing shall be performed by Hot-Mix Asphalt Level I, II, or III Technicians . An approved mix design that will be used as WMA through the use of foaming technology alone (without WMA additives) will not require a new submittal. Mix designs shall be submitted with the following design data:

A. The average mix plant stockpile gradations and aggregate blend percentages used to design the mix. Each of the individual aggregate gradations used in the Contractor design shall be an average of a minimum of five stockpile gradations from existing stockpiles at the plant. Adjusted average aggregate source gradations (stockpile gradations preferred) may be substituted if aggregate has not been shipped to the mix plant. The adjustment shall be based on the amount of aggregate degradation anticipated during shipment to, and handling at, the mix plant. A design using gradation information not comparing to mix plant or aggregate source gradations shall be considered unacceptable.

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Hot-Mix Asphalt Mixture Design Verification Procedure
Appendix B.9
(continued)
Effective Date: January 1, 2002
Revised Date: December 1, 2022

3.4 All design data and material samples shall be submitted to the Department a minimum of 30 calendar days prior to production.

3.5 By submitting a mix design and the constituent materials for verification, the Contractor certifies that they meet Department requirements and represent the materials to be used during mix production.

4.1 DEPARTMENT VERIFICATION

4.2 At the option of the Department, new mix designs will be verified using Method A or Method B listed below. Previously approved mix designs adjusted per Section 5.2.A will be verified using Method A or Method B. Mix designs adjusted per Sections 5.2.B, 5.2.C, 5.2.D, or Section 5.3 will be verified using Method C.

Method A (Contractor Four Point Mix Design). Department verification for mix designs will include review of all mix design data (including all aggregate field gradations) submitted by the Contractor, mixing the component materials submitted by the Contractor, and verification testing of the asphalt mixture. The verification testing; which includes volumetric (VMA, VFA, G_{mb}, G_{mm}, air voids), tensile strength, TSR, Hamburg Wheel, and I-FIT; shall meet the mix design criteria at the optimum asphalt content. A mixture made from the individual materials will be tested for volumetric properties. The Contractor shall provide compacted gyratory cylinders as per Section 3.3.D herein.

Method B (Contractor Four Point Mix Design). Department verification for mix designs will be based on 1) a review of all mix design data (including all aggregate field gradations) submitted by the Contractor and 2) Department verification testing for tensile strength, TSR, Hamburg Wheel, and I-FIT. The Contractor shall provide compacted gyratory cylinders as per Section 3.3.D herein. The mixture at the optimum design asphalt binder content shall meet the mix design criteria for the following: VMA, VFA, G_{mb}, G_{mm}, air voids, tensile strength, TSR values, Hamburg Wheel, and I-FIT.

Method C (Contractor One Point Mix Design). Department verification for mix designs will include review of all mix design data (including all aggregate field gradations) submitted by the Contractor, mixing the component materials submitted by the Contractor, and verification testing of the asphalt mixture. The verification testing; which includes volumetric (VMA, VFA, G_{mb}, G_{mm}, air voids), tensile strength, TSR, Hamburg Wheel, and I-FIT; shall meet the mix design criteria at the optimum asphalt content. A mixture made from the individual materials will be tested for volumetric properties. The Contractor shall provide compacted gyratory cylinders as per Section 3.3.D herein.

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Hot-Mix Asphalt Mixture Design Verification Procedure
Appendix B.9
(continued)
Effective Date: January 1, 2002
Revised Date: December 1, 2022

3.3 The Contractor shall submit the following to the Department a minimum of 30 calendar days prior to production: samples of blended aggregate, asphalt binder, additives, and compacted gyratory cylinders, at the optimum asphalt content according to Section 3.3.D as specified herein, which represent the materials in the mix design. These representative samples shall be identified and submitted as follows:

A. Aggregate (including the mineral filler or collected dust) -- Dried, split into the individual sizes specified for the Batching Worksheet as stated in the current *Hot-Mix Asphalt Level III Technician Course* manual, and then blended to the chosen gradation. The amount submitted shall be two 10,000-gram samples of dry aggregate, with an additional 2,000 grams for gradation testing if requested by the District. All material shall be bagged in plastic bags or other airtight containers. Each container shall be identified with the source names, source locations, source Producer/Supplier Numbers, material codes, sample location, and sample date.

B. Asphalt Binder -- A minimum of four individual one quart cans with friction lids. Each container shall be identified with source name, source location, source Producer/Supplier Number, material code, sample location, and sample date.

C. Additive(s) (including anti-strip, WMA and fibers) -- Each container shall be identified with the source name, source location, brand name or number, material code, sample location, sample date, Safety Data Sheet (SDS), the manufacturer's recommended dosage rate, and the dosage rate used in the design. NOTE: Prior to submitting the additive(s), the Contractor shall contact the District Materials Engineer for the required sample size.

D. Compacted Gyratory Cylinders – The Contractor shall provide compacted 150 mm (5.91 in.) diameter gyratory cylinders meeting the air void requirements of the respective tests shown in the following table. The number of gyratory cylinders and the height of the gyratory cylinders per test is also specified in the following table.

	TSR	**Hamburg Wheel**	**I-FIT**	**I-FIT Long-Term Aging**
IL Modified AASHTO Procedure	T 283	T 324	T 393	T 393
No. of Gyratory Cylinders*	6	2/4	1/2	1/2
Height of Gyratory Cylinders mm (in.)*	95 (3.74)	160/115 (6.30/4.53)	160/115 (6.30/4.53)	160/115 (6.30/4.53)

* If a Contractor does not possess the equipment to prepare 160 mm (6.30 in.) tall gyratory cylinders, twice the number of 115 mm (4.53 in.) tall gyratory cylinders per test will be acceptable.

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Hot-Mix Asphalt Mixture Design Verification Procedure
Appendix B.9
(continued)
Effective Date: January 1, 2002
Revised Date: December 1, 2022

3.4 All design data and material samples shall be submitted to the Department a minimum of 30 calendar days prior to production.

3.5 By submitting a mix design and the constituent materials for verification, the Contractor certifies that they meet Department requirements and represent the materials to be used during mix production.

4.1 DEPARTMENT VERIFICATION

4.2 At the option of the Department, new mix designs will be verified using Method A or Method B listed below. Previously approved mix designs adjusted per Section 5.2.A will be verified using Method A or Method B. Mix designs adjusted per Sections 5.2.B, 5.2.C, 5.2.D, or Section 5.3 will be verified using Method C.

Method A (Contractor Four Point Mix Design). Department verification for mix designs will include review of all mix design data (including all aggregate field gradations) submitted by the Contractor, mixing the component materials submitted by the Contractor, and verification testing of the asphalt mixture. The verification testing; which includes volumetric (VMA, VFA, G_{mb}, G_{mm}, air voids), tensile strength, TSR, Hamburg Wheel, and I-FIT; shall meet the mix design criteria at the optimum asphalt content. A mixture made from the individual materials will be tested for volumetric properties. The Contractor shall provide compacted gyratory cylinders as per Section 3.3.D herein.

Method B (Contractor Four Point Mix Design). Department verification for mix designs will be based on 1) a review of all mix design data (including all aggregate field gradations) submitted by the Contractor and 2) Department verification testing for tensile strength, TSR, Hamburg Wheel, and I-FIT. The Contractor shall provide compacted gyratory cylinders as per Section 3.3.D herein. The mixture at the optimum design asphalt binder content shall meet the mix design criteria for the following: VMA, VFA, G_{mb}, G_{mm}, air voids, tensile strength, TSR values, Hamburg Wheel, and I-FIT.

Method C (Contractor One Point Mix Design). Department verification for mix designs will include review of all mix design data (including all aggregate field gradations) submitted by the Contractor, mixing the component materials submitted by the Contractor, and verification testing of the asphalt mixture. The verification testing; which includes volumetric (VMA, VFA, G_{mb}, G_{mm}, air voids), tensile strength, TSR, Hamburg Wheel, and I-FIT; shall meet the mix design criteria at the optimum asphalt content. A mixture made from the individual materials will be tested for volumetric properties. The Contractor shall provide compacted gyratory cylinders as per Section 3.3.D herein.

Illinois Department of Transportation

Hot-Mix Asphalt Mixture Design Verification Procedure
Appendix B.9
(continued)
Effective Date: January 1, 2002
Revised Date: December 1, 2022

Verification Method	Department Tests/Calculations Performed on[1/]:									
	Mixture Prepared by the Department					Gyratory Cylinders Prepared by Contractor				
	VMA	VFA	G_{mb}	G_{mm}	Air Voids	Unconditioned Tensile strength	Conditioned Tensile strength	Tensile strength Ratio	Hamburg Wheel	I-FIT
A[2/]	X	X	X	X	X	X	X	X	X	X
B[2/]						X	X	X	X	X
C[3/]	X	X	X	X	X	X	X	X	X	X

1/ At the optimum asphalt binder content using materials provided by the Contractor.

2/ Contractor Four Point Mix Design.

3/ Contractor One Point Mix Design at Optimum Asphalt Content.

In all cases the Department will review test data, including aggregate field gradations, provided by the Contractor for compliance with the specifications. All mixtures shall meet specifications at the optimum asphalt content for approval.

4.3 The Contractor mix design data and Department verification testing shall meet the mix design criteria in the Standard Specifications, any Special Provision in the Contract, and the following tolerances (where applicable):

Illinois Department of Transportation

Hot-Mix Asphalt Mixture Design Verification Procedure
Appendix B.9
(continued)
Effective Date: January 1, 2002
Revised Date: December 1, 2022

Volumetric Testing	Tolerance
G_{se} (effective SG of combined aggregates)	± 0.014
G_{mb}	± 0.020
G_{mm}	± 0.014
Air Voids	± 0.5 %

Gradation	Tolerance
12.5 mm (1/2 in)	± 3.0
4.75 mm (No. 4)	± 2.0
2.36 mm (No. 8)	± 2.0
600 µm (No. 30)	± 1.0
75 µm (No. 200)	± 0.5
Pb (Asphalt Binder Content)	± 0.15

All aggregate field gradations submitted by the Contractor will be compared to previous mix plant and/or Aggregate Gradation Control System gradations for validity.

4.4 If a mix fails any of the Department's volumetric or verification tests, the Contractor shall make necessary changes to the mix and provide passing tensile strength, TSR, Hamburg Wheel, and I-FIT test results, as required, from a private lab before resubmittal. The Department will verify the passing results.

4.5 The Department will notify the Contractor in writing within 30 calendar days of receiving the design data/materials as to the acceptability of the submitted Contractor mix design. If the mixture volumetrics or verification tests fail, the 30-calendar-day time for the Department to notify the Contractor starts over.

5.1 MIX DESIGN APPROVAL STATUS

5.2 All mix designs verified as specified herein are approved indefinitely provided that the current contract documents have been met, no changes are made to mixture ingredients and the aggregate bulk specific gravities are updated annually using the current Department published values. The resulting combined aggregate bulk specific gravity shall be used for volumetric calculations during production that year. The following actions will occur to maintain verified mix designs due to changes at Aggregate Producers.

Illinois Department of Transportation

Hot-Mix Asphalt Mixture Design Verification Procedure
Appendix B.9
(continued)
Effective Date: January 1, 2002
Revised Date: December 1, 2022

A. If the combined aggregate bulk specific gravity of the mix changes by more than ±0.020 from the original mix design, the mix design shall be resubmitted for verification as per Section 4.2.
B. If the aggregate producer changes ledges prior to the construction season, the Department will require Method C verification of a previously approved mix design as per Section 4.2.

C. If the aggregate producer changes ledges during the construction season, the Department will require the Contractor to submit compacted gyratory cylinders of plant-produced mix as per Section 3.3.D herein to verify tensile strength, TSR values, Hamburg Wheel, and I-FIT criteria. The Department will require Method C verification as per Section 4.2 after the current construction season is completed.
D. If the aggregate producer changes production practices (including, but not limited to changing crushers, stockpiling practices, or production rate), the Contractor shall submit material for Method C verification as per Section 4.2.
E. The Contractor may at any time resubmit a mix design for verification as per Section 4.1.

5.3 If a mix design adjustment is needed to meet current contract requirements and is outside of the adjustment limits stated in Article 1030.10, the Department will require Method C verification as per Section 4.2.

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MIX DESIGN WORKSHEET

DESIGN NO. HMA SURFACE, MIX D, N70 DISTRICT ____TY____DATE ________

CONTRACTOR: __Example Company Inc._____ Somewhere, IL

POINT #: _1__

P_b	MIX (d)	Mix (D)	VOIDS
4.5	2.322	2.499	7.1

BRIQ. NO.	1	2	3	
ORIG. WT.	1207.1	1207.9	1204.4	
SAT. SURF. DRY	1215.7	1218.7	1209.9	
SUBMERGED WT.	695.7	697.9	692.2	
VOLUME	520.0	520.8	517.7	
SPECIFIC GRAVITY	2.321	2.319	2.326	2.322
HEIGHT (decimal)	2.56	2.63	2.50	

POINT #: _2__

P_b	MIX (d)	Mix (D)	VOIDS
5.0	2.353	2.478	5.0

BRIQ. NO.	4	5	6	
ORIG. WT.	1205.7	1205.0	1205.2	
SAT. SURF. DRY	1207.9	1207.1	1206.9	
SUBMERGED WT.	694.2	696.1	694.9	
VOLUME	513.7	511.0	512.0	
SPECIFIC GRAVITY	2.347	2.358	2.354	2.353
HEIGHT (decimal)	2.50	2.50	2.56	

POINT #: _3__

P_b	MIX (d)	Mix (D)	VOIDS
5.5	2.370	2.459	3.6

BRIQ. NO.	7	8	9	
ORIG. WT.	1204.1	1204.6	1204.3	
SAT. SURF. DRY	1205.7	1206.3	1206.0	
SUBMERGED WT.	697.3	698.2	698.2	
VOLUME	508.4	508.1	507.8	
SPECIFIC GRAVITY	2.368	2.371	2.372	2.370
HEIGHT (decimal)	2.50	2.50	2.50	

POINT #: _4__

P_b	MIX (d)	Mix (D)	VOIDS
6.0	2.389	2.443	2.2

BRIQ. NO.	10	11	12	
ORIG. WT.	1202.1	1200.1	1200.8	
SAT. SURF. DRY	1203.2	1201.1	1201.8	
SUBMERGED WT.	700.0	698.3	699.8	
VOLUME	503.2	502.8	502.0	
SPECIFIC GRAVITY	2.389	2.387	2.392	2.389
HEIGHT (decimal)	2.44	2.50	2.50	

BATCHING WORKSHEET

Batch Size	10,000

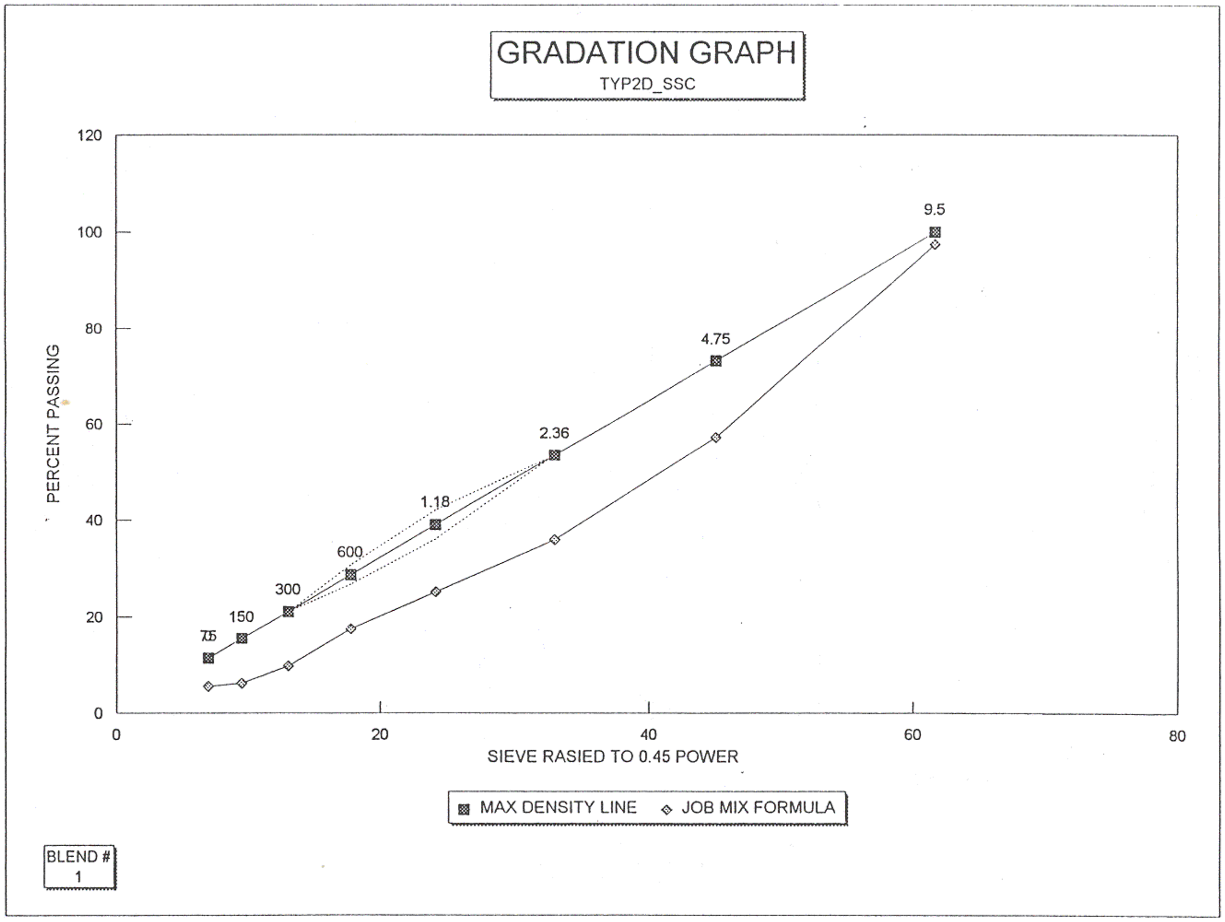
Design No. HMA Surf. "D", N70 Dist TY Date ______________

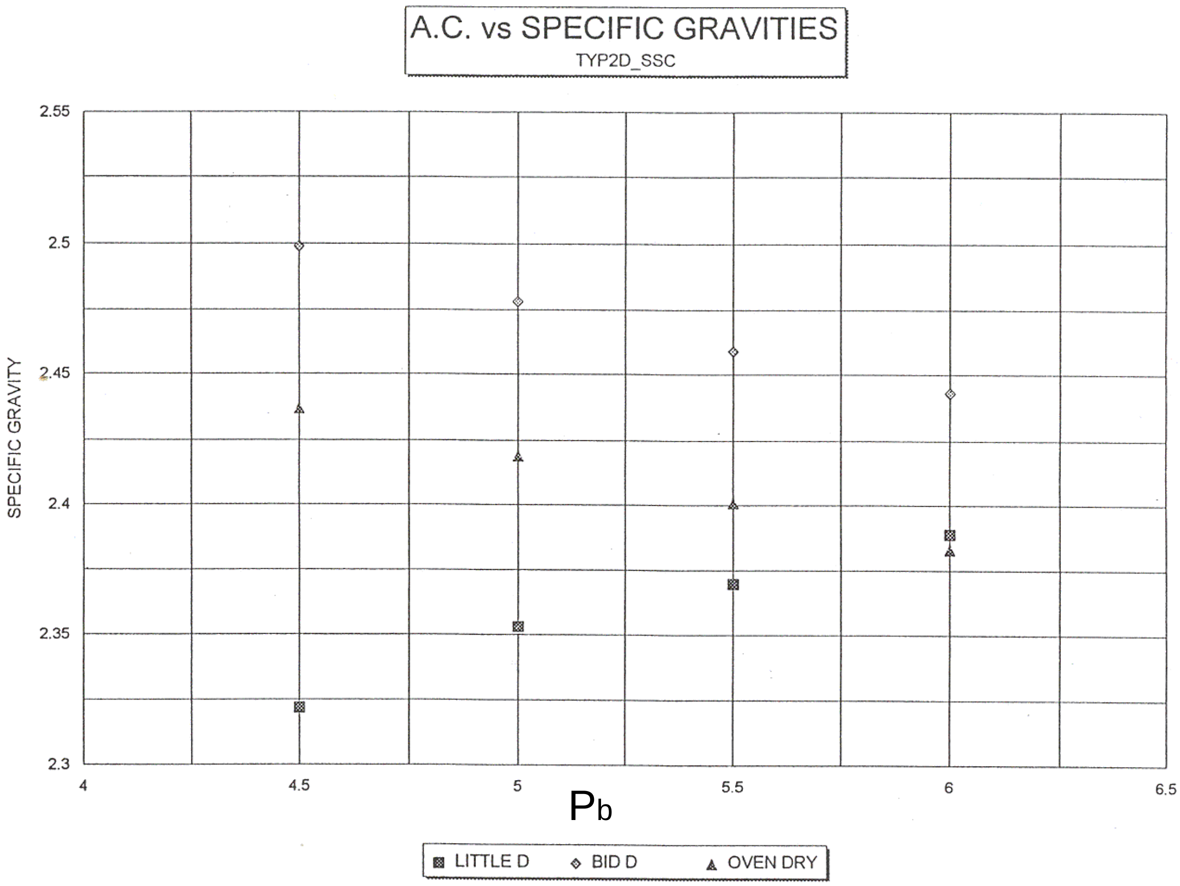
Contractor Example Company Inc., Somewhere, IL Sheet 1 of 1

Mix Type HMA Surface, Mix D, N70

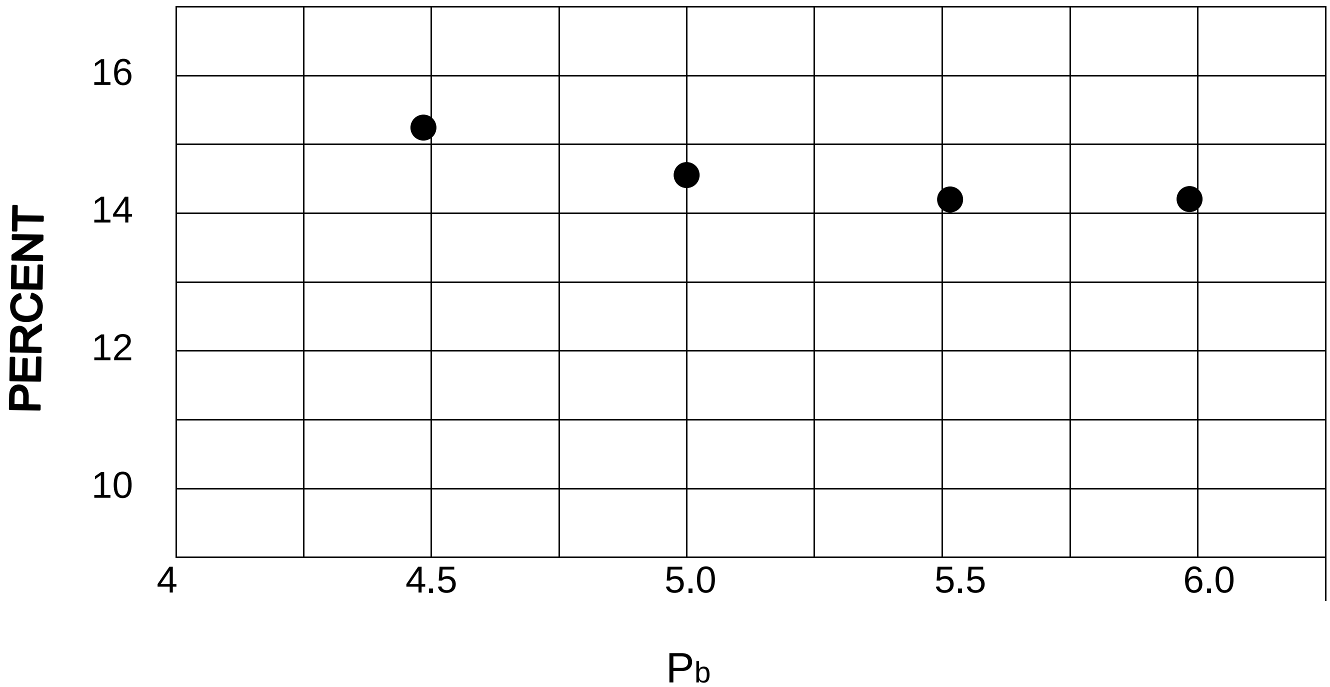
AGG. #1->	032CMM16	What %->	63.2	AGG. #4->	037FAM02	What %->	22.3
MATERIAL	PERCENT	WEIGHTS	ACCUMULATIVE WEIGHTS	MATERIAL	PERCENT	WEIGHTS	ACCUMULATIVE WEIGHTS
+ 9.5	4	253	253	+2.36	11	245	7,765
9.5 – 4.75	63	3,982	4,234	-2.36 - +600	43	959	8,724
4.75 – 2.36	25	1,580	5,814	-600	46	1,026	9,750
-2.36 - +600	3	190	6,004				
-600	5	316	6,320				
			6,320				
			6,320				
TOTAL	100.0	6,320	6,320	TOTAL	100.0	2,230	9,750
AGG. #2->		What %->		AGG. #5->	004MFM01	What %->	2.5
			6,320	-2.36	100.0	250	10,000
			6,320				
			6,320				
			6,320				
			6,320				
			6,320				
			6,320				
TOTAL			6,320	TOTAL	100.0	250	10,000
AGG. #3->	038FAM20	What %->	12.0	ASPHALT:	10112 2260-01 EMUL (URBANA)		
+2.36	28	336	6,656	ADDITIVE:			
-2.36 - +600	59	708	7,364	P_b	AC WT.		
-600	13	156	7,520	6.0	638	10,638	
				5.5	582	10,582	
				5.0	526	10,526	
				4.5	471	10,471	
TOTAL	100.0	1,200	7,520	4.0	417	10,417	

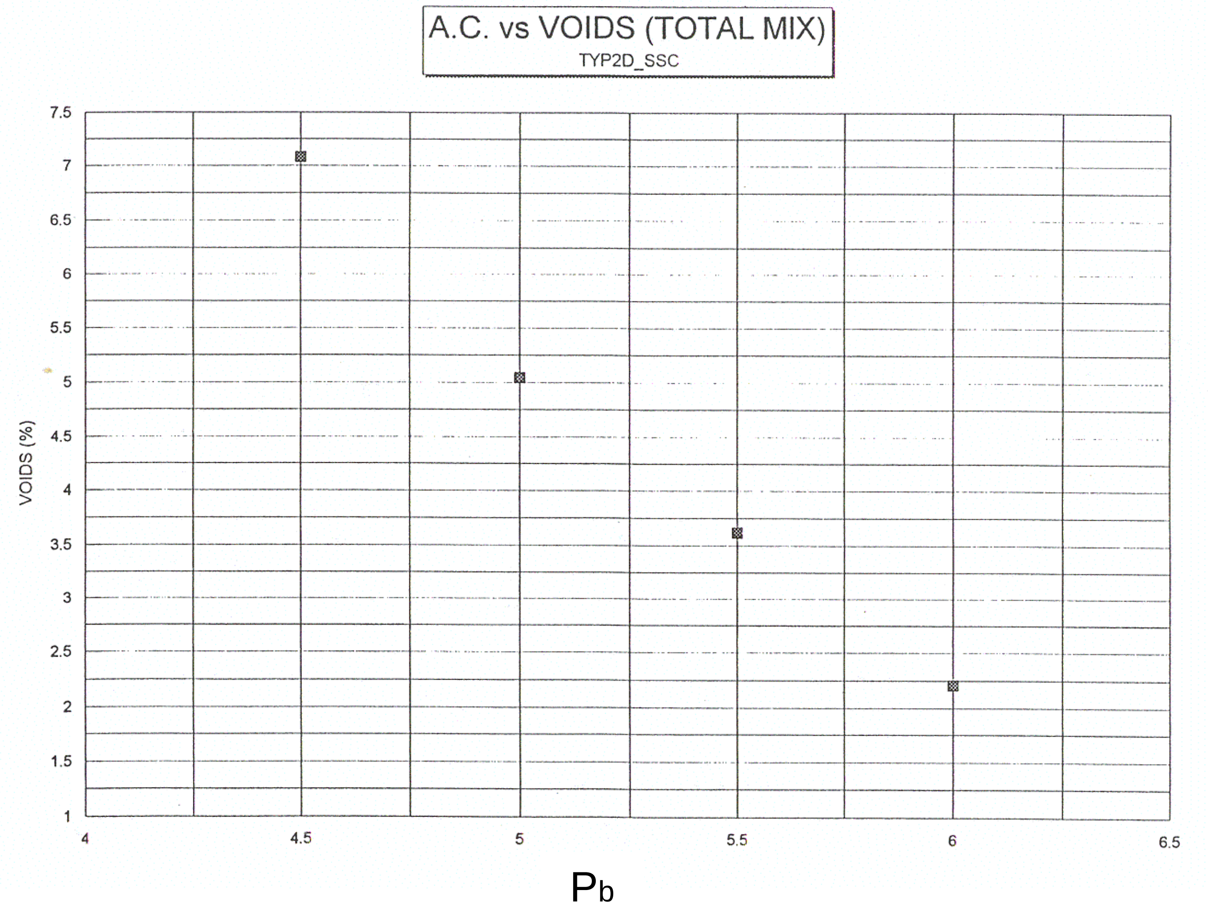
NOTES:____

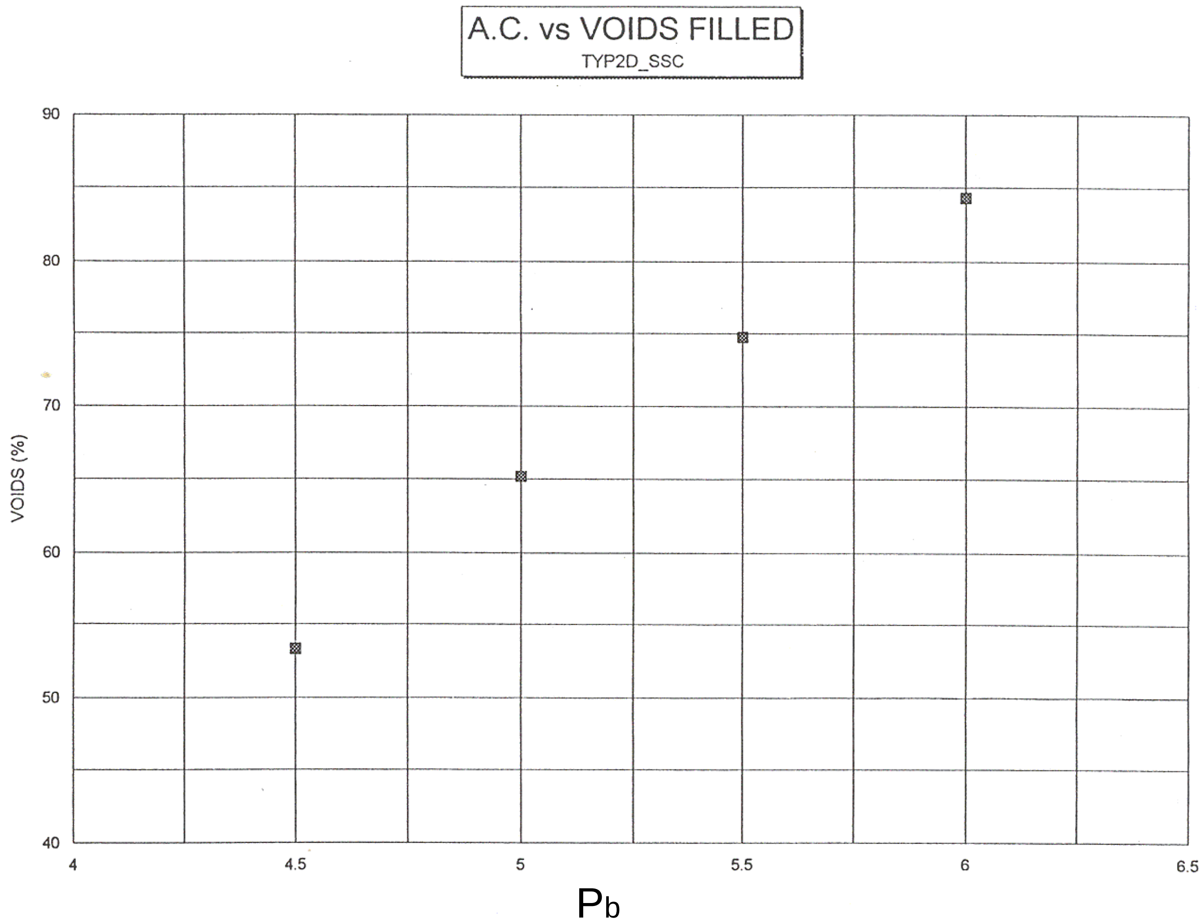

GRADATION GRAPH
TYP2D_SSC
PERCENT PASSING
SIEVE RASIED TO 0.45 POWER
0
20
40
60
80
100
120
75
150
300
600
1.18
2.36
4.75
9.5
MAX DENSITY LINE
JOB MIX FORMULA
BLEND #
1


A.C. vs SPECIFIC GRAVITIES
TYP2D_SSC
SPECIFIC GRAVITY
2.55
2.5
2.45
2.4
2.35
2.3
4
4.5
5
5.5
6
6.5
Pb
LITTLE D
BID D
OVEN DRY

AB vs. VMA




A.C. vs VOIDS (TOTAL MIX)
TYP2D_SSC
VOIDS (%)
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
4
4.5
5
5.5
6
6.5
Pb


A.C. vs VOIDS FILLED
TYP2D_SSC
90
80
70
60
50
40
VOIDS (%)
4
4.5
5
5.5
6
6.5
Pb

STRIPPING TEST WORKSHEET

LAB NO.	17564	DESIGN LAB:	PP	INSPECTOR:	
MIX NO.	TYP2D_SSC	MATL.CODE:	17564	DATE	24-Oct-95

MATL.CODE	MATL. NAME	SOURCE NO.	BLEND
032CMM16	VULCAN	50912-02	63.2
038FAM20	CHAR STN	50292-02	12.0
037FAM02	C&H GRAVEL	50350-04	22.3
004MFM01	FIN GRND	51832-02	2.5
10112	EMUL	2260-01	5.4

Specimen #	1	2	3	4	5	6
Thickness	2.440	2.440	2.440	2.440	2.440	2.440
Orig. Wt.	1139.2	1140.5	1141.1	1140.2	1140.4	1140.2
SSD WT.	1143.6	1146.6	1146.6	1146.1	1143.8	1145.0
SUB WT.	650.0	651.7	649.0	649.2	649.1	649.0
Volume	493.6	494.9	497.6	496.9	494.7	496
SPGR. "d"	2.308	2.305	2.293	2.295	2.305	2.299
%VOIDS	6.2%	6.3%	6.8%	6.7%	6.3%	6.6%
VOIDS (CC)	30.5	31.3	33.7	33.4	31.1	32.5

BIG "D"- 2.460 AV.SPGR- 2.301 AVG. % VOIDS- 6.5%

SPECIMEN NO. (S) UNCONDITIONED	4	1	3	
SPECIMEN NO. (S) CONDITIONED	6	2	5	
WEIGHT FOR 55% SATURATION	1158.1	1157.7	1157.5	
WEIGHT FOR 80% SATURATION	1166.2	1165.5	1165.3	
FINAL STAURATED WEIGHT	1159.2	1160.4	1157.8	AVE.SAT.
FINAL % SATURATION	58.5%	63.6%	55.9%	59.3%

	CONDITIONED			UNCONDITIONED		
SPEC. NO.(S)	6	2	5	4	1	3
LOAD (LBS)	1950	1750	1900	2225	2300	2215
TENS.STR.(P/CI)	127.3	114.2	124.0	145.2	150.1	144.6

CONDITIONED AV.TENS.STR. 121.8

UNCONDITIONED AVE.TEN.STR. 146.6

TENSILE STRENGTH RATIO 0.83

NO. BLOWS 27

DTT03111

IDOT-BITUMINOUS MIX RECORD

CREATE: HMA Surf. "D" N70 UPDATE: ____ DELETE: ____

BIT MIX#: TYP2D_SSC MATERIAL: 17564

TYPE: DES LAB DESIGN LAB DESIGN: _______ EFFECT DATE: _______

RESP: 9Y LAB: PP LAST YR USED: _______ TERM DATE: _______

MIX PROD: Example Company Inc CONTRACT: _______

MATL CODE	MATERIAL NAME	SOURCE#	SOURCE NAME	BLEND
032CMM16		50912-02	VULCAN	63.2
038FAM20		50292-02	CHAR STN	12.0
037FAM02		50350-04	C&H GRAVEL	22.3
004MFM01		51832-02	FIN GRND	2.5
10112		2260-01	EMUL	5.4

MIX FORMULA:

mm / in		mm / in		OPTIMUM DESIGN DATA:				VMA:	14.4
37.5 (1.5)		2.36 (#8)	36	AC:	5.4	MARSHALL:	2193	BLOWS:	
25.4 (1)	100	1.18 (#16)	25	RAP AC:	____	BULK SPGR:	2.367	MAX SPGR:	2.4628
19.0 (3/4)	100	.600 (#30)	17	NEW AC:	____	FLOW:	8.3	% VOIDS:	4.0
12.5 (1/2)	100	.300 (#50)	10	ITS COND:	121.8	ITS UNCOND:	146.6	TSR:	0.83
9.5 (3/8)	97	.150 (#100)	6	ADDITIVE PROD:	____	CODE:	____	PCT:	____
4.75 (#4)	57	.075 (#200)	5.3	ITS COND:	____	ITS UNCOND:	____	TSR:	____

REMARK #1: Verified: By: ______

REMARK #2: VFA = 72.8

MESSAGES: ______ PROCESS: ______

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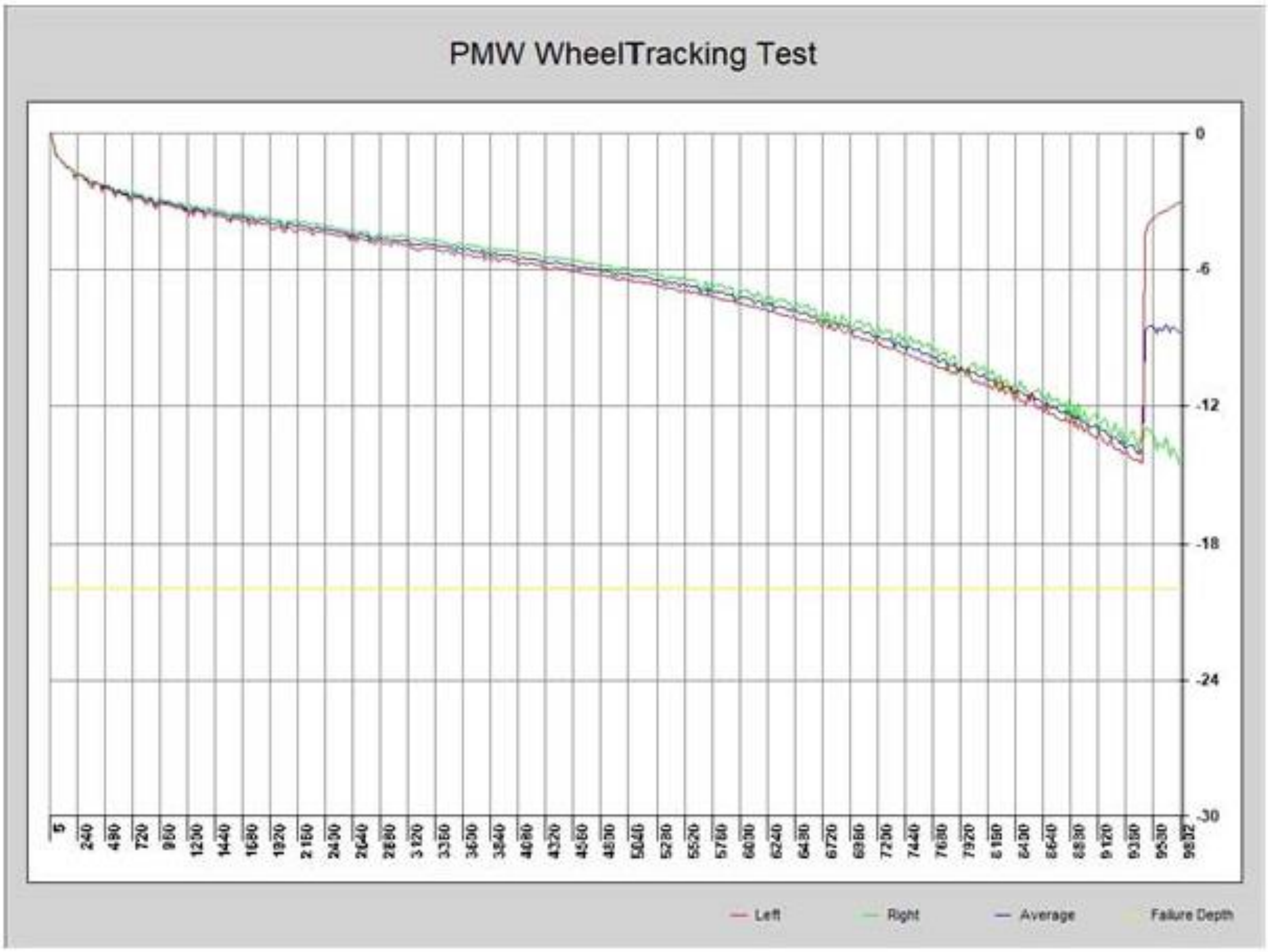
WheelTracker Report

Project Name:		**Date:**	9/27/2021
Project Number:		**Date Sampled:**	9/27/2021
Job Number:	44	**Lab Number:**	290
Project Engineer:		**Mix Type:**	
Submitted By:		**Asphalt Grade:**	64-22
Temperature:	50°C	**Pit Source:**	
Comments:	Left -9.8 @ 7500 , Right -9.7 @ 7500		

	Left	Right	Average
Max Impression:	-14.55 mm Pass #: 9484 / Pt: 8	-14.55 mm Pass #: 9802 / Pt: 8	-14.55 mm
Fail Depth: 20mm	PASS	PASS	PASS



CC:

I-FIT REPORT - Specimen Set 1

Dist.: ______ Date Tested: 9/28/21 Lab Test ID: ______ Contract: ______

Producer: ______ ______ Location: ______ Test Type: Production-Plant Date Produced: 9/27/21

BIT#: ______ Mix Code: 19523R Mix Name: HMA SC N70 C REC

Mix Type: Surf Gsb: 2.628 VMA: 15.9 NMAS: 9.5mm Gmm: 2.447 Ndes: 70

AB Source: ______ AB Seq #: N/A Design AB Grade: PG 64-22 AB% 6.0

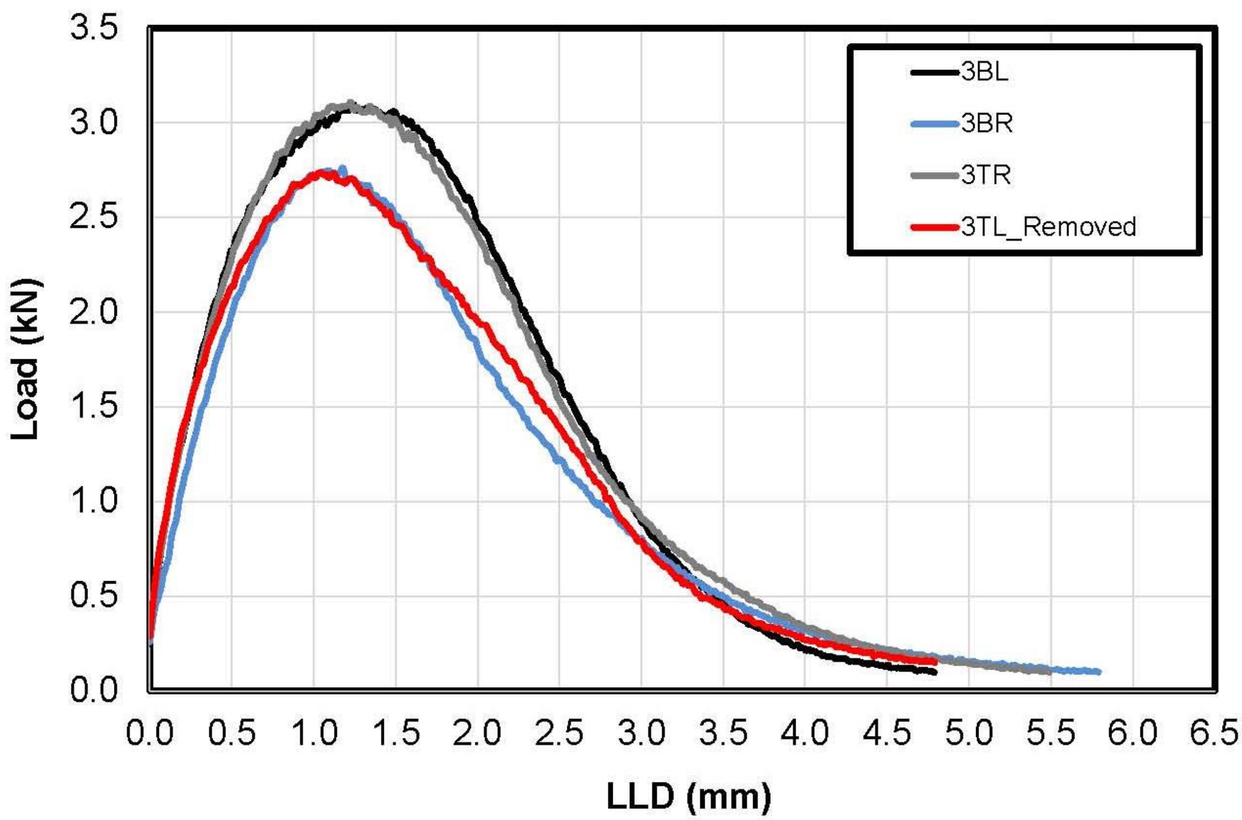
Plan AB Grade: PG 64-22

	(F)RAP	RAS
Agg %	21.0	0.0

Long-Term Aged: No ABR % 17.4

Individual Specimen Results	3BL	3BR	3TL	3TR	Average	COV (%)
Air Voids (%)	7.1	6.7	6.6	6.7	6.8	
Fracture Energy (J/m^2)	2540.6	2156.1	2247.5	2537.5	2411.4	9.2
Post-Peak Slope (kN/mm)	1.7	1.5	1.3	1.8	1.7	9.4
Flexibility Index	14.6	14.5	17.5	14.3	14.5	1.1
Specimen 3TL Furthest from Mean and Removed from Analysis						
Short-Term Aged FI = 14.5						

Comments: ______



I-FIT REPORT - Specimen Set 2

Dist.: ______ Date Tested: 10/4/21 Lab Test ID: ______ Contract: ______

Producer: ______ ______ Location: ______ Test Type: Production-Plant Date Produced: 9/27/21

BIT#: ______ Mix Code: 19523R Mix Name: HMA SC N70 C REC

Mix Type: Surf Gsb: 2.628 VMA: 15.9 NMAS: 9.5mm Gmm: 2.447 Ndes: 70

AB Source: ______ AB Seq #: N/A Design AB Grade: PG 64-22 AB% 6.0

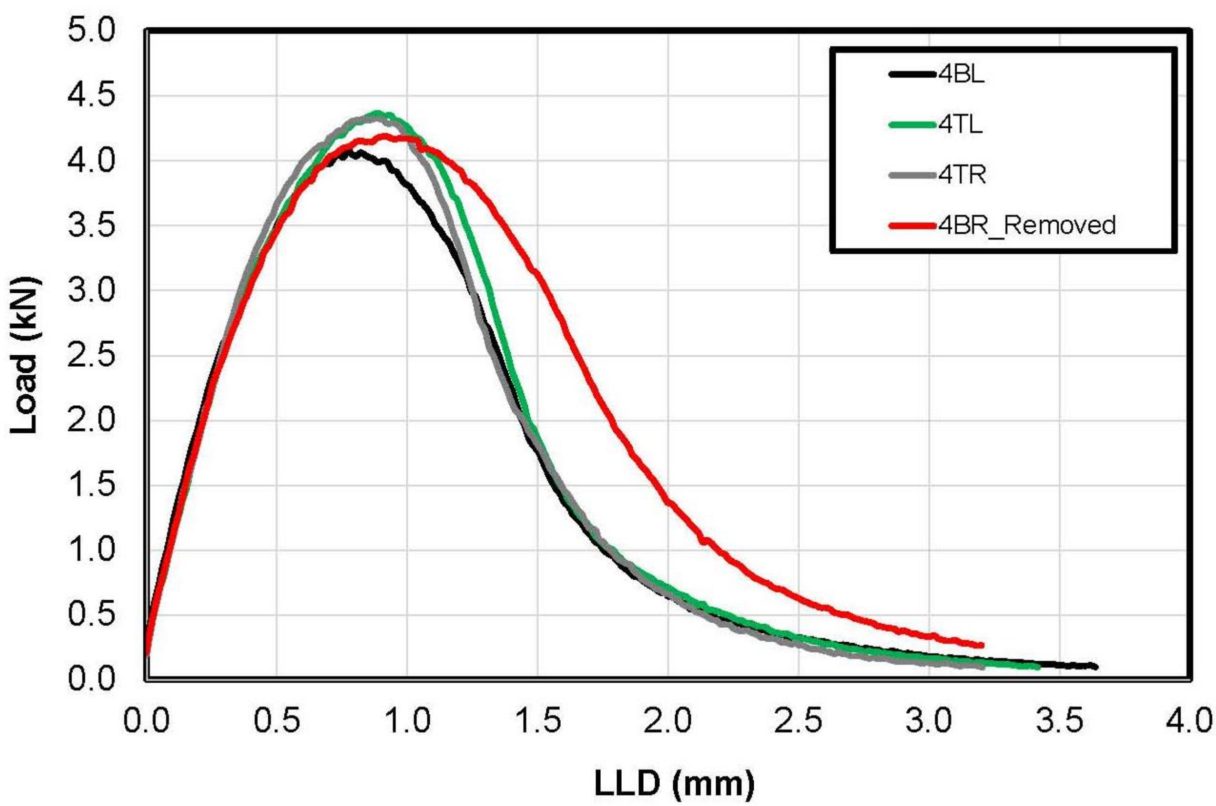
Plan AB Grade: PG 64-22

	(F)RAP	RAS
Agg %	21.0	0.0

Long-Term Aged: Yes ABR % 17.4

Individual Specimen Results	4BL	4BR	4TL	4TR	Average	COV (%)
Air Voids (%)	7.0	6.3	6.4	6.6	6.7	
Fracture Energy (J/m^2)	1866.6	2368.8	1898.8	1883.7	1883.0	0.9
Post-Peak Slope (kN/mm)	4.6	3.7	5.4	4.9	5.0	8.1
Flexibility Index	4.1	6.4	3.5	3.8	3.8	7.9
Specimen 4BR Furthest from Mean and Removed from Analysis						
Long-Term Aged FI = 3.8						

Comments: ______



I-FIT LABORATORY WORKSHEET

District#		Lab ID#		Contract			
Producer Name		Producer #		Location			
Bit Number		Mix Code	19523R	Mix Name	HMA SC N70 C REC		
Sample Test	Production-Plant	NMAS	9.5mm	Ndes	70	Type Mix	Surf
☐ WMA		☐ SMA		☐ Fine Graded			
Mix Production Date	9/27/21	Date Tested - Spec # 1	9/28/21	Date Tested - Spec # 2	10/4/21		
VMA	15.9	ABR%	17.4	Dsgn Aging (hr)	1	Dsgn AB Grade	PG 64-22
AB%	6.0	(F)RAP%	21.0	Dsgn Aging (°F)	295	Plan AB Grade	PG 64-22
Gsb	2.628	RAS%	0.0	Spec #1 Long-Term Aged	No	Asphalt Supplier #	
				Spec #2 Long-Term Aged	Yes	AB Seq #	N/A
Gmm	2.447	Target Voids	8.0	Target Height	160.0 (mm)	Approx Sample Size	6253
Gyro MFR	Pine	Gyro MDL	AFGB1				

Gyro Spec	1				2			
Gyro Spec Voids (%)	7.6				7.5			
Name	3BL	3BR	3TL	3TR	4BL	4BR	4TL	4TR
Dry Wt.	979.8	1004.4	977.3	994.2	967.4	987.6	1000.8	983.2
SSD Wt.	981.5	1006.2	978.7	995.9	969.9	988.9	1002.8	985.4
Sub Wt.	550.6	566.2	551.1	560.4	544.8	558.2	565.8	555.3
Spec #	1				2			
Volume	430.9	440.0	427.6	435.5	425.1	430.7	437.0	430.1
Gmb	2.274	2.283	2.286	2.283	2.276	2.293	2.290	2.286
%Voids	7.1	6.7	6.6	6.7	7.0	6.3	6.4	6.6
# of Gyrations	43				41			

Spec # 1	Thickness			AVG	Ligament	Notch		AVG	Tot Length		AVG
3BL	50.5	50.7	50.7	50.6	58.1	15.1	15.4	15.5	73.6	73.6	73.6
3BR	50.7	50.7	50.9	50.7	59.1	15.2	15.7	15.5	74.7	74.5	74.6
3TL	50.6	50.1	50.0	50.2	58.5	15.2	15.7	15.5	74.0	74.0	74.0
3TR	49.8	50.5	50.4	50.2	59.1	15.6	15.4	15.5	74.7	74.5	74.6
Spec # 2	Thickness			AVG	Ligament	Notch		AVG	Tot Length		AVG
4BL	49.8	50.1	50.3	50.0	58.9	15.0	15.3	15.0	73.9	73.9	73.9
4BR	49.7	50.0	49.4	49.7	59.4	15.4	15.4	15.5	74.9	74.8	74.9
4TL	50.5	50.8	50.8	50.7	59.3	15.3	15.5	15.5	74.9	74.7	74.8
4TR	50.9	50.7	51.2	50.9	58.1	15.3	15.5	15.5	73.5	73.6	73.6

Ver. 1.42-04.30.21

Flexibility Index Set #1 14.5

Flexibility Index Set #2 3.8

Remarks Set #1:

Remarks Set #2:

Hamburg Data

Pass #	Left	Right	Average
5000	-6.5	-6.2	-6.3
7500	-9.8	-9.7	
10000			
15000			
20000			

NUMBER OF PASSES @ 12.5mm	
LEFT	8740
RIGHT	8840
Req'd Passes	7500

Voids VMA and VFA: The Building Blocks of Hot Mix Asphalt

Designing & Building HMA Successfully to *Your* Agency Specification

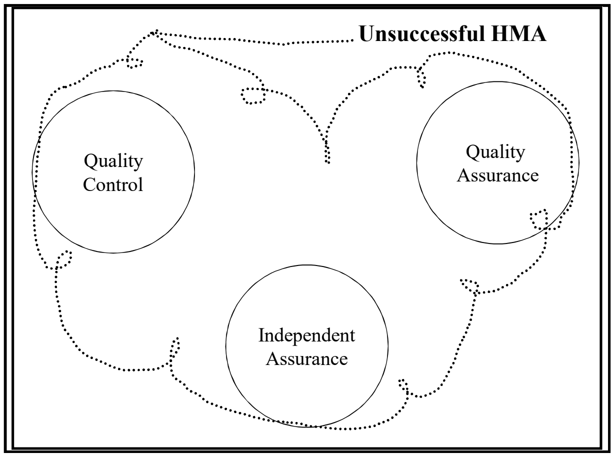
Timothy R. Murphy, P.E.
President
Murphy Pavement Technology

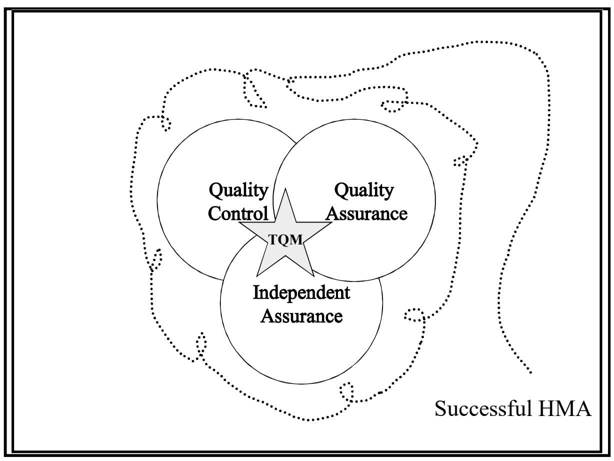
Preparing for Hot Mix Asphalt

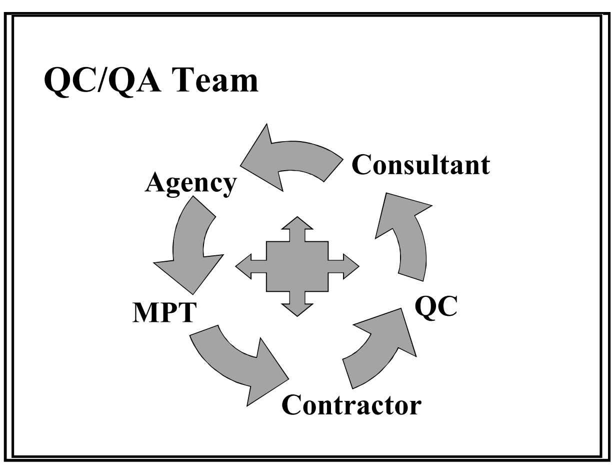
From the bucket to the road and all the twists and turns you take to get there!

The bucket vs. the field

- **Permissive Use,**
- **Differences between design and field,**
- **What if's.**


Unsuccessful HMA
Quality Control
Quality Assurance
Independent Assurance


Quality Control
Quality Assurance
TQM
Independent Assurance
Successful HMA


QC/QA Team
Agency
Consultant
MPT
QC
Contractor

Designing & Building HMA Successfully

- Certifying Hot Mix Facility
- Mix Design
- Incoming Aggregates
- Mixture Production ⇒ Adjustments
- Field Density
- Smoothness

Certifying Hot Mix Facility

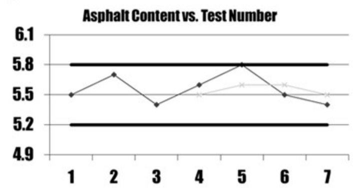
- Certify asphalt plants via permissive use regimen,
- Segregation mitigation.

HMA Plant Certification

Ingredients	*Sieve Sizes*	*JMF*
Product A @ 39.1%	1"	100
Product B @ 27.2%	½"	78
Product C @ 16.3%	#4	45
Product D @ 16.3%	#8	32
MF @ 1.7%	#30	15
Opt. AC @ 4.7%	#200	3.9

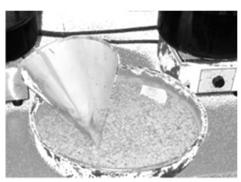
HMA Plant Certification

- 5,000 tons of large stone mix production,
- Asphalt content,
- Washed gradations.



HMA Plant Certification

- Reflux Extraction, Vacuum Extraction, Ignition Oven extraction:
  - Asphalt Content,
  - Gradation,
  - Positive Dust Control for P200



HMA Plant Certification

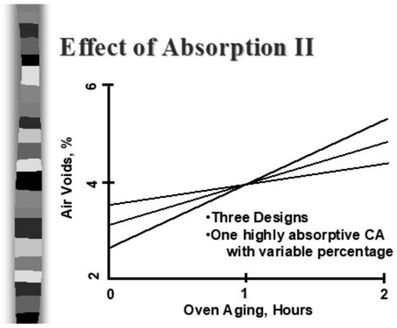
Sieve Size	Single Test*	Running Ave. of 4*
½"	6%	4%
#4	5%	4%
#8	5%	3%
#30	4%	2.5%
#200	1.5%	1.0%
AC	0.3%	0.2%

**Deviation from JMF*

Laboratory vs. Plant Produced Mixes

- **Job-mix formula**
  - differences between lab and plant
  - how characteristics vary
  - why characteristics vary

Short-Term Aging Procedures To Simulate HMA Production



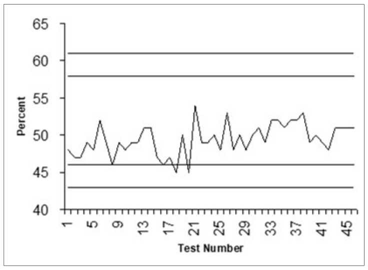
Field Verification of Laboratory Mix Designs

Quality Control Efforts

- Aggregate gradation
- Asphalt content
- Volumetric analysis
- In-place density

Laboratory Mix Designs vs. Plant-Produced Mixture

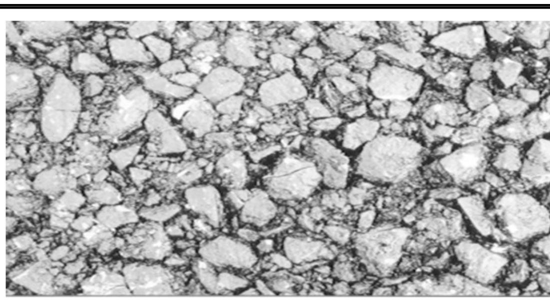
Control Charts - # 4 Sieve



Where are these samples taken from and what do they mean?

Aggregate Gradation

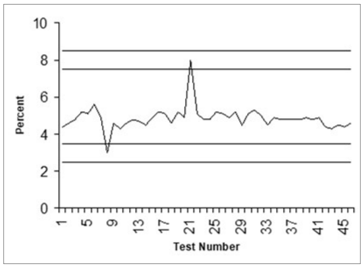
- Cross-Contamination of Stock Piles
- Cross-Contamination Between Cold Feed Bins



Aggregate Gradation

Breakage of Coarse Aggregate Particles During Production

Control Charts - P200

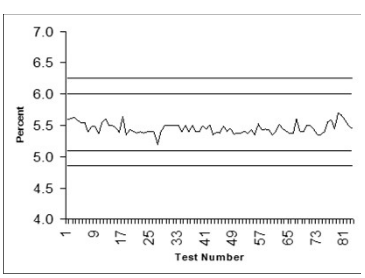


Aggregate Gradation

Dust Coating on Particle Surface

Dry Versus Washed Gradations

Control Charts - AC

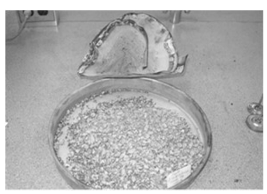


Asphalt Content

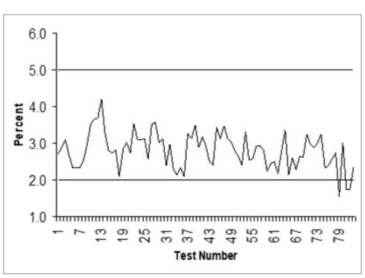
Nuclear AB Gauge

Asphalt Content & Gradation

- **Ignition Oven**
- **Centrifuge, or**
- **Reflux AB**



Control Charts - Air Voids



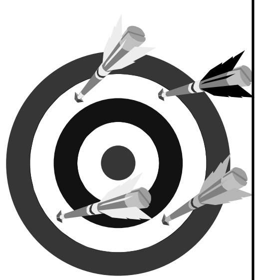
Designing & Building HMA Successfully

Test Strips
or HMA Beta

Test Strips

Always be ready for surprises...

- **Increased testing,**



Recommended Testing and Observations

Asphalt Content	***Twice per lot***
Gradation	***Twice per lot***
Volumetrics	***Twice per lot***
In-Place Density	***Once per ¼ mile***
Cores	***As needed***
Construction Methods	***Constantly***

Test Strips

Always be ready for surprises...

- Increased testing,
- Increased analysis,

Volumetrics

$$G_{mm} = \frac{100}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

$$V_a = \left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right) x\ 100$$

$$VMA = 100 - \frac{G_{mb}\ x\ P_s}{G_{sb}}$$

$$VFA = \left(\frac{VMA - V_a}{VMA}\right) x\ 100$$

$$P_{be} = P_b - \frac{P_{ba}\ x\ P_s}{100}$$

$$P_{ba} = 100\ x \left(\frac{G_{se} - G_{sb}}{G_{se}\ x\ G_{sb}}\right) x\ G_b$$

$$Eff.\ Vol. = VMA - V_a$$

Test Strips

Always be ready for surprises...

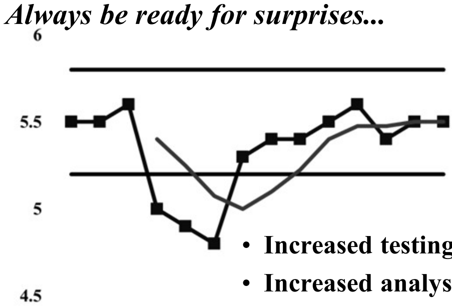
- Increased testing,
- Increased analysis,
- Increased comparisons.

Comparisons and Tolerances

Gse	± 0.014
Gmb	± 0.020
Gmm	± 0.014
Air Voids	± 0.5
12.5 mm	± 3.0
4.75 mm	± 2.0
2.36 mm	± 2.0
600 µm	± 1.0
75 µm	± 0.5
%AC	± 0.15

Test Strips

Always be ready for surprises...



- Increased testing,
- Increased analysis,
- Increased comparisons,
- Just-In-Time adjustments.

Test Strips can be Scary!

- Work through lunch and dinner,
- Test, Analyze, Compare and Adjust Under Pressure,
- Produce.

Test Strips and Equipment

Test Strips and Equipment

Test Strips and Equipment

Mixture Compaction

Density Technician Monitoring Paving Operations

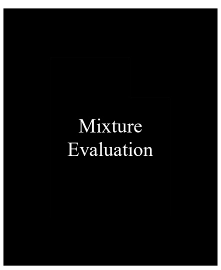
Factors Affecting Compaction

- Material Properties
- Thickness
- Mix Temperature
- Weather Conditions
- Compaction Forces

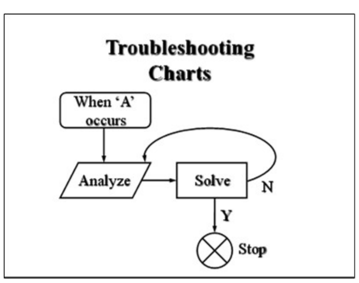
Test Strips and Equipment

Smoothness

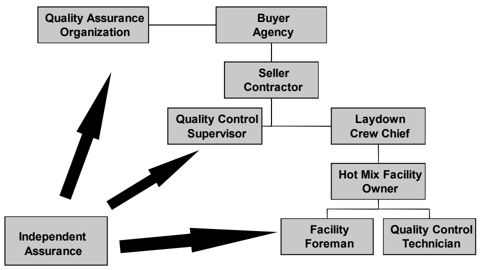
Examples



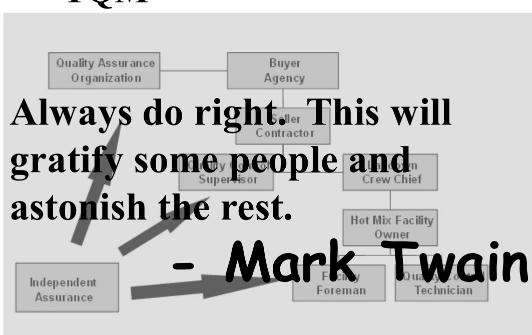
Problem Solving



One Solution for Achieving TQM



One Solution for Achieving TQM



Always do right. This will gratify some people and astonish the rest.

- Mark Twain

Be determined in achieving your goals...

Main Solution for Achieving TQM within Your TEAM

- **Communicate,**
- **Develop chemistry,**
- **Accountability.**

You need to be relentless in your pursuit of excellence… ...and consistent!

Designing & Building HMA Successfully

- **Certifying Hot Mix Facility**
- **Mix Design**
- **Incoming Aggregates**
- **Mixture Production ⇒ Adjustments**
- **Field Density**
- **Smoothness**

Total Quality Management

Timothy R. Murphy, P.E.
President
Murphy Pavement Technology
Teaching ⋆ Training ⋆ Troubleshooting ⋆ Testifying

Mixture Evaluation

From the bucket to the field!

Timothy R. Murphy, P.E.
President

Murphy Pavement Technology

Defining a "Good" Mix

- **An economical blend of aggregates and asphalt that produce the following results:**
  - **Sufficient Asphalt Binder to thoroughly coat all the aggregate particles and ensure a durable pavement. (P_{be} vs. P_{ba})**
  - **Complementary Voids in the Mineral Aggregate and Voids in the Mixture. (As goes VMA, so goes Voids.)**

Defining a "Good" Mix

- **Sufficient voids in the compacted mix to allow for a slight amount of additional compaction under traffic without:**
  - **Flushing,**
  - **Bleeding, or**
  - **Loss of Stability,**

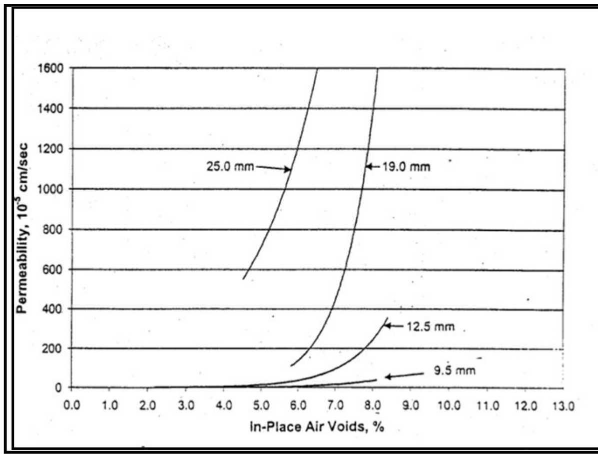
but low enough to keep out harmful effects like air and moisture, which cause premature aging and stripping.

Permeability, Background

- 100 x 10^-5 cm/s established by ETG as recommended limit for permeability,
- Substantial research nationally underway.

Permeability, National Data

- NCHRP 9-27 - NCAT (Auburn University)
  "Relationships of HMA In-Place Air Voids, Lift Thickness, and Permeability"
  - In-place density needed to achieve impermeable pavement,
  - Minimum lift thickness of 3:1 needed to achieve desirable density levels and to allow for Aggregate orientation vs. degradation.



Permeability, Significance and Application

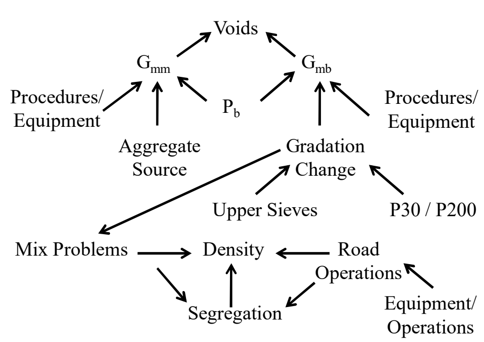
- **19 mm Mixes - Target 93% to 94%**
- **12.5 mm Mixes - Target 92% to 93%**

With stable mix design and appropriate compactive effort, these levels should provide good long term performance!

Review of Calculations

- **% Density = (G_{mb} / G_{mm}) * 100**
- **% Voids = 100 - % Density**
- **VMA = 100 - (G_{mb} * P_s) / G_{sb}**
- **Asphalt Binder Content equals measured value!**

Troubleshooting Flow Chart



Proportionality Rules

α Proportional - Each variable reacts in the same direction. One increases and the other increases.

$1/\alpha$ Inversely Proportional - Each variable reacts in the opposite direction. One increases and the other decreases.

Proportionality Rules of HMA

- Voids $1/\alpha$ Density
- Voids α G_{mm}
- Voids $1/\alpha$ G_{mb}
- Voids $1/\alpha$ Binder Content

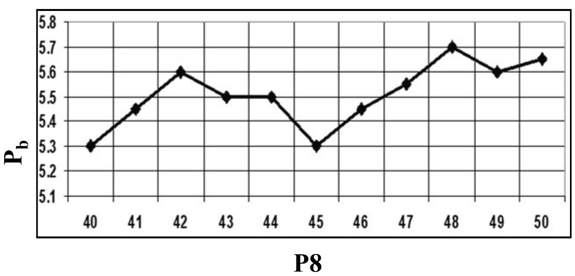
Proportionality Rules of HMA

- Voids $1/\alpha$ P200
- Voids α VMA
- Voids α Coarseness of mix
- Voids $1/\alpha$ Temperature
- Voids α Manufactured to Natural Sand Blend

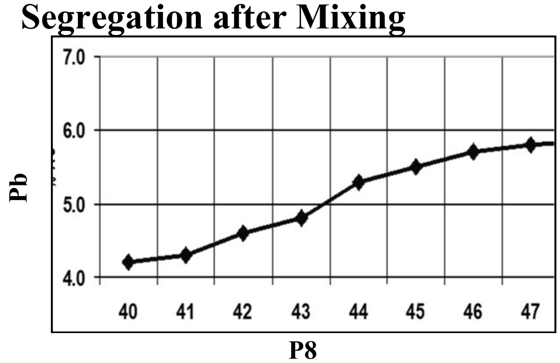
Additional Rules

- Change in minus #200 of 1.0% will change VMA and Voids by ~ 0.9%,
- Tender mixes will occur with too little or too much minus #200
- High natural sand to manufactured sand blends are typically tender mixes,
- Segregated samples lead to variable asphalt contents and volumetric results

Plotting Segregated Samples, Segregation Before Mixing



Plotting Segregated Samples, Segregation after Mixing



Additional Rules

- **Temperature for breakdown and rubber tired roller should be around 280°F for neat asphalt and 300 °F for modified asphalt.**
- **Finish rolling temperature should be based on visual observation.**
  - **Hot enough to remove marks**
  - **Cool enough to prevent mat from moving**

Problem 1

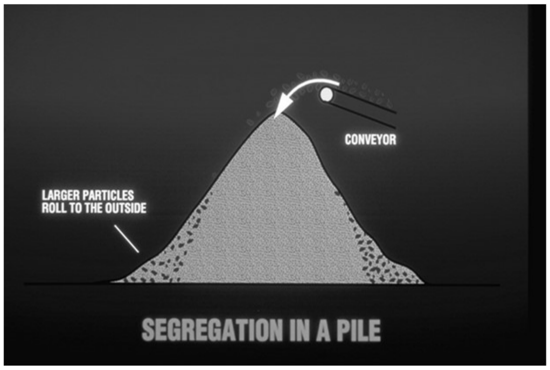
- **Voids falling,**
- **G_{mm} level,**
- **G_{mb} rising,**
- **P200 level,**
- **P8 rising,**
- **Density rising.**

Question: What is happening to VMA?

Problem 1, Solution

- **Voids falling,** **Voids 1/ α G_{mb}**
- **G_{mm} level,**
- **G_{mb} rising,** **(Mass/Volume) changing, Watch lab comp. temperature**
- **P200 level,**
- **P8 rising,** **Drum/Batch Plant/ Degradation?**
- **Density rising.**

Question: What is happening to VMA?



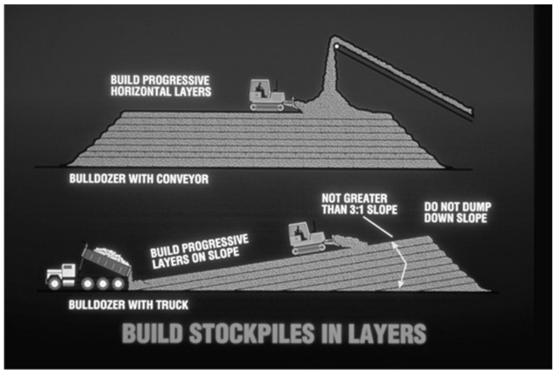
Problem 2

- **Voids falling,**
- **G_{mm} level,**
- **G_{mb} rising,**
- **P200 rising,**
- **P8 level,**
- **Density rising.**

Problem 2, Solution

- **Voids falling,** Voids 1/α P200
- **G_{mm} level,**
- **G_{mb} rising,**
- **P200 rising,** Drum/Batch Plant/ Degradation/MF System?
- **P8 level,**
- **Density rising.** Mix becomes gummy

Question: What is happening to VMA?



MF System

- Do you have positive dust control system?
- Does your aggregate supplier have a washed and unwashed manufactured sand?
- What particle shape does the CA have?
- What LA Abrasion value does the CA have?

Problem 3

- Voids level,
- G_{mm} level,
- G_{mb} level,
- P200 level,
- P8 level,
- Density rising.

Problem 3

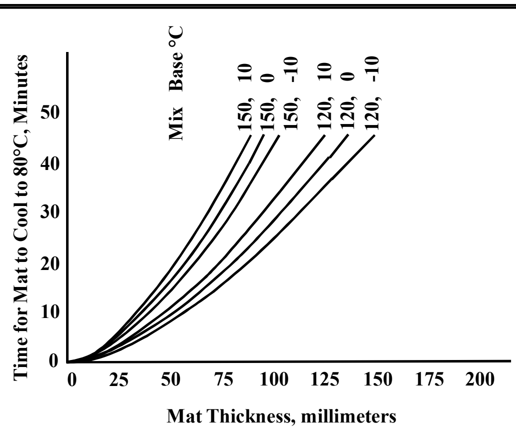
- Voids level,
- G_{mm} level,
- G_{mb} level,
- P200 level,
- P8 level,
- Density dropping. Density α Temperature

Question: What is happening to VMA?

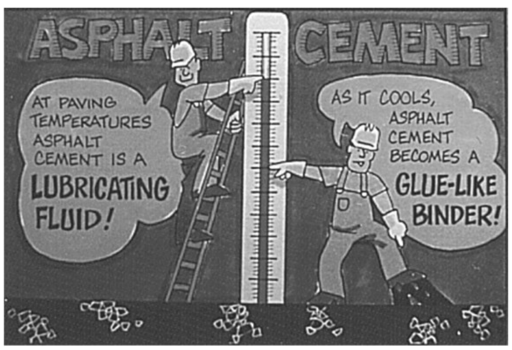
Time Available for Compaction

(TAC)

Sometimes the call comes back to the lab that the mixture is difficult to compact. Various changes in the field affect anticipated design compactability.



Major Factors Affecting Rolling Time	allows MORE time	allows LESS time
Mat Thickness	THICK	THIN
Mix Temperature	HIGH	LOW
Base Temperature	HIGH	LOW



Where did the HF go?

Where did the HF Go?

Problem 4

	P_b	Voids	VMA	P#8	P#200
Design	4.7	4.0	13.5	48	3.9
Field					

Problem 5

	P_b	Voids	VMA	P#8	P#200
Design	5.5	4.0	15.2	52	4.8
Field					

Class Mix Designs

01 vs. 02

- **Voids higher,**
- **G_{mm} level,**
- **G_{mb} lower,**
- **P200 level,**
- **P8 level,**
- **VMA higher.**

Class Mix Designs

01 (1:1) vs. 02 (+2:1)

- **Voids higher,**
- **G_{mm} level,**
- **G_{mb} lower,**
- **P200 level,**
- **P8 level,**
- **VMA higher.** **It's all about the sand!**

Question: What is happening to VMA?

Class Mix Designs

Review one mix from:
Design to
Proportioning to
Production
enclosed at the back of the chapter.

Basic equation for determining asphalt plant console percentages vs. mix design percentages

Given: JMF as follows:

Coarse Aggregate	=	60%
Fine Aggregate, Man.	=	25%
Fine Aggregate, Nat.	=	13%
MF	=	2%
Total Aggregate	=	100%

HMA facility based on 100% aggregate with mineral filler treated as an additive. Therefore, to from 100% aggregate (design) to 100% aggregate without mineral filler we determine the:

1. Correction factor,
2. Console percentages , and
3. Dust to return

Correction factor (CF) = (100% minus MF%)/100
= (100% -2%) / 100 = 0.98

Console percentages = (Design % / CF)

Coarse Aggregate	=	61.2
Fine Aggregate, Man.	=	25.5
Fine Aggregate, Nat.	=	13.3
Total Aggregate	=	100
Total Asphalt	=	Target @ 4.0% voids

Changes that may occur from mix design through construction.
Given: Hot-Mix Asphalt Mix Design, Intermediate Course.

Product	CA #1	CA #2	Man FA	Nat FA	MF	
%Agg.	43.0	28.0	15.0	13.0	1.0	
Sieve Size						JMF
25.0	100	100	100	100	100	100
19.0	83	100	100	100	100	93
12.5	40	100	100	100	100	74
9.5	22	99	100	100	100	66
4.75	6	33	97	99	100	40
2.36	4	9	69	90	100	27
1.18	3	6	41	73	100	20
0.600	3	5	25	52	100	14
0.300	3	5	14	23	100	9
0.150	3	5	8	6	95	6
0.075	2.4	4.3	5.5	2.3	90	4.3

Comments: Total Coarse Aggregate is too high.
Total Sand is too low.
P200 is low for N50.

Volumetrics: Optimum AB = 4.7% @ 4.0% voids
VMA = 14.6% >> 13.0 minimum
VFA = 72%

Test Strip: Prior to starting we adjusted CA #1 and CA#2 down 1% each and increased Man FA and Nat FA up by 1% each. Targeted and metered MF @ 1% instead of ¾%.
Test Strip Data yielded 4.8% voids.

We adjusted CA #1 down 2% and increased Nat FA up by 2%. Targeted metered MF @ 1.5% instead of 2%.
Test Data yielded 4.0% voids with correct AB content.

Total CA was at 71% to begin>>65% max. desired however, Through adjustments we produced at 67% CA. Recommended targets on the 4.75 mm sieve for this mixture is 45%.

Adjustments made to mixture during the test strip.

Product	CA #1	CA #2	Man FA	Nat FA	MF	
%Agg.	40.0	27.0	16.0	16.0	1.0	
Sieve Size						JMF
25.0	100	100	100	100	100	100
19.0	83	100	100	100	100	93
12.5	40	100	100	100	100	76
9.5	22	99	100	100	100	69
4.75	6	33	97	99	100	44
2.36	4	9	69	90	100	30
1.18	3	6	41	73	100	22
0.600	3	5	25	52	100	16
0.300	3	5	14	23	100	9
0.150	3	5	8	6	95	6
0.075	2.4	4.3	5.5	2.3	90	4.3

The __Basics__ Of

The Bailey Method

William J. Pine
Emulsicoat, Inc. / Heritage Research Group
Urbana, IL / Indianapolis, IN

Aggregate Blending
The Bailey Method

- Originally developed by Robert D. Bailey
- Evaluate aggregate **packing** characteristics
- Determine what is "**Coarse**" and "**Fine**"
- Evaluate individual aggregates **__and__** the combined blend by **VOLUME** as well as by **weight**

2

Aggregate Packing
What Influences the Results?

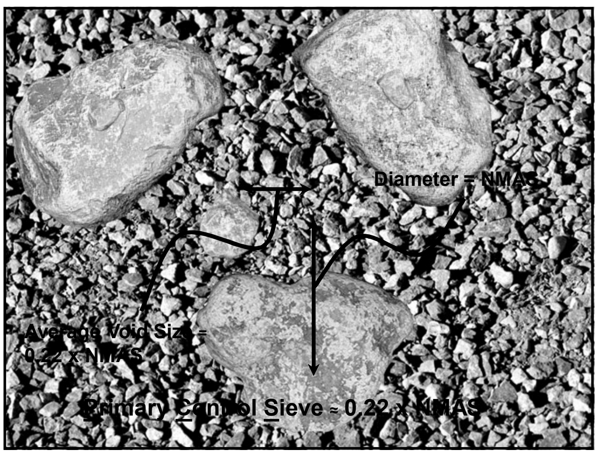
- **Gradation**
  - continuously-graded, gap-graded, etc.
- **Type & Amount of Compactive Effort**
  - static pressure, impact or shearing
- **Shape**
  - flat & elongated, cubical, round
- **Surface Texture** (micro-texture)
  - smooth, rough
- **Strength**
  - Weak vs. Strong, Influence of particle **__shape__**?

3

Defining "**Coarse**" and "**Fine**"

- "**Coarse**" fraction
  - Larger particles that **create voids**
- "**Fine**" fraction
  - Smaller particles that **fill voids**
- Estimate **void size**
  - Using **N**ominal **M**aximum **A**ggregate **S**ize (**NMAS**)
- **Break** between "**Coarse**" and "**Fine**"
  - **Primary Control Sieve (PCS)**

4



Primary **C**ontrol **S**ieve

Mixture NMAS	NMAS x 0.22	Primary Control Sieve
37.5mm	8.250mm	9.5mm
25.0mm	5.500mm	4.75mm
19.0mm	4.180mm	4.75mm
12.5mm	2.750mm	2.36mm
9.5mm	2.090mm	2.36mm
4.75mm	1.045mm	1.18mm

PCS determines the **break** between **Coarse** and **Fine** in the combined blend **and** if a **given** aggregate is a **CA** or **FA**

6

Evaluating Aggregates by **Volume**

- Why?
  - Better understand **aggregate packing**
  - Control **VOLUME** of **Coarse** and **Fine** for Mix "**Type**"
- How?
  - Test the **individual Coarse** and **Fine** aggregates

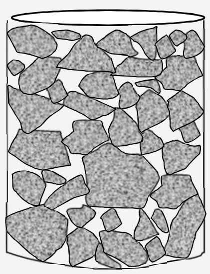
Fine-graded

Coarse-graded

SMA

7

Loose **U**nit **W**eight - CA

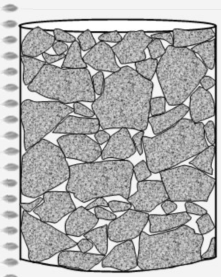


- **NO** compactive effort applied
- **Start** of particle-to-particle contact
- Use **shoveling** procedure
- Strike off ~ level
  - Careful **not** to compact
- Determine **LUW**
  - Kg/m^3 or $lbs./ft^3$
- Determine **volume** of **voids**

AASHTO T19

8

Rodded **U**nit **W**eight - CA



- **With** compactive effort applied
- **Increased** particle-to-particle contact
- **Three** equal lifts using **shoveling** procedure
- Rod **25** times per lift
- Strike off ~ level
  - Careful **not** to compact
- Determine **RUW**
  - Kg/m^3 or $lbs./ft^3$
- Determine **volume** of **voids**

AASHTO T19

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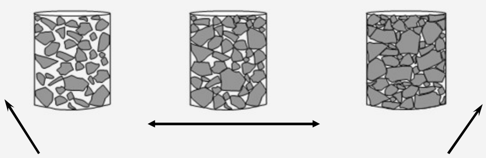
Chosen Unit Weight - CA(s)

< LUW | LUW | RUW



Fine-Graded **60-85%** | **Coarse-Graded** **95-105%** | **SMA** **110-125%**

→ INCREASING CA CUW →

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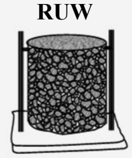
Chosen Unit Weight - FA(s)

100% LUW

SMA

FA CUW "SET" According To Mix Type

100% RUW



Dense-graded

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Developing the Combined Blend

1. Determine Mix **Type** & **NMAS**
2. Chose the **VOLUME** of **CA**
3. Blend the **CA's** by **VOLUME**
4. Blend the **FA's** by **VOLUME**
5. Choose the ***desired*** % Minus 0.075mm

Convert the Individual aggregate %'s from **VOLUME** to **weight**

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Combined Blend Evaluation

- Evaluation method depends on which **fraction** (**Coarse** or **Fine**) is in **control**:
  - **Coarse**-graded, **SMA**
  - **Fine**-graded

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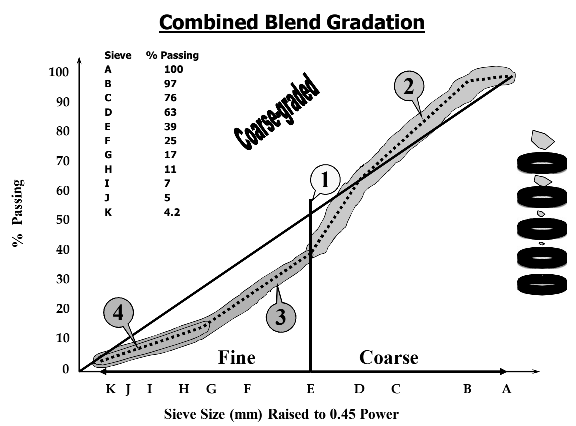
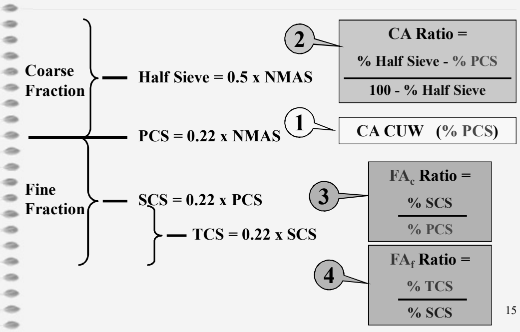


Combined Blend Evaluation
Coarse-Graded Mixes



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Combined Blend Evaluation
Coarse-Graded Mixes

1. **CA CUW increase = VMA increase**
   - **4%** change in **PCS ≅ 1%** change in **VMA or Voids**
   - **Range 3 - 5%**
2. **CA Ratio increase = VMA increase**
   - **0.20** change ≅ **1%** change in **VMA or Voids**
   - **Range 0.10 – 0.30**
3. **FA_c Ratio increase = VMA decrease** (Has the most influence on VMA or Voids)
   - **0.05** change ≅ **1%** change in **VMA or Voids**
   - **Range 0.025 – 0.075**
4. **FA_f Ratio increase = VMA decrease**
   - **0.05** change ≅ **1%** change in **VMA or Voids**
   - **Range 0.025 – 0.075**

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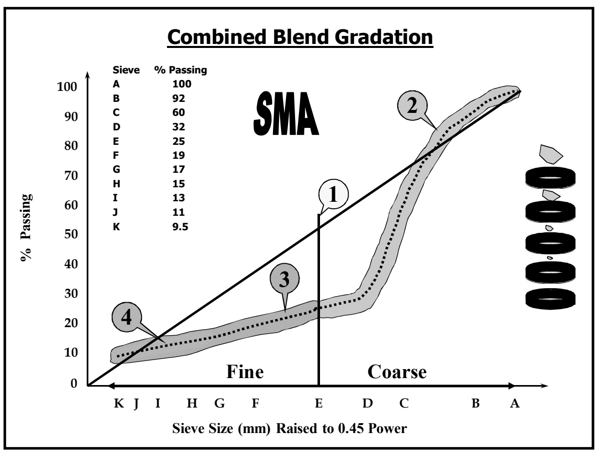

Combined Blend Evaluation
SMA Mixes

1. **CA CUW increase = VMA increase** (Has the most influence on VMA or Voids)
   - **2%** change in **PCS ≅ 1%** change in **VMA or Voids**
   - **Range 1 - 3%**
2. **CA Ratio increase = VMA increase**
   - **0.20** change ≅ **1%** change in **VMA or Voids**
   - **Range 0.10 – 0.30**
3. **FA_c Ratio increase = VMA decrease**
   - **0.10** change ≅ **1%** change in **VMA or Voids**
   - **Range 0.075 – 0.125**
4. **FA_f Ratio increase = VMA decrease** (Has the 2nd most influence on VMA or Voids)
   - **0.10** change ≅ **1%** change in **VMA or Voids**
   - **Range 0.075 – 0.125**

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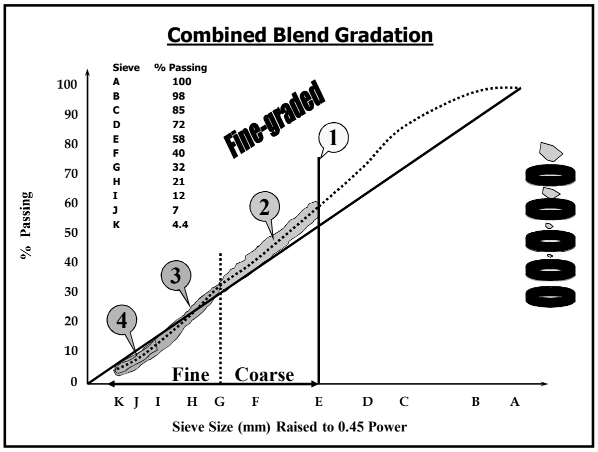

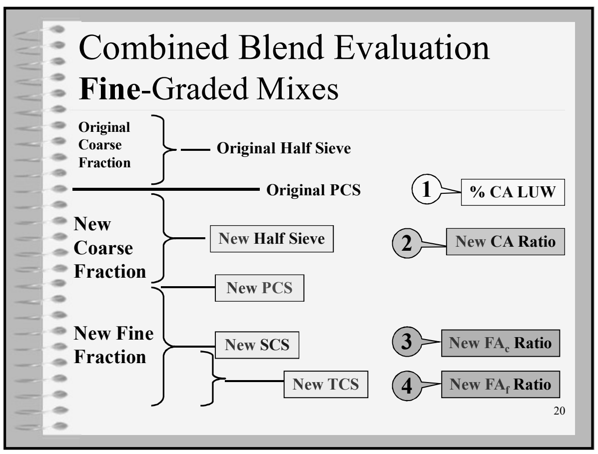

Combined Blend Evaluation
Fine-Graded Mixes

1. **CA CUW decrease** = **VMA increase**
   - **6%** change **ORIGINAL PCS ≅ 1%** change in **VMA or Voids**
   - **Range 5 - 7%**
2. **New CA Ratio increase** = **VMA increase**
   - **0.35** change ≅ **1%** change in VMA or Voids
   - **Range 0.25 – 0.45**
3. **New FA_c Ratio increase** = **VMA decrease**
   - **0.05** change ≅ **1%** change in VMA or Voids
   - **Range 0.025 – 0.075**
4. **New FA_f Ratio increase** = **VMA decrease**
   - **0.05** change ≅ **1%** change in VMA or Voids
   - **Range 0.025 – 0.075**

Has the most influence on VMA or Voids

- **Old CA Ratio** still relates to **segregation** susceptibility

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Estimating VMA or Voids
Coarse-Graded Mix Example

Trial #1 (% Passing)			**Trial #2** (% Passing)	
25.0mm	**100.0**		**25.0mm**	**100.0**
19.0mm	**97.4**	← NMAS →	**19.0mm**	**98.0**
12.5mm	**76.2**		**12.5mm**	**76.5**
9.5mm	**63.5**	← HALF →	**9.5mm**	**63.6**
4.75mm	**38.2**	← PCS →	**4.75mm**	**37.2**
2.36mm	**23.6**		**2.36mm**	**22.1**
1.18mm	**18.8**	← SCS →	**1.18mm**	**16.5**
0.60mm	**13.1**		**0.60mm**	**11.8**
0.30mm	**7.4**	← TCS →	**0.30mm**	**6.8**
0.15mm	**5.7**		**0.15mm**	**5.2**
0.075mm	**4.0**		**0.075mm**	**3.5**

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Estimating VMA or Voids
Trial #2 vs. Trial #1

- **PCS**
  37.2 – 38.2 = - 1.0
- **CA** ratio
  0.725 – 0.693 = + 0.032
- **FA$_c$** ratio
  0.444 – 0.492 = - 0.048
- **FA$_f$** ratio
  0.412 – 0.394 = + 0.018

- **Increases** VMA or Voids
  1.0/4.0 = + 0.25%
- **Increases** VMA or Voids
  0.032/0.2 = + 0.16%
- **Increases** VMA or Voids
  0.048/0.05 = + 0.96%
- **Decreases** VMA or Voids
  0.018/0.05 = - 0.36%
- Total Estimated Change:
  – **Plus ~ 1.0% VMA**

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Sample	Mix Design	1	2	3	4
Date					
Identification					Proposed
19.0mm	100.0	100.0	100.0	100.0	100.0
12.5mm	98.1	95.9	95.7	98.9	97.5
9.5mm	71.2	71.0	68.4	70.7	70.7
6.25mm	40.1	40.6	39.4	39.4	39.8
4.75mm	25.7	26.6	26.0	24.9	25.6
2.36mm	21.7	21.2	20.7	20.4	22.0
1.18mm	17.4	16.9	16.5	16.0	17.4
0.600mm	14.8	14.1	14.0	13.1	14.6
0.300mm	13.1	12.1	11.7	11.1	12.7
0.150mm	10.9	10.0	9.5	9.3	10.6
0.075mm	9.2	7.8	8.2	7.4	8.3
% AC	5.70	5.86	5.65	5.72	5.72
% AC Absptn	0.41	0.61	0.23	0.46	0.46
Actual VMA	17.9	18.5	17.6	18.7	
Actual Voids	4.0	4.8	3.4	4.9	
CA	0.307	0.327	0.308	0.313	0.297
FAc	0.682	0.665	0.676	0.642	0.664
FAf	0.736	0.709	0.679	0.710	0.726
PCS	Compares Each Sample to the Mix Design	0.17	0.33	0.43	-0.10
CA		0.20	0.01	0.06	-0.10
FAc		0.23	0.08	0.53	0.24
FAf		-0.36	-0.76	-0.35	-0.13
Total		0.23	-0.34	0.68	-0.09
Est VMA		18.1	17.6	18.6	17.8
Act VMA		18.5	17.6	18.7	0.0
Diff in VMA		**-0.4**	**0.0**	**-0.1**	**17.8**
Est Voids		4.3	3.4	4.7	4.0
Act Voids		4.8	3.4	4.9	0.0
Diff in Voids		**-0.5**	**0.0**	**-0.2**	**4.0**
PCS	Compares Each Sample to the Previous Sample	0.17	0.17	0.10	-0.53
CA		0.20	-0.19	0.05	-0.16
FAc		0.23	-0.15	0.45	-0.29
FAf		-0.36	-0.40	0.41	0.21
Total		0.23	-0.57	1.02	-0.77
Est VMA		18.1	17.9	18.6	17.9
Act VMA		18.5	17.6	18.7	0.0
Diff in VMA		**-0.4**	**0.3**	**-0.1**	**17.9**
Est Voids		4.3	3.8	4.8	4.1
Act Voids		4.8	3.4	4.9	0.0
Diff in Voids		**-0.5**	**0.4**	**-0.1**	**4.1**

The Four Main Principles

1. **% PCS** (**Volume** of **CA**)
   - **Increase/decrease** in VMA depends on mix **type**
2. **CA ratio** (Control with **CA Volume** blend)
   - **Low** values can be susceptible to **segregation**
   - **High** values can be difficult to **compact**
   - **As it increases, VMA increases**
3. **FA_c ratio** (Control with **FA Volume** blend)
   - **As it increases, VMA decreases**
4. **FA_f ratio** (Control with % minus 0.075mm)
   - **As it increases, VMA decreases**

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So How Does the Method *Help*?

- In Developing **New** Blends:
  - Field Compactability
  - Segregation Susceptibility
- In Evaluating **Existing** Blends:
  - What's worked and what hasn't?
  - More clearly define principle ranges
- In **Estimating** VMA/Void changes:
  - Between Design trials
  - Between QC and/or QA samples
  - For **PROPOSED** blend changes
- **Saves Time and Reduces Risk!**

It's a TOOL!

Not a SPEC!

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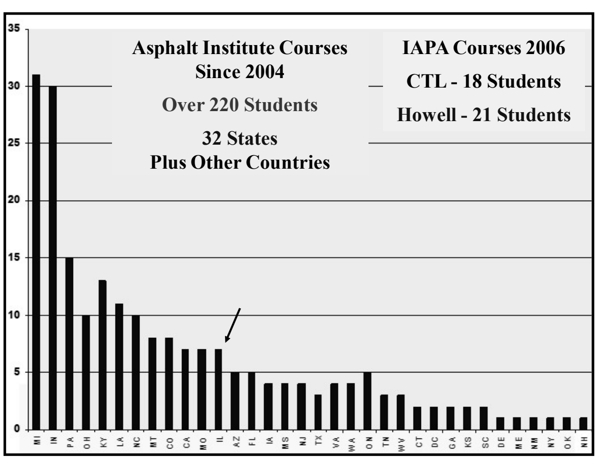


Questions or Comments?
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