Hot Mix Asphalt Level III Technician Course

LAKE LAND COLLEGE

2015-2016

Illinois Department of Transportation
Bureau of Materials & Physical Research

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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:

Time Limit is 4 hours
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.

↓↓↓ ↓↓↓ ↓↓↓ ↓↓↓ **Please continue filling out the other side of this form** ↓↓↓ ↓↓↓ ↓↓↓ ↓↓↓

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 150
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.

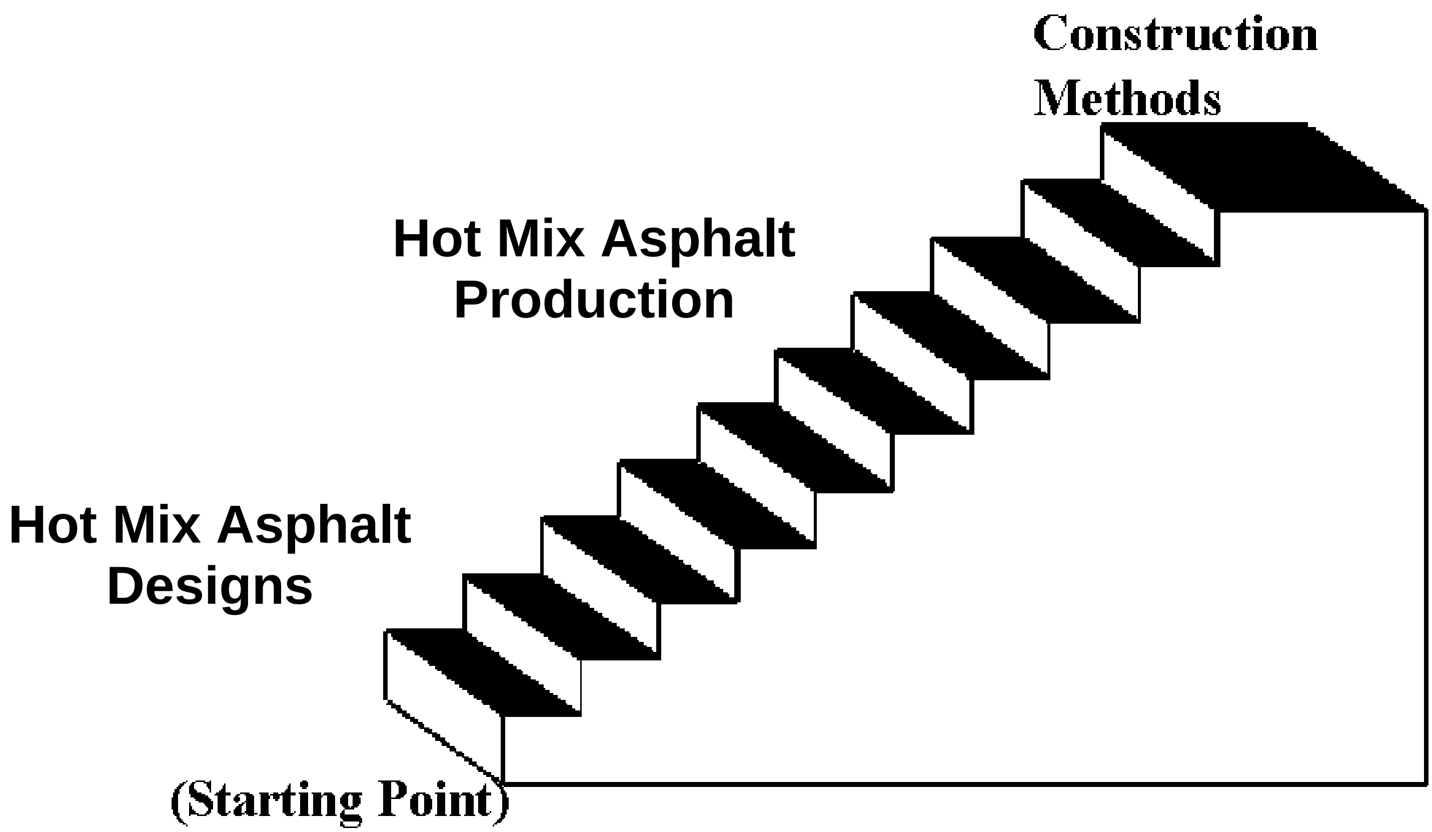
Correct mix design involves adhering to an established set of laboratory techniques and design criteria. These techniques and criteria serve as the design philosophy of the governing agency. They are based on scientific research and equally important on many years of experience in observing the performance 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 and Physical Research.

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
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)	79.0	98.0	100.0	100.0	100.0	100.0	92.9
4.75 (#4)	14.0	27.0	100.0	99.0	100.0	100.0	48.4
2.36 (#8)	8.0	8.0	88.0	82.0	100.0	100.0	35.1
1.18 (#16)	5.0	6.0	54.0	62.0	100.0	100.0	24.9
600µm (#30)	4.0	5.0	31.0	42.0	100.0	100.0	17.3
300µm (#50)	3.0	5.0	12.0	17.0	100.0	100.0	9.5
150µm (#100)	3.0	4.0	7.0	5.0	95.0	100.0	6.1
75µm (#200)	2.2	4.1	4.3	2.0	90.0	100.0	4.9

Mixture Specifications		FORMULA	FORMULA RANGE	
Min	Max		Min	Max
	100	100	100	100
	100	100	100	100
90	100	100	100	100
66	100	93	93	93
24	65	48	43	53
16	48	35	30	40
10	32	25	25	25
--	--	17	13	21
4	15	10	10	10
3	10	6	6	6
2	6	4.9	3.4	6.4

	#1	#2	#3	#4	#5	#6	Blended SpGr
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

Dust AC Ratio
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) Target	VMA	VFA	G_{se}	G_{sb}	TSR
Asphalt determined at 4.0% voids: -	6.51								
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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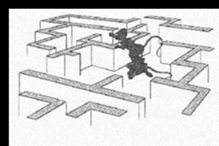
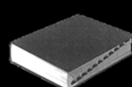
Illinois DOT Specifications

- Standard Specifications for Road & Bridge Construction, current edition
  - Hot Mix Asphalt (HMA) – 1030
  - QC / QA – 1030.05
- Special Provisions
  - RAP



Murphy Pavement Technology

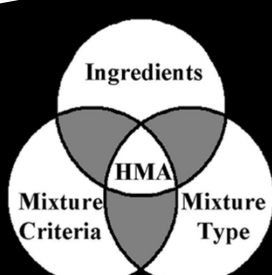
Hierarchy



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

Murphy Pavement Technology

Successful Hot Mix Asphalt



Murphy Pavement Technology

Ingredients

- Coarse Aggregate: 1004.03; p. 742
- Fine Aggregate: 1003.03; p. 734
- Mineral Filler: 1011.01; p. 780
- Asphalt Cement: 1032.05; p. 847

Ingredients

- Coarse Aggregate: Friction Issues
- Fine Aggregate: QC Criterion
- Performance Graded: Certified Source
- RAP: Special Provision

Mixture Types

- Standard Specifications for Road and Bridge Construction: current edition
- HMA – Article 1030
  - High ESAL – Art. 1030.04(1)
  - Low ESAL – Art. 1030.04(2)
  - ~~Stabilized Sub base – Art. 1030.04(3)~~
  - ~~HMA Shoulders – Art. 1030.04(3)~~
  - Stone Matrix Asphalt (SMA)
  - IL-4.75 mm

Mixture Types

- Special Provisions
  - Reclaimed Asphalt Pavement (RAP)
  - IL – 9.5 mm Fine Graded

Mixture Criteria

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

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

(2) Initial and Final Set Time (ASTM C 266).
(3) Strength (ASTM C 109).

The test results for the water sample shall not deviate from the test results for the deionized water, except as allowed by the precision in the test method.

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 current Bureau of Materials and Physical Research 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 current Bureau of Materials and Physical Research

Policy Memoranda, "Crushed Slag Producer Certification and Self-Testing Program" and "Slag Producer 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 furnace. The acceptance and use of steel slag sand shall be according to the current Bureau of Materials and Physical Research 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 current Bureau of Materials and Physical Research 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 current Bureau of Materials and Physical Research 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, ITP 104, % Loss max.	10	15	20
Minus No. 200 (75 µm) Sieve Material, ITP 11, % max. 4/	3	6 1/	10 1/
Organic Impurities Check, ITP 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 (ITP 21) will be checked for mortar making properties according to ITP 71, 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 current Bureau of Materials and Physical Research 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.

Art. 1003.01 Fine Aggregates

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

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

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 the fine aggregate gradation FA 22, the aggregate producer shall set the midpoint percent passing, and the Department will apply a range of ± ten 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 current Bureau of Materials and Physical Research Policy Memorandum, “Aggregate Gradation Control System” 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 current Bureau of Materials and Physical Research 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.

(b) Quality. The fine aggregate for portland cement concrete shall meet Class A Quality, except that the minus No. 200 (75 μm) sieve ITP 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 current Bureau of Materials and Physical Research 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.

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-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.

For trench backfill, crushed concrete sand and construction and demolition debris sand may be used in lieu of the above.

For pipe underdrains, Type 3, the fine aggregate shall consist of sand or crushed gravel 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 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 1003.02(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.

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-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.

For trench backfill, crushed concrete sand and construction and demolition debris sand may be used in lieu of the above.

For pipe underdrains, Type 3, the fine aggregate shall consist of sand or crushed gravel 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 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 1003.02(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.

(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 current Bureau of Materials and Physical Research 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.

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 current Bureau of Materials and

Physical Research 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 (ITP 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 current Bureau of Materials and Physical Research Policy Memoranda, “Crushed Slag Producer Certification and Self-Testing Program” and “Slag Producer 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 current Bureau of Materials and Physical Research 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 current Bureau of Materials and Physical Research 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, ITP 104 1/, % Loss max.	15	15	20	25 2/
Los Angeles Abrasion, ITP 96, % Loss max.	40 3/	40 4/	40 5/	45
Minus No. 200 (75 µm) Sieve Material, ITP 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/	---

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, 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 ITP 113.

10/ Test shall be run according to ITP 203.

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 current Bureau of Materials and Physical Research Policy Memorandum, “Aggregate Gradation Control System”.

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.

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3/ When used in HMA (High and Low ESAL) mixtures, the percent passing the No. 16 (1.18 mm) sieve for gradations CA 8, 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.

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 current Bureau of Materials and Physical Research Policy Memorandum, "Aggregate Gradation Control System" 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 current Bureau of Materials and Physical Research 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, and 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 and Percent Passing						
		2 1/2 in.	2 in.	1 3/4 in.	1 1/2 in.	1 in.	1/2 in.	No. 4
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

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Class of Concrete 1/	Combined Sizes	Sieve Size (metric) and Percent Passing						
		63 mm	50 mm	45 mm	37.5 mm	25 mm	12.5 mm	4.75 mm
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 (ITP 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.

Coarse Aggregates Art. 1004.03

<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 Leveling Binder
IL-9.5 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="5">HMA
High ESAL</td><td rowspan="5">D Surface and Leveling Binder
IL-9.5

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></td><td></td><td>75% Limestone</td><td>Crushed Slag (ACBF) or Crushed Sandstone</td></tr>
</table>

Art. 1004.03 Coarse Aggregates

Use	Mixture	Aggregates Allowed	
HMA High ESAL	E Surface IL-9.5 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 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.

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

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), other binder courses, and surface course IL-9.5L (Low ESAL), 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, 2, & 3	3/8 in. (10 mm) Seal	CA 16
Class A-1	1/2 in. (13 mm) Seal	CA 15
Class A-2 & 3	Cover	CA 14
HMA High ESAL	IL-19.0 IL-9.5	CA 11 1/ CA 16 and/or CA 13 CA 16
HMA Low ESAL	IL-19.0L IL-9.5L Stabilized Subbase or Shoulders	CA 11 1/ CA 16

1/ CA 16 or CA 13 may be blended with the gradations listed.

(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; Stabilized 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 stabilized subbase, 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

1029.03 Equipment. Equipment shall be according to the following.

Item	Article/Section
(a) Concrete Mixers and Trucks	1103.01
(b) Batching and Weighing Equipment	1103.02
(c) Automatic and Semi-Automatic Batching Equipment	1103.03
(d) Water Supply Equipment	1103.11
(e) Mobile Portland Cement Concrete Plants	1103.04
(f) Foam Generator (Note 1)	
(g) Mobile Site Batch Plants (Note 2)	

Note 1. Foam generating equipment shall be calibrated daily to produce an accurate volume of foam.

Note 2. Mobile site batch plants shall be capable of mixing and pumping cellular concrete, and shall have a minimum 1 cu yd (0.76 cu m) capacity. Mobile site plants shall be calibrated before the start of a project and during the project as necessary.

ASPHALT AND BITUMINOUS ITEMS

SECTION 1030. HOT-MIX ASPHALT

1030.01 Description. This section describes the materials, mix design, quality control/quality assurance (QC/QA), proportioning, mixing, and transportation requirements to produce hot-mix asphalt (HMA) using Illinois Modified Strategic Highway Research Program (SHRP) Superpave criteria.

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

High ESAL	IL-19.0 binder; IL-9.5 surface
Low ESAL	IL-19.0L binder; IL-9.5L surface; Stabilized Subbase (HMA) 1/ HMA Shoulders 2/

1/ Uses 19.0L binder mix.

2/ Uses 19.0L for lower lifts and 9.5L for surface lift.

1030.02 Materials. Materials shall be according to the following.

Item	Article/Section
(a) Coarse Aggregate	1004.03
(b) Fine Aggregate	1003.03
(c) RAP Material	1031
(d) Mineral Filler	1011
(e) Hydrated Lime	1012.01

(f) Slaked Quicklime (Note 1)
(g) Performance Graded Asphalt Binder (Note 2) 1032
(h) Fibers (Note 3)
(i) Warm Mix Asphalt (WMA) Technologies (Note 4)

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

Note 2. The asphalt binder shall be an SBS PG 76-28 when the SMA is used on a full-depth asphalt pavement and SBS PG76-22 when used as an overlay.

Note 3. A stabilizing additive such as cellulose or mineral fiber shall be added to SMA mixtures according to Illinois Modified AASHTO M 325. The stabilizing additive shall meet the Fiber Quality 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 4. Warm mix additives or foaming processes shall be selected from the Department's qualified producer list.

1030.03 Equipment. Equipment shall be according to the following.

	Item	Article/Section
(a)	Hot-Mix Asphalt Plant	1102.01
(b)	Heating Equipment (Note 1)	1102.07
(c)	Hot-Mix Surge Bins	1102.01(a)(6)

Note 1. 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. Polymer modified asphalt binder shall be placed in an empty tank and shall not be blended with other asphalt binders.

1030.04 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 current Bureau of Materials and Physical Research 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 current Quality Control/Quality Assurance document "Hot-Mix Asphalt Design Verification Procedure". In no case will a mix design be verified until determination of the apparent low bidder.

When specified on the plans, RAP material meeting the requirements of Section 1031 may be used. The Engineer reserves the right to adjust the quantities of RAP material contained in the mixture for the purpose of mix design or field production, on the basis of test results.

The HMA mixtures shall be designed according to the respective Illinois Modified AASHTO references listed below.

AASHTO M 323	Standard Specification for Superpave Volumetric Mix Design
AASHTO R 30	Standard Practice for Mixture Conditioning of Hot-Mix Asphalt (HMA)
AASHTO R 35	Standard Practice for Superpave Volumetric Design for Hot-Mix Asphalt (HMA)
AASHTO T 209	Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
AASHTO T 305	Standard Method of Test for Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures
AASHTO T 312	Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor
AASHTO T 308	Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method
AASHTO T 324	Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA)
AASHTO T 283	Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture-Induced Damage

The SMA mixture shall be designed according to the following additional Illinois Modified AASHTO references listed below, except as modified herein.

AASHTO M 325	Standard Specification for Designing Stone Matrix Asphalt (SMA)
AASHTO R 46	Standard Practice for Designing Stone Matrix Asphalt (SMA)
AASHTO T 305	Determination of Draindown Characteristics in Uncompacted Mixtures

(a) Mixture Composition. The Job Mix Formula (mix design) represents the aggregate grading and asphalt binder content that produce the desired mix criteria in the laboratory. The ingredients of the HMA shall be combined in such proportions as to produce a mixture conforming to the composition limits by weight.

For all HMA mixtures, it is recommended that the selected combined aggregate gradation not pass through the restricted zones specified in Illinois Modified AASHTO M 323.

(1) High ESAL Mixtures. The Job Mix Formula (JMF) shall fall within the following limits.

HIGH ESAL, MIXTURE COMPOSITION (% PASSING) 1/								
Sieve Size	IL-19.0 mm		SMA 12.5 4/		IL-9.5 mm		IL-4.75 mm	
	min	max	min	max	min	max	min	max
1 1/2 in. (37.5 mm)								
1 in. (25 mm)		100						
3/4 in. (19 mm)	90	100		100				
1/2 in. (12.5 mm)	75	89	90	99		100		100
3/8 in. (9.5 mm)			50	85	90	100		100
#4 (4.75 mm)	40	60	20	40	32	69	90	100
#8 (2.36 mm)	26	42	16	24 5/	32	52 2/	70	90
#16 (1.18 mm)	15	30			10	32	50	65
#50 (300 µm)	6	15			4	15	15	30
#100 (150 µm)	4	9			3	10	10	18
#200 (75 µm)	3	6	8.0	11.0 3/	4	6	7	9 3/
Ratio Dust/Asphalt Binder		1.0				1.0		1.0

1/ Based on percent of total aggregate weight.

2/ The mixture composition shall not exceed 44 percent passing the #8 (2.36 mm) sieve for surface courses with Ndesign = 90.

3/ Additional minus No. 200 (0.075 mm) material required by the mix design shall be mineral filler, unless otherwise approved by the Engineer.

4/ The maximum percent passing the #635 (20 µm) sieve shall be ≤ 3 percent.

5/ When establishing the Adjusted Job Mix Formula (AJMF) the percent passing the #8 (2.36 mm) sieve shall not be adjusted above 24 percent.

(2) Low ESAL Mixtures. The Job Mix Formula (JMF) shall fall within the following limits.

Low ESAL, MIXTURE COMPOSITION (% PASSING)				
Sieve Size	IL-9.5L		IL-19.0L	
	min.	max.	min.	max.
1 in. (25.0 mm)				100
3/4 in. (19.0 mm)			95	100
1/2 in. (12.5 mm)		100		
3/8 in. (9.5 mm)	95	100		
#4 (4.75 mm)	52	80	38	65
#8 (2.36 mm)	38	65		
#30 (600 µm)		< 50% of the percentage passing the #4		< 50% of the percentage passing the #4
#200 (75 µm)	4.0	8.0	3.0	7.0
Asphalt Binder %	4.0	8.0	4.0	8.0
Ratio Dust/Asphalt Binder		1.0 @ design		1.0 @ design

(b) Volumetric Requirements.

(1) High ESAL Mixtures. The target value for the air voids of the HMA shall be 4.0 percent at the design number of gyrations. The VMA and VFA 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.

<table>
<tr><th colspan="5">VOLUMETRIC REQUIREMENTS
High ESAL</th></tr>
<tr><th rowspan="2">Ndesign</th><th colspan="3">Voids in the Mineral Aggregate (VMA), % minimum</th><th rowspan="2">Voids Filled with Asphalt Binder (VFA),%</th></tr>
<tr><th>IL-19.0</th><th>IL-9.5</th><th>IL-4.75 1/</th></tr>
<tr><td>50</td><td rowspan="3">13.5</td><td rowspan="3">15.0</td><td>18.5</td><td>65 - 78 2/</td></tr>
<tr><td>70</td><td rowspan="2"></td><td rowspan="2">65 - 75</td></tr>
<tr><td>90</td></tr>
</table>

1/ Maximum Draindown for IL-4.75 shall be 0.3 percent.

2/ VFA for IL-4.75 shall be 76-83 percent.

(2) Low ESAL Mixtures.

VOLUMETRIC REQUIREMENTS Low ESAL				
Mixture Composition	Design Compactive Effort	Design Air Voids Target, %	VMA (Voids in the Mineral Aggregate), % min.	VFA (Voids Filled with Asphalt Binder), %
IL-9.5L	N_{DES}=30	4.0	15.0	65 - 78
IL-19.0L	N_{DES}=30	4.0	13.5	N/A

(3) SMA Mixtures.

ESALs (million)	Ndesign	Design Air Voids Target, %	Voids in the Mineral Aggregate (VMA), % min.	Voids Filled with Asphalt (VFA), %
≤ 10	50	4.0	16.0	75 – 80
> 10	80	4.0	17.0	75 – 80

(c) Determination of Need for Anti-Stripping Additive. The mixture designer shall determine if an additive is needed in the mix to prevent stripping. The determination will be made on the basis of tests performed according to Illinois Modified AASHTO T 283. To be considered acceptable by the Department as a mixture not susceptible to stripping, the conditioned to unconditioned split tensile strength ratio (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 original conditioned tensile strength determined for 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, at the Contractor's option.

Dry hydrated lime shall be added at a rate of 1.0 to 1.5 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 exact rate of application for all anti-stripping additives will be determined by the Engineer. The method of application shall be according to Article 1102.01(a)(10).

(d) Verification Testing. High ESAL, IL-4.75, and SMA mix designs submitted for verification will be tested to ensure that the resulting mix designs will pass the required criteria for the Hamburg Wheel Test (Illinois Modified AASHTO T 324) and the Tensile Strength Test (Illinois Modified AASHTO T 283). The Department will perform a verification test on gyratory specimens compacted by the Contractor. If the mix fails the Department's verification test, the Contractor shall make necessary changes to the mix and provide passing Hamburg Wheel and tensile strength test results from a private lab. The Department will verify the passing results.

All new and renewal mix designs shall meet the following requirements for verification testing.

(1) Hamburg Wheel Test Criteria. 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 criteria shall be based on the high temperature binder grade of the mix as specified in the mix requirements table of the plans.

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

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

(2) Tensile Strength Criteria. The minimum allowable conditioned tensile strength shall be 60 psi (415 kPa) for non-polymer modified performance graded (PG) asphalt binder and 550 kPa (80 psi) for polymer modified PG asphalt binder. The maximum allowable unconditioned tensile strength shall be 200 psi (1380 kPa).

1030.05 Quality Control/Quality Assurance (QC/QA).

(a) QC/QA Documents. QC/QA documents shall be as follows.

(1) Model Annual Quality Control (QC) Plan for Hot-Mix Asphalt (HMA) Production
(2) Model Quality Control (QC) Addenda for Hot-Mix Asphalt (HMA) Production
(3) Hot-Mix Asphalt QC/QA Laboratory Equipment
(4) Illinois Modified ASTM D 2950, Standard Test Method for Determination of Density of Bituminous Concrete In-Place by Nuclear Method
(5) Standard Test Method for Correlating Nuclear Gauge Densities with Core Densities
(6) Hot-Mix Asphalt QC/QA Start-Up Procedures
(7) Hot-Mix Asphalt QC/QA QC Personnel Responsibilities and Duties Checklist
(8) Hot-Mix Asphalt QC/QA Initial Daily Plant and Random Samples
(9) Determination of Random Density Test Site Locations
(10) Hot-Mix Asphalt QC/QA Control Charts/Rounding Test Values

(11) Hot-Mix Asphalt Design Verification Procedure
(12) Hot-Mix Asphalt Mix Design Procedure for Dust Correction Factor Determination
(13) Development of Gradation Bands on Incoming Aggregate at Mix Plants
(14) Bureau of Materials and Physical Research Policy Memorandum, "Minimum Private Laboratory Requirements for Construction Materials Testing or Mix Design"
(15) Segregation Control of Hot-Mix Asphalt
(16) Calibration of Equipment for Asphalt Content Determination

(b) Laboratory. The Contractor shall provide a laboratory, at the plant, according to the current Bureau of Materials and Physical Research Policy Memorandum, "Minimum Private Laboratory Requirements for Construction Materials Testing or Mix Design". The laboratory shall be of sufficient size and be furnished with the necessary equipment and supplies for adequately and safely performing the Contractor's QC testing. The Contractor is referred to the QC/QA document "Model Annual Quality Control Plan for Hot-Mix Asphalt (HMA) Production" for detailed information on the required laboratories. The required laboratory equipment for production and mix design is listed in the QC/QA document "Hot-Mix Asphalt QC/QA Laboratory Equipment".

The laboratory and equipment furnished by the Contractor shall be properly maintained. The Contractor shall maintain a record of calibration results at the laboratory. The Engineer may inspect measuring and testing devices at any time to confirm both calibration and condition. 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. If laboratory equipment becomes inoperable, the Contractor shall cease mix production.

(c) Annual Quality Control (QC) Plan and Addenda. 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 will result in suspension of HMA production or other appropriate actions as directed by the Engineer.

The Contractor shall submit, in writing to the Engineer, a proposed Annual QC Plan for each HMA plant for approval before each construction season. Job-specific QC Addenda to the Annual QC Plan must be submitted in writing to the Engineer 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. The proposed QC Plan shall be the QC/QA document "Model Annual Quality Control Plan for Hot-Mix Asphalt (HMA) Production", and the QC Addenda shall be the QC/QA document "Model Quality Control Addendum for Hot-Mix Asphalt (HMA) Production".

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

The Contractor may propose revisions to portions of the Annual QC Plan and QC Addenda. Likewise, the Annual QC Plan and QC Addenda may be amended during the progress of the work, by either party, subject to mutual agreement. Revisions require proper justification 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.

(d) Quality Control by Contractor. The Contractor shall perform or have performed the inspection and tests required to assure conformance to contract requirements. Control includes the recognition of obvious defects and their immediate correction. This 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. Inability to control HMA production is cause for the Engineer to stop the operation until the Contractor completes an investigation identifying the problems causing failing test results.

The Engineer shall be immediately notified of any failing tests and subsequent remedial action. Passing tests shall be reported to the Engineer no later than the start of the next work day.

If the Contractor receives approval to use an alternative mixture to that required by the contract, the QC program will be specified by the Department.

(1) Personnel. The Contractor shall provide a Quality Control (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” Technician 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”. All technicians performing mix design testing and plant sampling/testing shall have successfully completed the Department's “Hot-Mix Asphalt Level I Technician 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 required density tests on the job site.

All quality control personnel shall perform the required quality control duties. The Contractor is referred to the QC/QA document "Hot-Mix Asphalt QC/QA QC Personnel Responsibilities and Duties Checklist" for a description of personnel qualifications and duties. Testing shall be conducted to control the production of the mixture.

(2) Plant Tests. Contractor testing of all plant samples shall be completed within 3 1/2 hours of sampling.

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

Parameter	Frequency of Tests High ESAL Mixture Low ESAL Mixture	Test Method See Manual of Test Procedures for Materials
Aggregate Gradation % passing sieves: 1/2 in. (12.5 mm), No. 4 (4.75 mm), No. 8 (2.36 mm), No. 30 (600 µm), No. 200 (75 µm)	1 washed ignition oven test on the mix per half day of production Note 3.	Illinois Procedure
Asphalt Binder Content by Ignition Oven Note 1.	1 per half day of production	Illinois Modified AASHTO T 308
VMA Note 2.	Day's production ≥ 1200 tons (1090 metric tons) 1 per half day of production	Illinois Modified AASHTO R 35
	Day's production < 1200 tons (1090 metric tons) 1 per half day of production for first 2 days and 1 per day thereafter (first sample of the day)	

Parameter	Frequency of Tests High ESAL Mixture Low ESAL Mixture	Test Method See Manual of Test Procedures for Materials
Air Voids Bulk Specific Gravity of Gyratory Sample Note 4.	Day's production ≥ 1200 tons (1090 metric tons) 1 per half day of production	Illinois Modified AASHTO T 312
	Day's production < 1200 tons (1090 metric tons) 1 per half day of production for first 2 days and 1 per day thereafter (first sample of the day)	
Maximum Specific Gravity of Mixture	Day's production ≥ 1200 tons (1090 metric tons) 1 per half day of production	Illinois Modified AASHTO T 209
	Day's production < 1200 tons (1090 metric tons) 1 per half day of production for first 2 days and 1 per day thereafter (first sample of the day)	

Note 1. The Engineer may waive the ignition oven requirement for asphalt binder content if the aggregates to be used are known to have ignition asphalt binder content calibration factors which exceed 1.5 percent. If the ignition oven requirement is waived, other Department approved methods shall be used to determine the asphalt binder content.

Note 2. The G_{sb} used in the voids in the mineral aggregate (VMA) calculation shall be the same average G_{sb} value listed in the mix design.

Note 3. The Engineer reserves the right to require additional hot bin gradations for batch plants if control problems are evident.

Note 4. The WMA compaction temperature for mixture volumetric testing shall be 270 ± 5 °F (132 ± 3 °C) for quality control testing. The WMA compaction temperature for quality assurance testing will be 270 ± 5 °F (132 ± 3 °C) if the mixture is not allowed to cool to room temperature. If the mixture is allowed to cool to room temperature, it shall be reheated to standard HMA compaction temperatures.

b. Dust-to-Asphalt and Moisture Content. During production, the dust-to-asphalt binder ratio and the moisture content of the mixture at discharge from the mixer shall meet the following.

Parameter	High ESAL Mixture Low ESAL Mixture
Ratio Dust/Asphalt Binder 1/	0.6 to 1.2
Moisture	0.3 %

1/ Does not apply to SMA.

If at any time the dust-to-asphalt binder 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.

c. Anti-Strip Additive. During production, mixtures containing an anti-strip additive will be tested by the Department for stripping according to Illinois Modified AASHTO T 283. If the mixture fails to meet the TSR criteria for acceptance, no further mixture will be accepted until the Contractor takes such action as is necessary to furnish a mixture meeting the criteria.

d. Small Tonnage. The Contractor may apply the following for small tonnage of mixture.

Gradation analysis, voids, and asphalt binder content tests may not be required on a specific mixture if the day's production is less than 250 tons (225 metric tons) per mix. A minimum of one set of plant 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 quality control operations. If the required tonnage of any mixture for a single pay item is less than 250 tons (225 metric tons) in total, the Contractor shall state his/her intentions of waiving the "Required Plant 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.

e. Asphalt Binder Sampling. Asphalt binder samples shall be taken by the Contactor and witnessed by the Engineer at a frequency of one injection line-sample per week, per HMA plant. Sample containers will be furnished by the Department. The Engineer will submit the properly identified samples to the Bureau of Materials and Physical Research for testing.

f. HMA Sampling. For HMA mixture sampling, the Contractor shall obtain required plant samples according to the QC/QA document, "Hot-Mix Asphalt QC/QA Initial Daily Plant and Random Samples". The Contractor shall split all required samples and identify the split samples per the Engineer's instructions. These split samples shall be retained by the Contractor for assurance testing by the Engineer and be disposed of only with the permission of the Engineer. The split samples shall be stored in a dry, protected location.

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 and shall not be plotted on the control charts. The Contractor shall detail the situations in which check samples will be taken in his/her Annual QC Plan.

(3) Required Field Tests. The Contractor shall control the compaction process by testing the mix density at random locations as determined according to the QC/QA document, "Determination of Random Density Test Site Locations", and recording the results on forms approved by the Engineer. The Contractor shall follow the density testing procedures detailed in the QC/QA document, "Illinois Modified ASTM D 2950, Standard Test Method for Determination of Density of Bituminous Concrete In-Place by Nuclear Method".

The Contractor shall be responsible for establishing the correlation to convert nuclear density results to core densities according to the QC/QA document, "Standard Test Method for Correlating Nuclear Gauge Densities with Core Densities". The Engineer may require a new nuclear/core correlation if the Contractor's gauge is recalibrated during the project.

If the Contractor and Engineer agree the nuclear density test method is not appropriate for the mixture, cores shall be taken at random locations determined according to the QC/QA document "Determination of Random Density Test Site Locations". Three cores shall be taken at equal distances across the test site. These cores shall be averaged to provide a single test site result. Core densities shall be determined using the Illinois Modified AASHTO T 166 or T 275 procedure.

Quality control density tests shall be performed at randomly selected locations within 1/2 mile (800 m) intervals and 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 1/4 mile (400 m) intervals.

Testing of lifts equal to or greater than 4 in. (100 mm) compacted thickness shall be performed in the direct transmission mode according to the QC/QA document "Illinois Modified ASTM D 2950, Standard Test Method for Determination of Density of Bituminous Concrete In-Place by Nuclear Method". Density testing shall be accomplished intermittently throughout the day. In no case shall more than one-half day's production be completed without performing density testing.

Density tests shall be performed each day on patches located nearest the randomly selected location. The daily testing frequency shall be a minimum of two density tests per mix. Density testing shall be accomplished intermittently throughout the day. In no case shall more than one half day's production be completed without performing density testing.

(4) Control Limits. Target values shall be determined by applying adjustment factors to the AJMF where applicable. The target values shall be plotted on the control charts within the following control limits.

CONTROL LIMITS						
Parameter	High ESAL Low ESAL		SMA		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 %		
No. 4 (4.75 mm)	± 5 %	± 4 %	± 5 %	± 4 %		
No. 8 (2.36 mm)	± 5 %	± 3 %	± 4 %	± 2 %		
No. 16 (1.18 mm)			± 4 %	± 2 %	± 4 %	± 3 %
No. 30 (600 µm)	± 4 %	± 2.5 %	± 4 %	± 2.5 %		
Total Dust Content No. 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 %
Voids	± 1.2 %	± 1.0 %	± 1.2 %	± 1.0 %	± 1.2 %	± 1.0 %
VMA	-0.7 % 2/	-0.5 % 2/	-0.7 % 2/	-0.5 % 2/	-0.7 % 2/	-0.5 % 2/

1/ Based on washed ignition oven

2/ Allowable limit below minimum design VMA requirement

DENSITY CONTROL LIMITS		
Mixture Composition	Parameter	Individual Test
IL-4.75	Ndesign = 50	93.0 – 97.4 % 1/
IL-9.5	Ndesign = 90	92.0 – 96.0 %
IL-9.5, IL-9.5L,	Ndesign < 90	92.5 – 97.4 %
IL-19.0	Ndesign = 90	93.0 – 96.0 %
IL-19.0, IL-19.0L	Ndesign < 90	93.0 2/ – 97.4 %
SMA	Ndesign = 50 & 80	93.5 – 97.4 %

1/ Density shall be determined by cores or by correlated, approved thin lift nuclear gauge.

2/ 92.0 percent when placed as first lift on an unimproved subgrade.

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

Individual required test results 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. Any additional testing of check samples may be used for controlling the Contractor's processes, but shall be documented in the plant diary.

The results of assurance tests performed by the Engineer will be posted as soon as available.

The following parameters shall be recorded on standardized control charts as described in the QC/QA document "Hot-Mix Asphalt QC/QA Control Charts/Rounding Test Values".

Control limits for each required parameter, both individual tests and the average of four tests, shall be exhibited on control charts. Test results shall be posted within the time limits previously outlined.

CONTROL CHART REQUIREMENTS	HIGH ESAL, LOW ESAL, SMA, & IL-4.75
Gradation 1/ 3/	% Passing Sieves: 1/2 in. (12.5 mm) 2/ No. 4 (4.75 mm) No. 8 (2.36 mm) No. 30 (600 µm)
Total Dust Content 1/	No. 200 (75 µm)
	Asphalt Binder Content
	Bulk Specific Gravity
	Maximum Specific Gravity of Mixture
	Voids
	Density
	VMA

1/ Based on washed ignition oven.

2/ Does not apply to IL-4.75.

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

(6) Corrective Action for Required Plant Tests.

a. 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 continue the required plant test frequency. Additional check samples should be taken to verify mix compliance.

1. Voids, VMA, and Asphalt Binder Content for High ESAL and Low ESAL Mixtures. If the retest for voids, 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. HMA production may continue when approved by the Engineer. The corrective action shall be documented.

2. 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.

b. 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 operations. Corrective action shall be immediately instituted by the Contractor. Operations shall not be reinstated without the approval of the Engineer. Failure to cease operations shall subject all subsequently produced material to be considered unacceptable.

c. Dust Control. If the washed ignition oven gradation test results indicate a problem with controlling dust, corrective action to control the dust shall be taken and approved by the Engineer. If the Engineer determines that Positive Dust Control Equipment is necessary, the equipment as specified in Article 1102.01(d)(7), shall be installed prior to the next construction season.

d. HMA Production Control. If the Contractor is not controlling the production process and is making no effort to take corrective action, the operation shall stop.

(7) Corrective Action for Required Field Tests (Density). When an individual 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.

a. 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.

b. 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, any 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.

If the Contractor is not controlling the compaction process and is making no effort to take corrective action, the operation, as directed by the Engineer, shall stop.

(e) Quality Assurance by the Engineer. The Engineer will conduct independent assurance tests on split samples taken by the Contractor for quality control testing. In addition, the Engineer will witness the sampling and splitting of these samples a minimum of twice a month and will immediately retain the samples for quality assurance testing.

The overall testing frequency will be performed over the entire range of Contractor samples and will be equal to or greater than ten percent for gradations and equal to or greater than 20 percent for asphalt binder content, bulk specific gravity, maximum specific gravity and field density. The Engineer may select any or all split samples for assurance testing. The Engineer will initiate independent assurance testing during mixture field verification. These tests may be performed immediately or anytime up to ten working days after sampling. The test results will be made available to the Contractor as soon as they become available.

The Contractor's nuclear/core correlation will be verified utilizing Department nuclear gauges.

The Engineer may witness the sampling and testing being performed by the Contractor. The Engineer will document all witnessed samples and tests.

The Engineer will promptly notify the Contractor, both verbally and in writing, of observed deficiencies. If the Engineer observes that the sampling and quality control tests are not being performed according to the applicable test procedures, the Engineer may stop production until corrective action is taken.

The Engineer may elect to obtain samples for testing, separate from the Contractor's quality control process, to verify specification compliance. No more than 20 cores per day will be required by the Engineer for the purpose of acceptance and/or comparison with nuclear gauge measurements. The cost of this work will not be paid for separately, but shall be considered as included in the unit price bid for the HMA item involved. Differences between the Contractor's and the Engineer's split sample test results will be considered acceptable if within the following limits.

Test Parameter	Acceptable Limits of Precision
% Passing: 1/	
1/2 in. (12.5 mm)	5.0 %
No. 4 (4.75 mm)	5.0 %
No. 8 (2.36 mm)	3.0 %
No. 30 (600 µm)	2.0 %
Total Dust Content No. 200 (75 µm)	2.2 %
Asphalt Binder Content	0.3 %
Maximum Specific Gravity of Mixture	0.026
Bulk Specific Gravity	0.030
VMA	1.4 %
Density (% Compaction)	1.0 % (Correlated)

1/ Based on washed ignition.

The Department may run extractions for assurance, when deemed necessary by the Engineer.

In the event comparison of the required plant test results is outside the above acceptable limits of precision, Department split or independent samples fail the control limits, a Department extraction indicates non-compliance, or a continual trend of difference between Contractor and Department test results is identified, the Engineer will immediately investigate. The Engineer may suspend production as stated in Article 108.07 of the Standard Specifications, while the investigation is in progress. The investigation may include testing by the Engineer of any remaining split samples or a comparison of split sample test results on the HMA currently being produced. The investigation may also include review and observation of the Contractor's technician performance, testing procedure, and equipment.

If a problem is identified with the mix, the Contractor shall take immediate corrective action. After corrective action, both the Contractor and the Engineer shall immediately resample and retest according to Article 1030.05(d)(6).

In the event comparison of the required field test results (densities) are outside the above acceptable limits of precision, Department split or independent samples fail the density limits, or a continual trend of difference between Contractor and Department test results is identified, the Engineer will immediately investigate. The investigation will include testing by the Engineer of any remaining random density locations. The Engineer may establish additional locations for testing by both the Contractor and the

Department to provide further comparison results. The investigation shall also include review and observation of the Density Tester performance, testing procedure, and equipment. The original correlation and/or comparison data, for both gauges, shall be reviewed as part of the investigation process. If the problem continues, the Engineer may require a new correlation be performed.

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

(1) Validation of the Contractor's quality control by the assurance process.

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

(3) Department assurance tests for voids, field VMA, and density.

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

(g) Documentation. 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 in duplicate and sent to the Engineer on forms approved by the Engineer.

Each construction season, prior to production of HMA, the Contractor shall submit to the Engineer, on appropriate forms, documentation that the HMA plant(s) have been calibrated and approved.

1030.06 Start of HMA Production and Job Mix Formula (JMF) Adjustments. The start of HMA production and JMF adjustments shall be as follows.

(a) High ESAL, IL-4.75, WMA, and SMA Mixtures. For each contract, a 300 ton (275 metric tons) test strip will be required at the beginning of HMA production for each mixture with a quantity of 3000 tons (2750 metric tons) or more according to the Manual of Test Procedures for Materials "Hot-Mix Asphalt Test Strip Procedures".

Before start-up, target values shall be determined by applying gradation correction factors to the JMF when applicable. These correction factors shall be determined from previous experience. The target values, when approved by the Engineer, shall be used to control HMA production. Plant settings and control charts shall be set according to target values.

Before constructing the test strip, target values shall be determined by applying gradation correction factors to the JMF when applicable. After any JMF adjustment, the JMF shall become the Adjusted Job Mix Formula (AJMF). 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 an adjustment/plant change is made, the Engineer may require a new test strip to be constructed. 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.

The limitations between the JMF and AJMF are as follows.

Parameter	Adjustment
1/2 in. (12.5 mm)	± 5.0 %
No. 4 (4.75 mm)	± 4.0 %
No. 8 (2.36 mm)	± 3.0 %
No. 30 (600 µm)	*
No. 200 (75 µm)	*
Asphalt Binder Content	± 0.3 %

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

Any adjustments outside the above limitations will require a new mix design.

Mixture sampled to represent the test strip shall include additional material sufficient for the Department to conduct Hamburg Wheel testing according to Illinois Modified AASHTO T 324 (approximately 60 lb (27 kg) total).

The Contractor shall immediately cease production upon notification by the Engineer of failing Hamburg Wheel tests. All prior produced material may be paved out provided all other mixture criteria is being met. No additional mixture shall be produced until the Engineer receives passing Hamburg Wheel tests.

The Department may conduct additional Hamburg Wheel tests on production material as determined by the Engineer.

(b) Low ESAL Mixtures. In the field, slight adjustments to the gradation and/or asphalt binder content may be necessary to obtain the desired air voids, density, uniformity, and constructability. These adjustments define the Adjusted Job Mix Formula (AJMF) and become the target values for quality control operations. Limitations between the JMF and AJMF are as follows. Any adjustments outside the limitations will require a new mix design.

Parameter	Adjustment
1/2 in. (2.5 mm)	± 6 %
No. 4 (4.75 mm)	± 5 %
No. 200 (75 µm)	± 2.5 %
Asphalt Binder Content	± 0.5 %

Production is not required to stop after a growth curve has been constructed. The test results shall be available to both the Contractor and Engineer before production may resume the following day.

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 plant tests.

1030.07 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 continuous-type mixing plant, the heated aggregate and asphalt binder shall be measured separately and accurately by volume. The heated aggregate and asphalt binder shall be mixed in the pug mill mixer for a period of time necessary to produce a homogeneous mixture 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 (PG58-22, PG64-22)	6-9 %

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

1030.08 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. (20 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 into the finishing machine.

SECTION 1031. RECLAIMED ASPHALT PAVEMENT

1031.01 Description. RAP is reclaimed asphalt pavement resulting from cold milling or crushing of an existing dense graded hot-mix asphalt (HMA) pavement. The Contractor shall supply written documentation that the RAP originated from routes or airfields under federal, state or local agency jurisdiction.

1031.02 Stockpiles. The Contractor shall construct individual, sealed RAP stockpiles meeting one of the following definitions. No additional RAP shall be added to the pile after the pile has been sealed.

(a) Homogeneous. Homogeneous RAP stockpiles shall consist of RAP from Class I, Superpave (High ESAL), HMA (High ESAL), or equivalent, mixtures only and represent; 1) the same aggregate quality, but shall be at least C quality or better; 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 “homogenous”, with a quality rating dictated by the lowest coarse aggregate quality present in the mixture. Stockpiles shall meet the testing requirements of Article 1031.07. Stockpiles not meeting these requirements may be processed (crushing and screening) and retested.

(b) Conglomerate. Conglomerate RAP stockpiles shall consist of RAP from Class I, Superpave (High ESAL), HMA (High ESAL), or equivalent, mixtures only. The coarse aggregate in this RAP shall be crushed aggregate only and may represent more than one aggregate type and/or quality but shall be at least C quality or better. This RAP may have an inconsistent gradation and/or asphalt binder content prior to processing. All 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. Stockpiles shall not contain steel slag or other expansive material as determined by the Department. Stockpiles shall meet the testing requirements of Article 1031.07.

(c) Conglomerate "D" Quality (DQ). Conglomerate DQ RAP stockpiles shall consist of RAP containing coarse aggregate (crushed or round) that is at least D quality or better. Conglomerate DQ RAP stockpiles shall not contain steel slag or other expansive material as determined by the Department. Conglomerate DQ RAP shall meet the testing requirements of Article 1031.07.

Reclaimed Superpave (Low ESAL)/HMA (Low ESAL) IL-19.0L binder and IL-9.5L surface mixtures shall be placed in conglomerate DQ RAP stockpiles due to potential of rounded aggregate.

(d) Other. RAP stockpiles that do not meet the requirements of the stockpile categories listed above shall be classified as "Other". "Other" RAP stockpiles shall not be used in HMA.

1031.03 Contaminants. RAP containing contaminants, such as earth, brick, sand, concrete, sheet asphalt, bituminous surface treatment (i.e. chip seal), pavement fabric, joint sealants, etc., will be unacceptable unless the contaminants are removed to the satisfaction of the Engineer. Sheet asphalt shall be stockpiled separately.

1031.04 Quality Designation of Aggregate in RAP. The use of RAP in HMA shall be set by the lowest quality of coarse aggregate in the RAP stockpile and are designated as follows.

(a) RAP from Class I, Superpave (High ESAL) or HMA (High ESAL) surface mixtures are designated as containing Class B quality coarse aggregate only.

(b) RAP from Superpave (Low ESAL)/HMA (Low ESAL) IL-19.0L binder and IL-9.5L surface mixtures are designated as Class C quality coarse aggregate only.

(c) RAP from Class I, Superpave (High ESAL), or HMA (High ESAL) binder mixtures, bituminous base course mixtures, and bituminous base course widening mixtures are designated as containing Class C quality coarse aggregate only.

(d) RAP from bituminous stabilized subbase and BAM shoulders are designated as containing Class D quality coarse aggregate only.

The Contractor shall supply written documentation that the RAP meets the above quality designations.

Any mixture not listed above shall have the designated quality determined by the Department.

1031.05 RAP in HMA. The use of RAP in HMA shall be as follows.

(a) 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 using RAP.

(b) Steel Slag Stockpiles. RAP stockpiles containing steel slag or other expansive material, as determined by the Department, shall be homogeneous and will be approved for use in HMA (High ESAL and Low ESAL) surface mixtures only.

(c) Use in High and Low ESAL Mixtures. RAP stockpiles for use in HMA mixtures (High ESAL and Low ESAL) shall be either homogeneous or conglomerate, except conglomerate stockpiles shall not be used in HMA surface mixture Ndesign 50 or greater.

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

1031.06 RAP in Aggregate Surface Course and Aggregate Shoulders. The use of RAP in Aggregate Surface Course and Aggregate Shoulders shall be as follows.

(a) Stockpiles. RAP stockpiles may be any of those listed in Article 1031.02.

(b) 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.

(c) Exclusion. The requirements of Article 1031.07 do not apply.

1031.07 Testing. All RAP shall be sampled and tested either during or after 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 2000 tons (1800 metric tons) and one sample per 2000 tons (1800 metric tons) thereafter. A minimum of five tests shall be required for stockpiles less than 4000 tons (3600 metric tons).

For testing existing stockpiles, the Contractor shall submit a plan for approval to the District proposing a satisfactory method of sampling and testing the RAP 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.

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Each field sample shall be split to obtain two samples for testing. One of the test samples from the final split shall be labeled and stored for Department use. The Contractor shall extract 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.

All of the extraction results shall be compiled and averaged for asphalt binder content and gradation. Individual extraction test results, when compared to the averages, will be accepted if within the tolerances listed below.

Parameter	Homogeneous / Conglomerate	Conglomerate "D" Quality
1 in. (25 mm)		± 5 %
1/2 in. (12.5 mm)	± 8 %	± 15 %
No. 4 (4.75 mm)	± 6 %	± 13 %
No. 8 (2.36 mm)	± 5 %	
No. 16 (1.18 mm)		± 15 %
No. 30 (600 µm)	± 5 %	
No. 200 (75 µm)	± 2.0 %	± 4.0 %
Asphalt Binder	± 0.4 %	± 0.5 %

If more than 20 percent of the individual sieves are out of the gradation tolerances, or if more than 20 percent of the asphalt binder content test results fall outside the appropriate tolerances, the RAP shall not be used in HMA unless the RAP representing the failing tests is removed from the stockpile. All test data and acceptance ranges shall be sent to the District for evaluation.

If additional RAP stockpiles are tested and found that no more than 20 percent of the results are outside of the control tolerances set for the original RAP stockpile and HMA mix design, the additional RAP stockpiles may be used in the original mix design at the percent previously verified.

With the approval of the Engineer, the ignition oven may be substituted for extractions according to the ITP, "Calibration of the Ignition Oven for the Purpose of Characterizing Reclaimed Asphalt Pavement (RAP)".

HMA

SPECIFICATION

GUIDELINES

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II. Introduction

HMA, Hot Mix Asphalt Design, using Illinois Modified Strategic Highway Research Program (SHRP) superpave criteria, 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 designs the asphalt mixture for a specific location, climate, and traffic.

The HMA 2007 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, 2007 edition of the Standard Specifications for Road and Bridge Construction, Article 1030. If RAP is allowed in the HMA mixture include the Special Provisions for Reclaimed Asphalt Pavement (RAP) (BDE).

II. General Notes Table

The following table was designed for HMA High ESAL and Low ESAL mixtures, and is required to be completed and inserted into the General Notes of the project plans.

MIXTURE REQUIREMENTS

The following mixture requirements are applicable for this project:

Location(s):	
Mixture Use(s):	
PG:	
Design Air Voids:	
Mixture Composition: (Gradation Mixture)	
Friction Aggregate:	

Use the following guidelines to fill out the above table:

Location(s): This space specifies the location(s) where the mix will be placed. It can be described by route or stations.

Mixture Use(s): This corresponds to the generic description of the mixture(s), i.e., surface course, level 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".

PG: This space specifies the PG asphalt binder for the mixture, including polymer modified asphalt binder, e.g., SB/SBS PG64-28, SB/SBS PG70-22, SB/SBS-PG70-28, SB/SBS PG76-22, SB/SBS-PG76-28, etc. The required PG binder should be obtained from the Materials Engineer.

RAP%: This space specifies the maximum RAP percentage allowed in the mixture, e.g., 0%, 10%, 15%, 25%, etc. RAP is not allowed in any mixtures that contain polymers. See Special Provision for changes to these criteria.

Design Air Voids: This space specifies the air void content in which the mixture shall be designed. For example, HMA Low ESAL may require air voids of 4.0%, 4.5%, etc., and HMA High ESAL may require "4.0% @ N_{design} = 50", "4.0% @ N_{design} = 70", etc. All HMA High ESAL projects will require 4.0% air voids, however, the N_{design} number will change. The HMA High ESAL mixtures will have N_{design} numbers from 50 to 105. The N_{design} number should be obtained from the Materials Engineer. HMA Low ESAL mixtures have N_{design} = 30 with air voids of 3% or 4%. For all other mixtures N_{design} = 30 and the air voids are 2%.

Mixture Composition: This space specifies the aggregate gradation which the mixture shall meet. For HMA High ESAL, these options are IL-25.0 mm, IL-19.0mm, IL-12.5mm, IL-9.5mm. For HMA Low ESAL mixtures, the options are IL-9.5L, IL-19.0L. For all other mixtures the aggregate gradation is as shown in the table in Article 1030.04(3) of the January 1, 2007 edition of the Standard Specifications for Road and Bridge Construction.

Friction Aggregate: This space specifies the aggregates which shall be used to meet the surface course friction requirements, i.e., Mixture C, Mixture D, Mixture E, or Mixture F. These are not used for binder mixes.

Contact the District Mixtures Control Engineer for further information.

III. ESALs(Equivalent Single Axel Loads)

In HMA, ESALs are calculated for the design lane according to Chapter 54 of IDOT's Design & Environment Manual. For selection of 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 54-5B. For HMA mixture design purposes, 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.

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.

IV. N_{design} Table

In the past, the laboratory compactive effort was defined by Class I and Type, i.e., Type 1, Type 2, or Type 3. In HMA, the compactive effort is expressed as a N_{design} number, which is selected based on the estimated 20-year ESAL loading of the traffic lane.

The following N_{design} table lists the compactive effort required for the different levels of traffic loading, as well as describes the typical roadway application. These are, however, just guidelines; consult the Materials Engineer for the appropriate Ndesign value.

Design ESAL's (millions) Based on 20-yr design	**N_{des}**	**Typical Roadway Application**
< 0.3	30	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	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, US highways, and some rural interstates.
≥	90	May include the previous class of roadways which have a high amount of truck traffic. Includes US 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.

V. Performance Graded Binders

Performance Graded (PG) binders will now be specified in place of varying grades of asphalt cement, i.e., AC-10 or AC-20. It does not mean the asphalt cement will be polymer modified; instead, it defines the asphalt cement based on the climate and pavement temperatures for which it is expected to serve.

In HMA, “binder” references the asphalt cement, not the “binder layer”.

A. Polymer Modified Performance Graded Binders. When polymer modifiers are required, put “SBS” or “SBR” in front of the PG binder requirement in the General Notes table. All of the following grades of asphalt binder must be polymer modified: SBS-PG70-28, SBS-PG76-22, SBS-PG76-28. When specifying SBS-PG64-28 or SBS-PG70-22, check with the Materials Engineer to verify the use of polymer since PG64-28 and PG70-22 can be made and used without being polymer modified.

B. Applications. The following table lists the common allowable Performance-Graded binders, the previous asphalt cement equivalent, and possible applications.

PG GRADE	PREVIOUS EQUIVALENT	APPLICATIONS
PG64-22	AC 20	Overlays Full Depth Pavements
PG70-22 or SBS-PG70-22	AC 40 or MAC 20	Overlays Full Depth Pavements
SBS-PG76-22	MAC 20HD	Overlays Full Depth Pavements
PG64-28 or SBS-PG64-28	AC 20 or MAC 10	Full Depth Pavements
SBS-PG70-28	MAC 10HD	Full Depth Pavements
SBS-PG76-28	MAC 10HD+	Full Depth Pavements
PG58-22	AC 10	Local Agencies
PG58-28	AC 7.5	RAP Mixtures
PG52-28	AC 5	Local Agencies RAP Mixtures
PG46-28	AC 2.5	Local Agencies

C. Binder Selection. Based on Design ESALs and the Traffic Load Rate, the PG binder may be “bumped” to a higher binder grade, as determined below. The binder selection options provided below are based on the recommendations of the Illinois-Modified AASHTO MP2 provisional standard in the Manual of Test Procedures for Materials.

1) Overlays. Most overlays should use the grades shown below for a standard traffic level. Adjustments to this grade are dependent upon conditions of slow moving traffic or high ESALs, or standing traffic. These modifications should be made according to the table below for the corresponding N_{design} number and/or ESAL number. The appropriate grade of asphalt binder should then be reported to the General Notes table of the plans.

Binder Selection

Illinois N_{design} Number	Design ESALs[1/] (million)	PG Binder Grade[5/] Traffic Load Rate		
		Standard[4/]	Slow[3/]	Standing[2/]
30	< 0.3	PG58-22	PG64-22	PG64-22[6/]
50	0.3 to < 3	PG64-22	PG70-22 or SBS-PG70-22	SBS-PG76-22
70	3 to < 10	PG64-22	PG70-22 or SBS-PG70-22	SBS-PG76-22
90	10 to < 30	PG64-22[6/]	PG70-22 or SBS-PG70-22	SBS-PG76-22
105	≥ 30	PG70-22 or SBS-PG70-22	PG70-22 or SBS-PG70-22	SBS-PG76-22

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/ Standing Traffic - where the average traffic speed is less than 12 mph (20 km/h).
3/ Slow Traffic - where the average traffic speed ranges from 12 mph (20 km/h) to 43 mph (70 km/h).
4/ Standard Traffic - where the average traffic speed is greater than 43 mph (70 km/h).
5/ The binder grade provided in the table is based on the recommendations given in Illinois-Modified AASHTO MP-2, Table 1, “Binder Selection on the Basis of Traffic Speed and Traffic Level”.
6/ Consideration should be given to increasing the high temperature grade by one grade equivalent.

2) **Full-Depth.** Full-Depth pavements should be designed using the PG binders required below.

PG BINDER GRADE SELECTION[5/,6/,7/] - FULL DEPTH ASPHALT

Districts 1-6	**Standard[4/]**	**Slow[3/] Traffic or High[1/] ESAL's**	**Standing[2] Traffic**
Surface	SBS-PG64-28	SBS-PG70-28	SBS-PG76-28
Top Binder	SBS-PG64-28	SBS-PG70-28	SBS-PG76-28
Lower Binders	PG64-22	PG64-22	PG64-22
Districts 7-9			
Surface	PG64-22	SBS-PG70-22	SBS-PG76-22
Top Binder	PG64-22	SBS-PG70-22	SBS-PG76-22
Lower Binders	PG64-22	PG64-22	PG64-22

See Notes following page

Notes:
1. High ESALs – where ESALs are > 30 million.
2. Standing Traffic - where the average traffic speed is less than 12 mph.
3. Slow Traffic - where the average traffic speed ranges from 12 mph to 43 mph.
4. Standard Traffic - where the average traffic speed is greater than 43 mph.
5. The binder grade provided in the table is based on the recommendations given in Illinois-Modified AASHTO MP-2, Table 1, "Binder Selection on the Basis of Traffic Speed and Traffic Level."
6. Consider increasing the high temperature grade by one grade for ESALs 10 to 30 million.
7. Consider increasing the high temperature grade by one grade and/or use polymer modified binder within 2500 ft upstream of the exit terminal stub to 2500 ft downstream of the entrance stub at weigh stations.

VI. RAP

Effective January 1, 2000, RAP in HMA mixtures will be allowed. The following table will be used to determine the maximum allowable RAP percentages. The districts should specify the correct maximum RAP percentages in the General Notes table in the plans.

SUPERPAVE MIXTURES	MAXIMUM % RAP	
Ndesign	**Binder/Leveling Binder**	**Surface**
30	30	30
50	25	15
70	15	10
90	10	10
105	0	0

RAP is not allowed in mixtures containing polymer modifiers. Indicate 0% in the plans when SBS-(or SBR) binders are specified. See Special Provision for changes to these criteria.

VII. Friction Policy

Four friction aggregate mixtures have been developed which will give adequate skid resistance: Mixtures C, D, E and F. The traffic levels from the expected year of construction should be used to determine the mixture.

The Department's TRA-16, "Skid-Accident Reduction Program", dictates their use. The following defines their use:

Mixture C. Mixture C will be used as the friction aggregate mixture in surface courses on roads and streets having an ADT of 5,000 or less.

Mixture D. Mixture D will be used as the surface course on two-lane roads and streets having an ADT greater than 5,000, on four-lane highways having an ADT between 5,001 and 25,000, and on six-lane (or greater) highways having an ADT of 60,000 or less.

Mixture E. Mixture E will be used as the surface course on four-lane highways having an ADT between 25,001 and 100,000, or on six-lane (or greater) highways having an ADT between 60,001 and 100,000.

Mixture F. Mixture F will be used as the surface course on any facility having an ADT greater than 100,000.

The PG binder grade can affect the performance of a HMA mixture. Rutting or permanent deformation of the HMA surface is a distress common to composite pavements. This design procedure assumes that HMA rutting is considered in the material selection and mixture design process. Because the binder grade can impact the ability of the mix to resist rutting, selection of the appropriate high temperature grade is important. Thermal cracking is not a failure mode for composite pavements, and so the lower temperature grade is not as critical. That is why PG XX-22 binders are specified for composite pavements rather than the PG XX-28 grades appropriate for full-depth HMA pavements, where thermal cracking is of concern.

Note that the PG binder grade selection tables for composite pavements for local agency pavement design differ from the tables used for the State system. A lower level of reliability is used for local agency design than for the State system.

The local agency must request a variance from Central BLRS to use a different PG binder than specified in Figure 37-5F and Figure 37-5G.

These tables are included on the following pages for reference purposes. Please check with the Bureau of Materials and Physical Research to determine which are applicable for your project.

The following tables are from IDOT's Local Roads and Streets Manual Chapter 37.

PG Binder Grade Selection [1] [2]			
	Traffic Loading Rate		
Districts 1 – 4	Standard Traffic [3]	Slow Traffic [4]	Standing Traffic [5]
Surface	PG 58-28 [6] [7]	PG 64-28, SBR PG 64-28 [8], or SBS PG 64-28	SBR PG 70-28 [8] or SBS PG 70-28
Top Binder Lift	PG 58-28 [6] [7]	PG 64-28, SBR PG 64-28 [8], or SBS PG 64-28	SBR PG 70-28 [8] or SBS PG 70-28
Lower Binder Lifts	PG 58-22	PG 58-22	PG 58-22
Districts 5 – 9			
Surface	PG 64-22 [6] [7]	PG 70-22, SBR PG 70-22 [8], or SBS PG 70-22	SBR PG 76-22 [8] or SBS PG 76-22
Top Binder Lift	PG 64-22 [6] [7]	PG 70-22, SBR PG 70-22 [8], or SBS PG 70-22	SBR PG 76-22 [8] or SBS PG 76-22
Lower Binder Lifts	PG 64-22	PG 64-22	PG 64-22

Notes:

1. *The binder grades provided in this table 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. For *mixtures containing a minimum of 15% RAP, both the high and low temperature binder grades should be decreased by one grade equivalent. For example, if use of a PG 64-22 is specified for a virgin aggregate mix, a PG 58-28 should be used for a mix containing a minimum of 15% RAP. Mixtures containing less than 15% RAP should use the binder grade specified in the above table.*
3. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*
4. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*
5. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*
6. *Consideration should be given to increasing the high temperature grade by one grade equivalent when 10 ≤ T.F. ≤ 30. For example, if use of a PG 64-22 is specified for standard traffic, a PG 70-22, a SBR PG 70-22, or a SBS PG 70-22 should be specified.*
7. *The high temperature grade should be increased by one grade equivalent when T.F. > 30. For example, if use of a PG 64-22 is specified for standard traffic, a PG 70-22, a SBR PG 70-22, or a SBS PG 70-22 should be specified.*

Illinois N_{design} Number	Flexible Design ESALs, millions [1] (Flexible T.F.)	PG Binder Grade Selection [2][3][4]		
		Traffic Loading Rate		
		Standard[5]	Slow[6]	Standing[7]
30	< 0.3	PG 58-22	PG 64-22[8]	PG 64-22[8]
50	0.3 to < 3	PG 64-22	PG 64-22[8]	PG 70-22, SBR PG 70-22[9], or SBS PG 70-22
70	3 to < 10	PG 64-22	PG 70-22, SBR PG 70-22[9], or SBS PG 70-22	SBR PG 76-22[9] or SBS PG 76-22
90	10 to < 30	PG 64-22[8]	PG 70-22, SBR PG 70-22[9], or SBS PG 70-22	SBR PG 76-22[9] or SBS PG 76-22
105	≥ 30	PG 70-22, SBR PG 70-22[9], or SBS PG 70-22	PG 70-22, SBR PG 70-22[9], or SBS PG 70-22	SBR PG 76-22[9] or 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 found in the full-depth pavement design procedure. Rigid traffic factors given in Figure 37-5B and Figure 37-5C are required for the composite pavement thickness design.*
2. *The binder grades provided in Figure 37-5G 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. *For mixtures containing a minimum of 15% RAP, the high temperature binder grade should be decreased by one grade equivalent. For example, if use of a PG 64-22 is specified for a virgin aggregate mix, a PG 58-22 should be used for a mix containing a minimum of 15% RAP. Mixtures containing less than 15% RAP should use the binder grade specified in Figure 37-5G.*
4. *Use these grades for composite pavements and all overlays.*
5. *Standard traffic is used where the average traffic speed is greater than 43 mph (70 km/h).*
6. *Slow traffic is used where the average traffic speed ranges from 12 to 43 mph (20 to 70 km/h).*
7. *Standing traffic is used where the average traffic speed is less than 12 mph (20 km/h).*
8. *Consideration should be given to increasing the high temperature grade by one grade equivalent.*
9. *SBR modified binders are not available in Illinois at this time.*

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

Figure 37-5G

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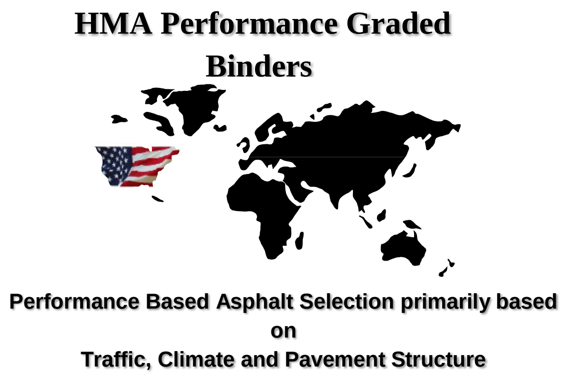
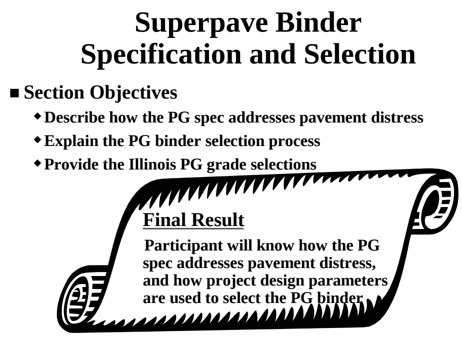
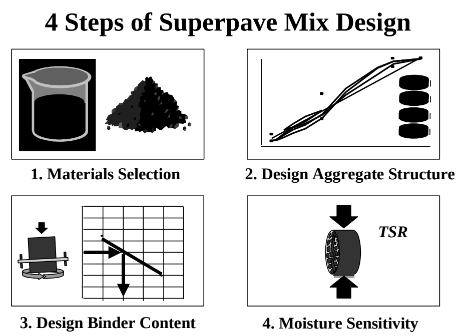


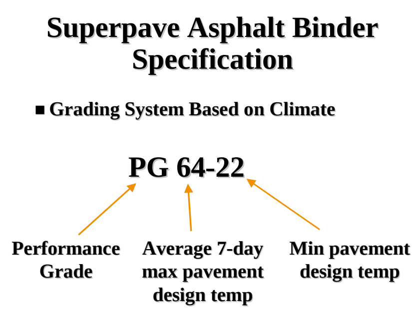


The goal of this section is to explain the role and selection of Performance Graded (PG) binders in Superpave mixtures.

HMA uses “binder” to describe the liquid asphalt, not to describe one of the lower level mixtures in the pavement.
Binder testing procedures are not covered here.



The first step in HMA mix design is materials selection, in this case, binders.



The PG binder grade numbers describe the <u>pavement</u> 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-day pavement temperature (e.g. - 22ºC).

Proper pronunciation is 64 minus 22.

Grades are separated by increments of 6ºC.

Formulas are used to convert measured <u>air</u> temperatures to <u>pavement</u> temperatures.

Binder will be specified by IDOT for state projects.

The PG specification has binder requirements at three simulated pavement ages.

The purpose of the aging is to simulate various stages of the pavement service life.

The binder specification criteria remain constant, while the testing temperature varies.

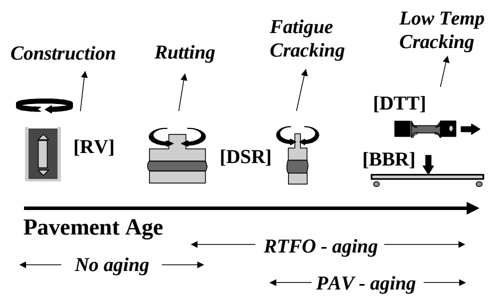
Typically for asphalt testing, the test temperature has remained constant while the test requirement has been varied (e.g. AC-10 vs. AC-20).

Tests also are performed to simulate real pavement service temperatures (hot, intermediate, and cold), and at production mixing temperatures.

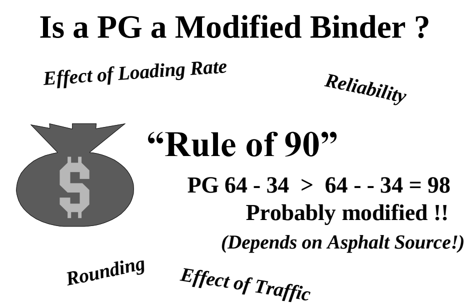
The tests also relate the aging condition to the distresses typically found.

Unaged and short term aging – related to rutting.

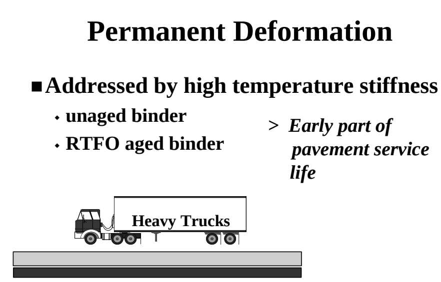
Short and long term aging – related to fatigue cracking and low temperature cracking.



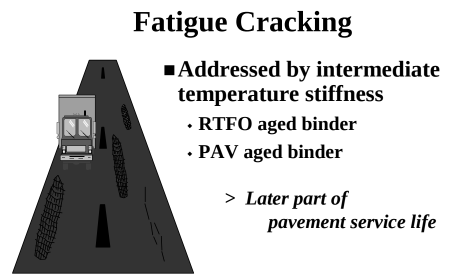
The "Rule of 90" is a rule of thumb for determining if a binder will be modified. If the temperature difference is >90, the binder may be modified. Greater differences mean more likelihood for modification.



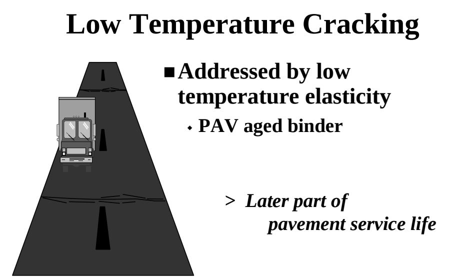
Permanent deformation (rutting and shoving) typically occurs at high temperatures early in pavement life.



Fatigue cracking (alligator cracking) typically occurs at intermediate temperatures a little later during the pavement's life.

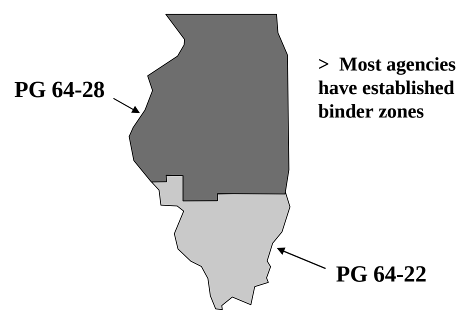


Low temperature cracking occurs later in the pavement life, when the binder has lost some elasticity.



IDOT has established binder grades for PG grades based upon traffic, district, and type of construction.

The IDOT grades are given later in this chapter. (This map is for illustration only.)



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".

However, if 33°C is the mean, you may want to select a binder that can handle 36°C.

By selecting a higher reliability, you move further out on the "tail" to lower the risk of encountering a temp that exceeds the design temp.

Reliability will change with temps and variation in climate.

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.

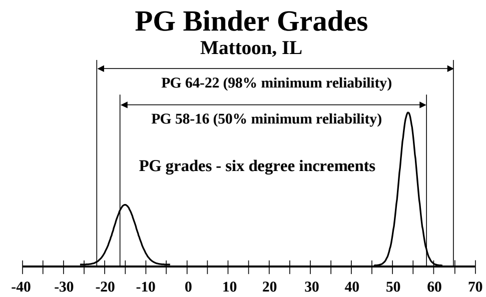
Because the PG spec is set up in 6 degree increments, when you specify a minimum reliability, you may actually be getting more reliability because you round up (conservatively).

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.

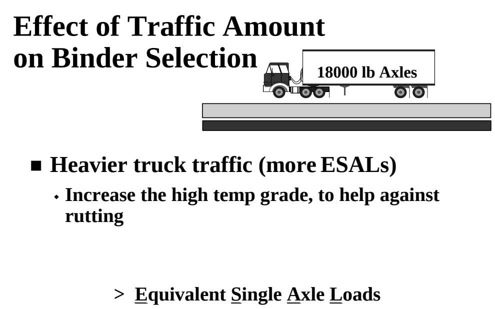
You can select different reliabilities, depending on distress concerns (rutting vs. cracking).

Reliability choice can greatly affect asphalt cost.



IDOT and AASHTO MP2 provide recommendations for "bumping" the high temperature binder grades.

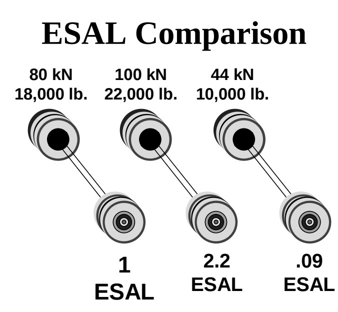
Remember, more than the binder contributes to preventing rutting.



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 4th power of load).

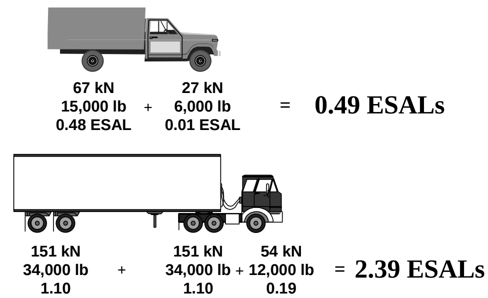
A slight change in axle load makes a large impact on the number of ESAL.



Very Heavy Passenger cars (Cadillac with keg of beer) equal about 0.0004 ESAL.

One heavy tractor-trailer (2.39 ESAL) at legal limit of 80,000 lb equals about 6000 cars.

Much more damage with trucks!



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.

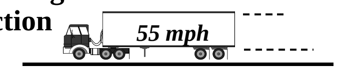
(Photo of shoving under truck traffic.) Both pavement structure (depth) and materials must be considered during design.

The speed of the traffic can make a difference in binder selection.

What about intersections or other slower moving conditions?

- Grade adjustments use the climate information first to determine grade, and then add more stiffness for <u>only the higher</u> temps to address the concern with rutting.

Effect of Loading Rate on Binder Selection

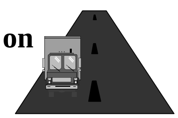


- **For slower traffic speeds, use binder with more stiffness at higher temps**
  - **slow - - increase one high temp grade**
  - **standing - - increase two high temp grades**
  - ***no effect on low temp grade***

Higher stiffness is needed for cases where slow moving and stopping traffic can routinely occur.

IDOT and AASHTO MP-2 provide recommendations for "bumping" the high temperature binder 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** ← **<u>Stopping</u>**

Intersections require different analysis due to slower traffic speed.

The low temperature grade is less of a concern for overlays -- reflective cracking will control how much the pavement cracks.

When using polymers for overlays, put “SBS” or “SBR” in front of grade. IDOT requires polymer modification for SBS-PG 70-28, SBS-PG 76-22, and SBS-PG 76-28.

PG 64-28 and PG 70-22 can be made and used with or without polymer modification.

- Standard traffic - average speed > 43 mph
- Slow traffic - average speed between 12 and 43 mph
- Standing traffic - average speed < 12 mph

* - Consider increasing the high temperature grade by one grade equivalent.

PG Grades for Overlays
All Districts

Illinois 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

When using polymers for full-depth, put “SBS” or “SBR” in front of grade. IDOT requires polymer modification for SBS-PG 70-28, SBS-PG 76-22, and SBS-PG 76-28.

PG 64-28 and PG 70-22 can be made and used with or without polymer modification.

- Standard traffic - average speed > 43 mph
- Slow traffic - average speed between 12 and 43 mph
- Standing traffic - average speed < 12 mph

PG Grades for Full Depth
Districts 1-6

	Standard	Slow Traffic or High ESALs	Standing Traffic
Surface & 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

When using polymers for full-depth, put "SBS" or "SBR" in front of grade. IDOT requires polymer modification for SBS-PG 70-28, SBS-PG 76-22, and SBS-PG 76-28.

PG 64-28 and PG 70-22 can be made and used with or without polymer modification.

- Standard traffic - average speed > 43 mph
- Slow traffic - average speed between 12 and 43 mph
- Standing traffic - average speed < 12 mph

PG Grades for Full Depth Districts 7-9

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

These are the grade translations between viscosity grades and PG grades for Illinois.

The softer grades of asphalt are used for lighter-duty pavements and for mixtures containing RAP.

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

These are the grade translations between polymer modified viscosity grades and PG grades for Illinois.

Illinois requires SBS or SBR use for modified Superpave binders.

Research is showing that not all of the binder tests are appropriate for modified binders.

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**

If RAP is greater than 20%, a softer grade is typically needed, as determined by the Engineer. The grade change is made by reducing the low temperature grade.

RAP in HMA Mixes

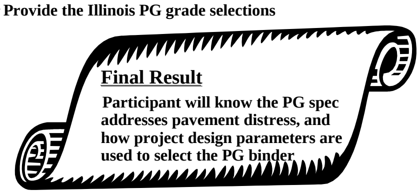
- No RAP in mixtures containing polymer modifiers
- If more than 20% RAP, a softer PG asphalt my be required.
- Maximum allowable RAP based on mix type and gyrations.
- RAP Chapter includes more detail.

Binder Selection Example

- Location: Madison County, District 6
- ADT: 25000
- Project: Remove and Replace 8 inches

Superpave Binder Selection

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



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Specific Gravity of Aggregates

Specific Gravity of Mineral Aggregates

Specific Gravity of Aggregates

Importance of Volumetric Properties

- Past experience:
- % air voids relates to performance
  - Lower than 3% - mixes unstable
  - Higher than 5%-mixes not durable enough

Specific Gravity of Aggregates

Importance of Volumetric Properties

- Past experience:
  - %VMA must be high enough to allow sufficient room for 4% air voids…and high enough asphalt % to provide stability, durability, impermeability

Specific Gravity of Aggregates

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

Importance of Volumetric Properties

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

Specific Gravity of Aggregates

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

- **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 of Aggregates

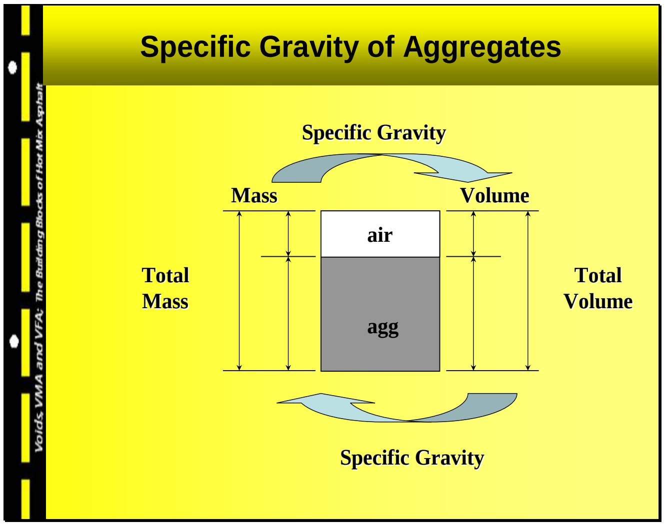
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

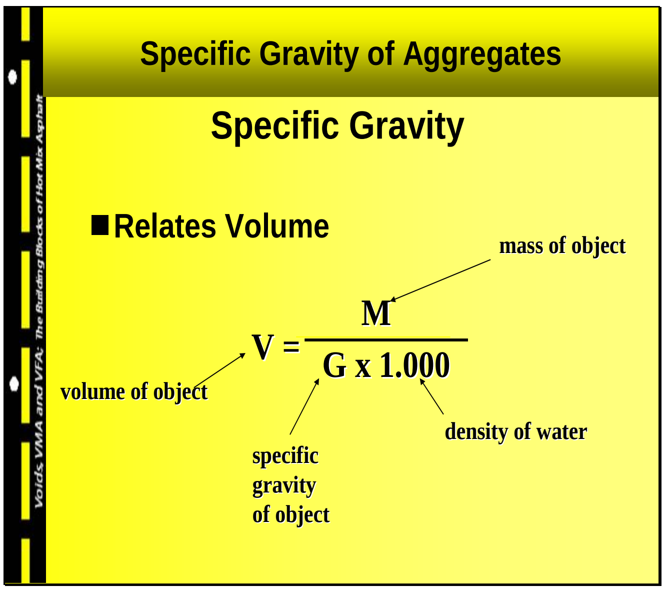
Specific Gravity

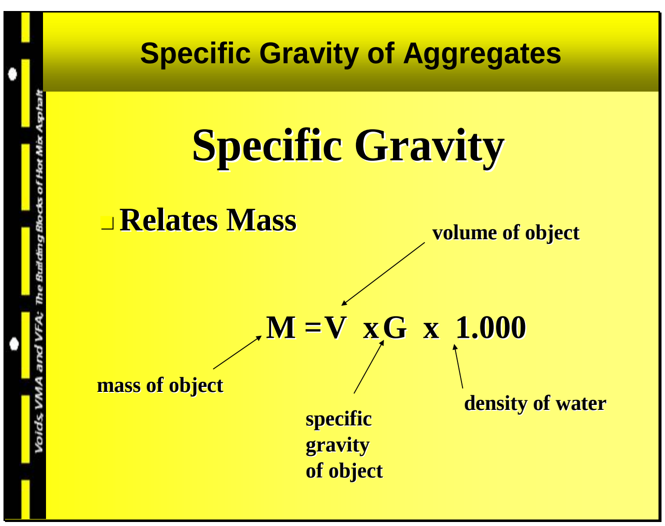
- **Definition:**
  - The ratio of the <u>mass</u> of a given <u>volume</u> of a substance to the mass of an <u>equal volume</u> of water, both at the same temperature.

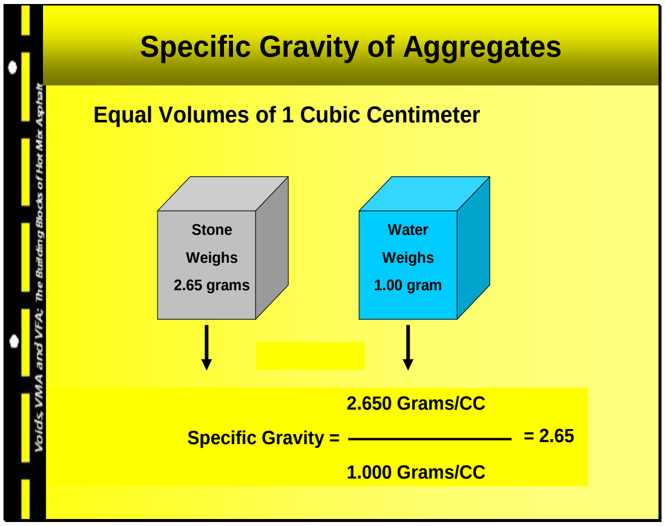
$$SG = \frac{M}{V \times 1.000}$$

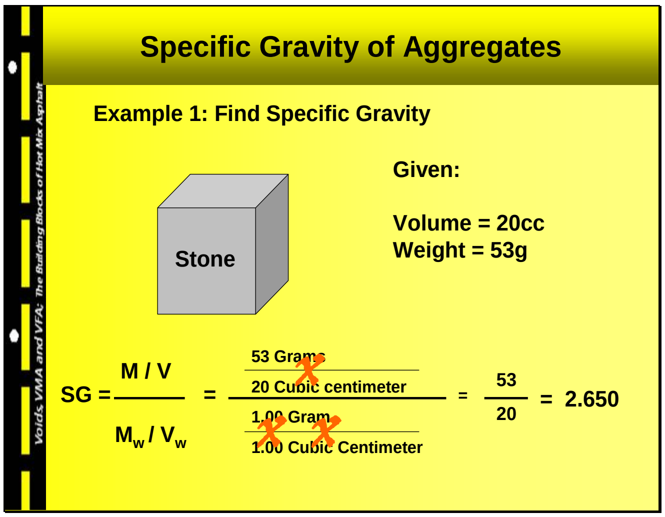
- SG: specific gravity of object
- M: mass of object
- V: volume of object
- 1.000: density of water (g/cc)

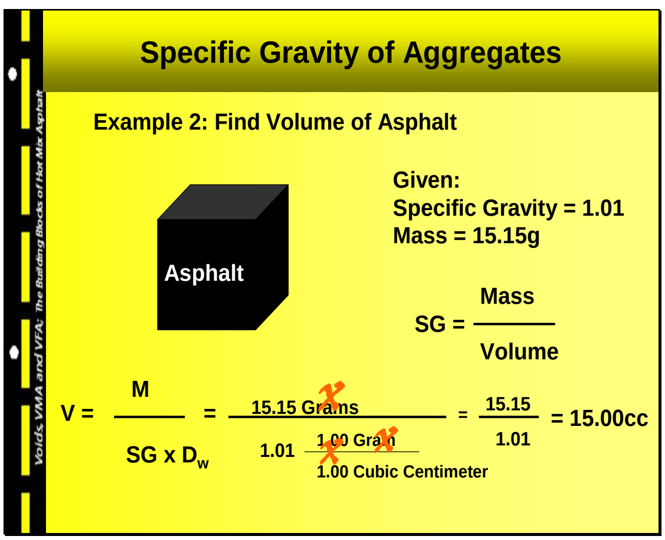

Specific Gravity of Aggregates
Specific Gravity
Mass
Volume
air
agg
Total Mass
Total Volume
Specific Gravity
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

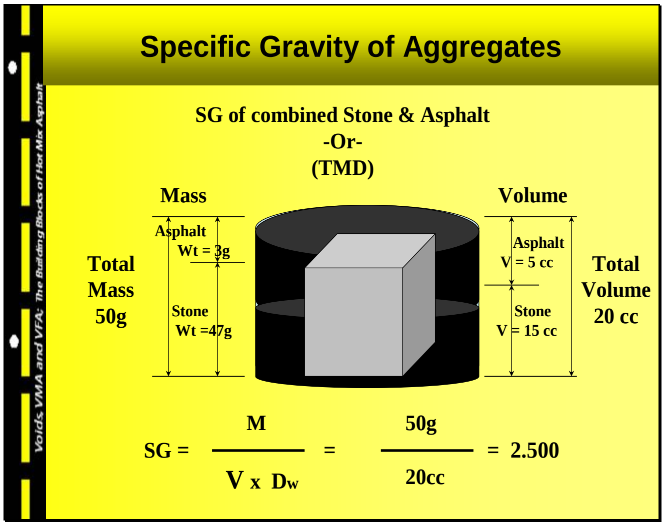

Specific Gravity of Aggregates
Specific Gravity
Relates Volume
mass of object
V = M / G x 1.000
volume of object
specific gravity of object
density of water
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

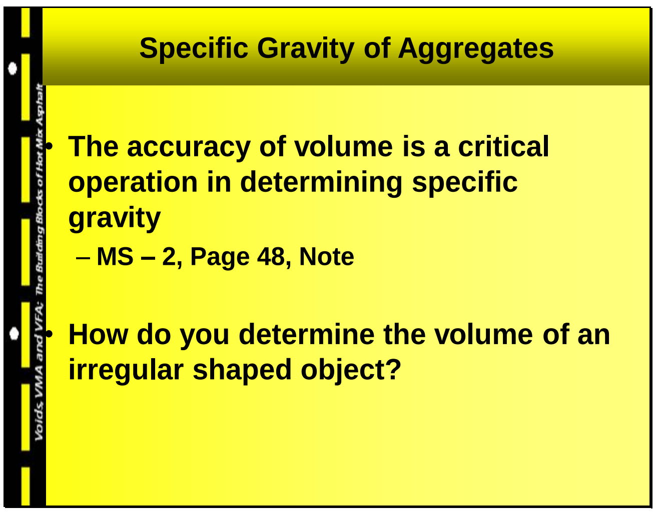

Specific Gravity of Aggregates
Specific Gravity
Relates Mass
volume of object
M = V x G x 1.000
mass of object
specific gravity of object
density of water
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

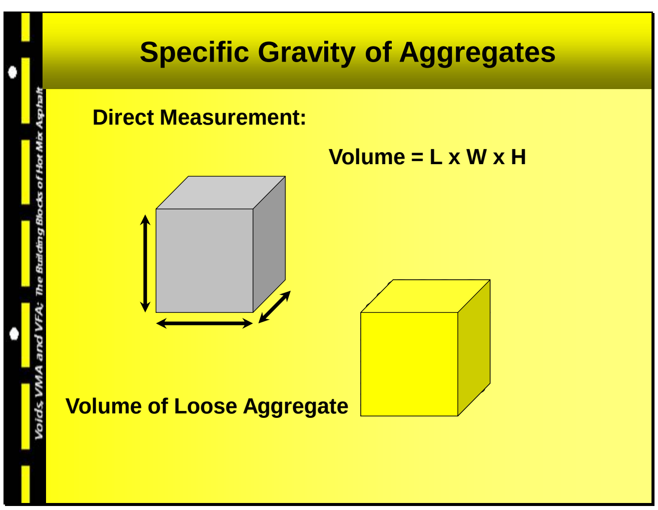

Specific Gravity of Aggregates
Equal Volumes of 1 Cubic Centimeter
Stone Weighs 2.65 grams
Water Weighs 1.00 gram
Specific Gravity = 2.650 Grams/CC / 1.000 Grams/CC = 2.65
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt


Specific Gravity of Aggregates
Example 1: Find Specific Gravity
Stone
Given:
Volume = 20cc
Weight = 53g
SG = M / V / M_w / V_w = 53 Grams / 20 Cubic centimeter / 1.00 Gram / 1.00 Cubic Centimeter = 53 / 20 = 2.650
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt


Specific Gravity of Aggregates
Example 2: Find Volume of Asphalt
Asphalt
Given:
Specific Gravity = 1.01
Mass = 15.15g
SG = Mass / Volume
V = M / SG x D_w = 15.15 Grams / 1.01 1.00 Gram / 1.00 Cubic Centimeter = 15.15 / 1.01 = 15.00cc
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt


Specific Gravity of Aggregates
SG of combined Stone & Asphalt
-Or-
(TMD)
Mass
Volume
Asphalt
Wt = 3g
Stone
Wt =47g
Total
Mass
50g
Asphalt
V = 5 cc
Stone
V = 15 cc
Total
Volume
20 cc
SG = M / V x Dw = 50g / 20cc = 2.500
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt


Specific Gravity of Aggregates
• The accuracy of volume is a critical operation in determining specific gravity
– MS – 2, Page 48, Note
• How do you determine the volume of an irregular shaped object?
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt


Specific Gravity of Aggregates
Direct Measurement:
Volume = L x W x H
Volume of Loose Aggregate
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Specific Gravity of Aggregates

- Archimedes' Principle
  - Fundamental law of natural buoyancy
  - First identified in the 3rd century BC
  - Greek mathematician and inventor

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

Specific Gravity of Aggregates

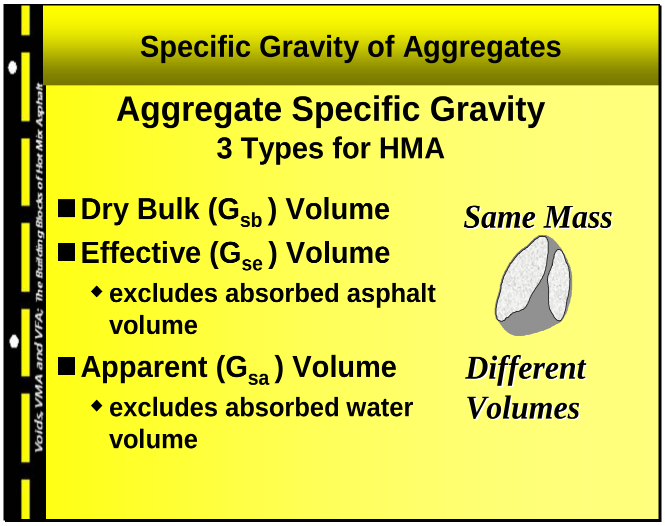
- Archimedes' Principle
  - A body immersed in a fluid is buoyed up by a force equal to the mass of the displaced fluid.
  - When the fluid is water, the mass of the displaced fluid is equal to the displaced volume.

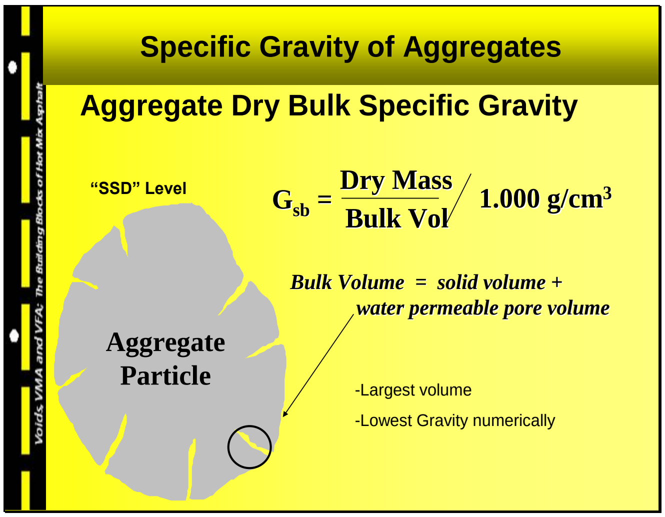
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt

Specific Gravity of Aggregates

- The difference in weight of an irregular shaped object weighed in air and in water yields it volume.
- With an object's weight and it's volume, it's specific gravity can be determined

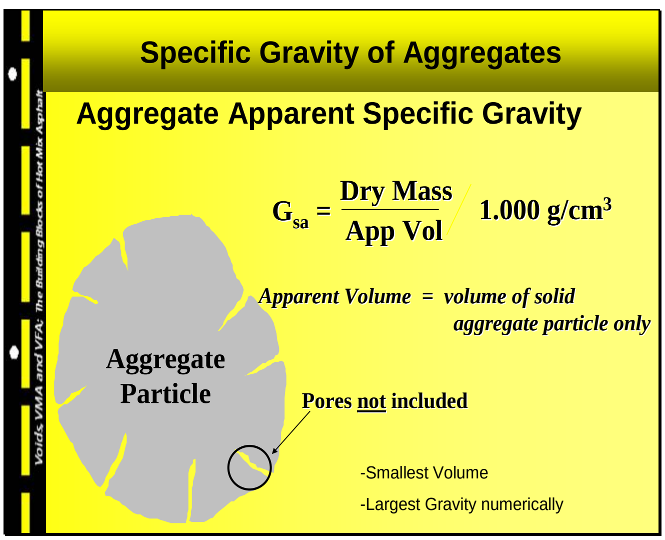
Voids, VMA and VFA: The Building Blocks of Hot Mix Asphalt





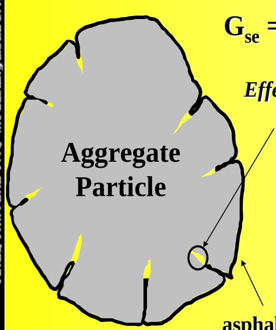
- Absorption and Specific Gravity test procedures
  - Coarse: AASHTO T85 (Illinois Modified)
  - Fine: AASHTO T84 (Illinois Modified)

- 1999 change in coarse aggregate procedure: All material finer than the 2.36 mm (No. 8) sieve is rejected. (Previously had been 4.75 mm sieve.)



Specific Gravity of Aggregates

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

-Determined on Asphalt / Aggregate mixture

-Volume in between Dry Bulk & Apparent

-Effective SG is Numerically between two other HMA gravity values.

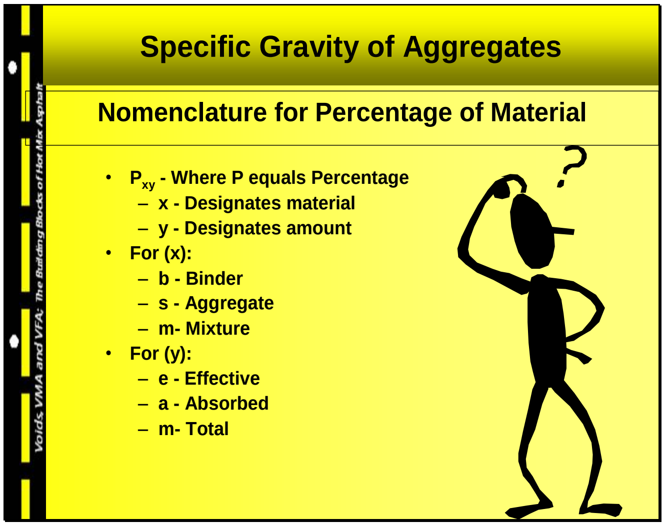
Specific Gravity of Aggregates

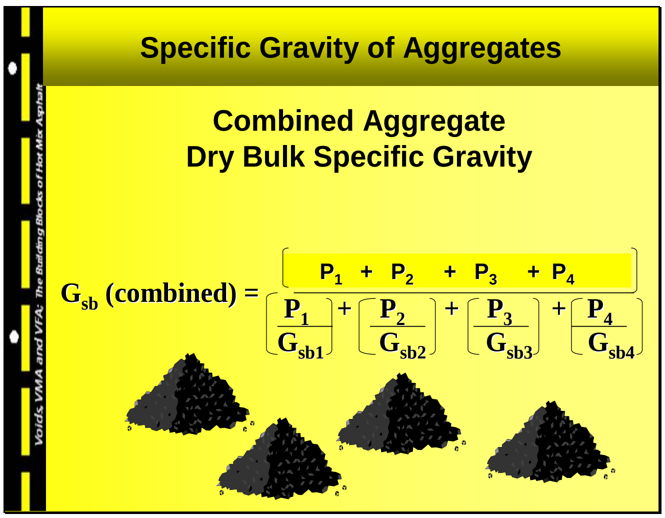
- **Asphalt Institute Recommendations**
  - MS-2, Page 46, first full paragraph
  - VMA calculations based only on aggregate dry bulk specific gravity
  - Effective specific gravity used to back-calculate asphalt content in compacted mixture
  - Table 4.1 shows how different aggregate SG affect values reported for VMA & V_a
  - Otherwise, AI mix design criteria do not apply (end of paragraph two)

Specific Gravity of Aggregates

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


Specific Gravity of Aggregates
Combined Aggregate
Dry Bulk Specific Gravity
$G_{sb}\text{ (combined)} = \dfrac{P_1 + P_2 + P_3 + P_4}{\dfrac{P_1}{G_{sb1}} + \dfrac{P_2}{G_{sb2}} + \dfrac{P_3}{G_{sb3}} + \dfrac{P_4}{G_{sb4}}}$
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)*

$$\text{Voids in Mineral Aggregate (VMA)} = 100 - (G_{mb} \times P_s)/G_{sb}$$

$$\text{Asphalt Absorption} = 100 \times \frac{(G_{se} - G_{sb})}{(G_{sb} \times G_{se})} \times G_b$$

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?

Because specific gravity is directly dependent on volume.

Two Equations to Work With

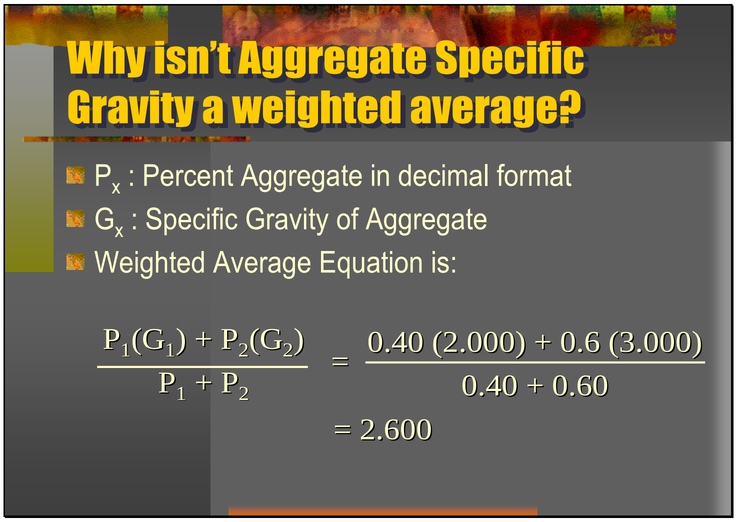
$$G = \frac{\left(\frac{M_x}{V_x}\right)}{\left(\frac{M_w}{V_w}\right)}$$

$$G_{sb} = \frac{(P_1 + P_2 + \cdots + P_n)}{\left[\left(\frac{P_1}{G_1}\right) + \left(\frac{P_2}{G_2}\right) + \cdots + \left(\frac{P_n}{G_n}\right)\right]}$$

Developed in Illinois Test Procedure 85, Appendix X1

Why isn't Aggregate Specific Gravity a weighted average?

Material	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?
P_x : Percent Aggregate in decimal format
G_x : 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

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

Obtaining the right balance

Achieved through:

- Volumetric Analysis of the Mixture
- Future 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

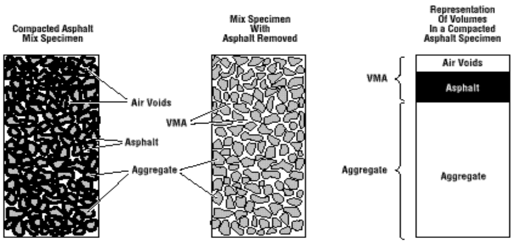
4.0% Superpave

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:

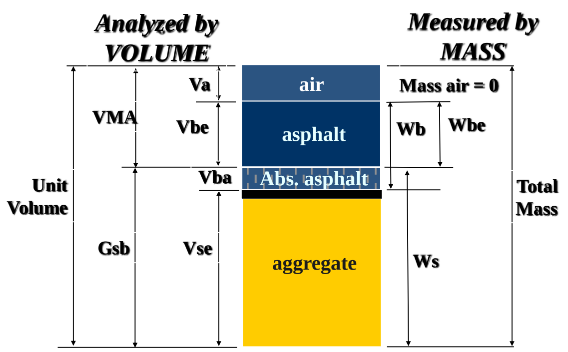
- Not a new concept; has played a role in most mixture design methods
- Is currently the best available method to readily measure mixture properties in the field on plant produced mix.

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

$$G_{mm} = \frac{100}{\dfrac{P_s}{G_{se}} + \dfrac{P_b}{G_b}}$$

$$V_a = \left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right) x\ 100$$

$$VMA = 100 - \frac{G_{mb}\ x\ P_s}{G_{sb}}$$

$$VFA = \left(\frac{VMA - V_a}{VMA}\right) x\ 100$$

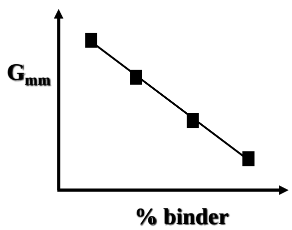
$$P_{be} = P_b - \frac{P_{ba}\ x\ P_s}{100}$$

$$P_{ba} = 100\ x \left(\frac{G_{se} - G_{sb}}{G_{se}\ x\ G_{sb}}\right) x\ G_b$$

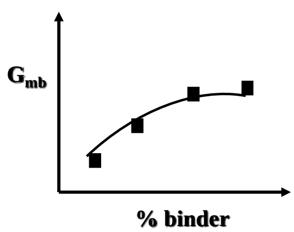
$$Eff.\ Vol. = VMA - V_a$$

What the Heck did Murphy Say?

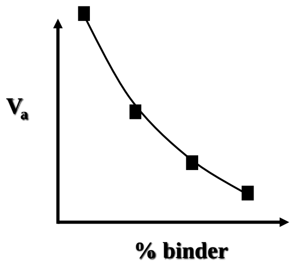
Maximum Theoretical Gravity at Other Asphalt Contents



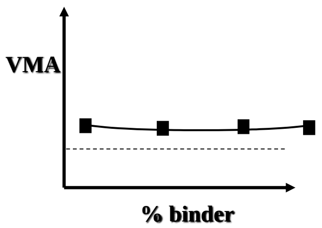
Bulk Specific Gravity at Other Asphalt Contents



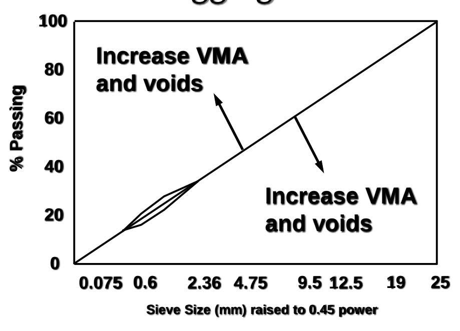
Air Void Content



Voids in the Mineral Aggregate



Voids in the Mineral Aggregate

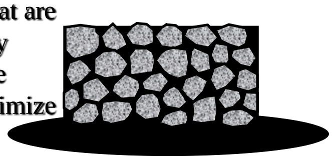


VMA Adjustments

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

• 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

I. AGGREGATE PROPERTIES

No single IDOT shelf gradation aggregate will meet the required aggregate blend composition for a HMA surface or binder mixture.

See Figure 5.1

Additional reasons shall be discussed and listed on the board.

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

Each is discussed below.

<u>Mineral Aggregates</u>

1. 90% to 95% of mix by weight
   75% to 85% by volume
2. Pavement performance heavily influenced by aggregate properties and characteristics.
3. Aggregate primarily carries vertical load (strain) of traffic and contributes slightly to resisting horizontal load.

<u>Blending</u>

1. *To obtain the desired mix properties*
2. *To utilize available material*
3. *To better control production (better with more sizes)*
4. *To improve frictional requirements*
5. *For flexibility*
6. *For specification compliance*

A. Maximum Particle Size and Gradation

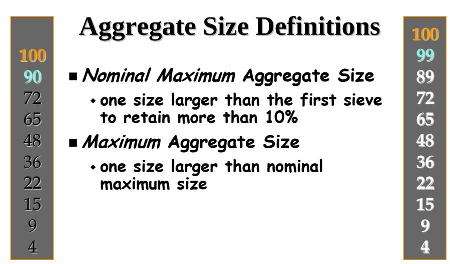
All hot-mix asphalt pavement specifications require aggregate particles to be within a certain range of sizes and for each size of particle to be present in a certain proportion. This distribution of various particles sizes within the aggregate used is called the aggregate gradation or mix gradation. To determine whether or not an aggregate gradation meets specifications requires an understanding of how particle size and gradation are measured. Articles 1003.03 and 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.

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.



- Illinois has adopted HMA's Maximum and Nominal Maximum Aggregate Size definitions.
- The gradation on the left would be defined as one size finer than the gradation on the right.

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 T 176) is a method of determining the relative proportion of detrimental fine dust and clay-like material in the fraction (portion) of aggregate passing the 4.75-mm (No. 4) sieve. Articles 1003.03 and 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.

<u>Cleanliness</u>

1. Deleterious Count:

   Percent of undesirable material in an aggregate (vegetation, shale, soft particles, clay lumps, coatings, etc.)

2. Sand-Equivalent (AASHTO T 176):

   Percent of detrimental fine dust or clay-like material smaller than the No. 4 sieve.

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 (AASHTO T 96) 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 AASHTO T 96 for the various classes of coarse aggregate.

<u>Toughness/Wear</u>

1. Describes resistance against crushing, degradation, and disintegration during manufacture, placement, compaction, and traffic loading.
2. Wear is usually more severe in top layers.
3. Evaluated by the L. A. Abrasion test (AASHTO T 96, ASTM C 131). Lower percent abrasion loss means higher resistance to wear.

D. 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.

<u>Surface Texture</u>

Rough surface texture vs. smooth surface:

1. Increased strength / decreased workability.
2. Higher VMA and additional space for asphalt.
3. Asphalt film adheres better.
4. Increased frictional characteristics.

E. Particle Shape

Particle shape influences the workability 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 gravels and 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 requires 100% crushed coarse aggregate.

<u>Particle Shape</u>

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.
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).

F. Affinity for Asphalt

An aggregate's affinity for asphalt is its tendency to accept and retain an asphalt coating. Limestone, dolomite, and trap rock 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 is 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 T 283 to determine the moisture sensitivity of bituminous mixtures.

Affinity for Asphalt

1. Ability to coat and resist stripping:
   - Hydrophilic (water-loving), e.g., siliceous aggregates (quartzite, some granites, chert)
   - Hydrophobic (water-hating), e.g., limestone, dolomite, trap rock
2. Moisture susceptibility test (AASHTO, ASTM)

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.

<u>Absorption/Porosity</u>

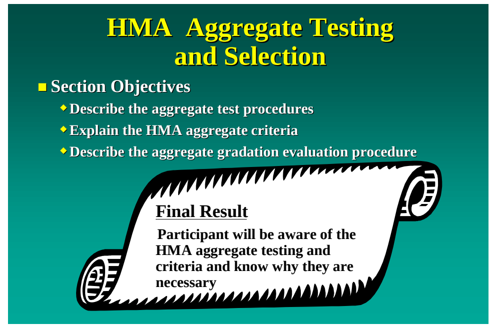
1. Measured by amount of water absorbed when soaked.
2. Compensated with additional asphalt.
3. Critical with porous aggregate (e.g., blast furnace slag, steel slag)
4. Benefits outweigh extra asphalt.

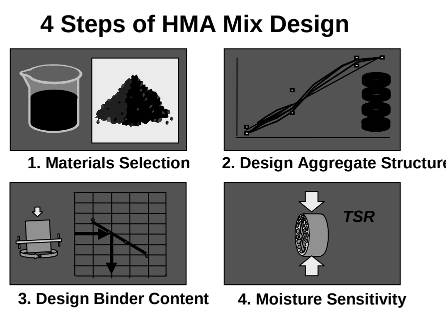
H. HMA Aggregates

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

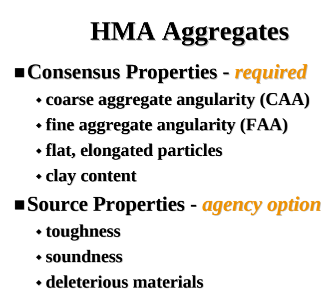




In addition to the aggregate source properties already discussed in this chapter, some HMA aggregate properties are required; some are optional for the agency.

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.

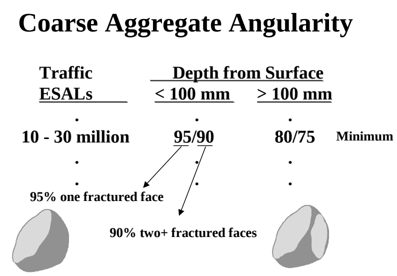


1. Coarse Aggregate Angularity (CAA) measures the fractured faces on the +4.75mm material.

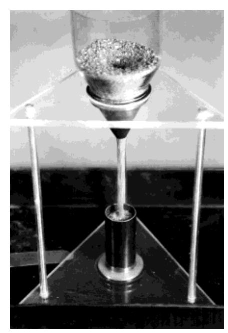
CAA requirements depend on traffic level and depth into pavement.

Illinois currently requires 100% crushed coarse aggregate for high type mixes, and believes this complies with the intent of HMA

Non-crushed materials are allowed for low-volume mixes, both in Illinois and by HMA.



2. Fine Aggregate Angularity (FAA) is measured on the -2.36 mm material.



Illinois is not measuring FAA. The test is currently being nationally evaluated for validity.

Illinois requires at least 50% manufactured sand for high types mixes (N_{design} = 90), and feels this complies with the intent of HMA.

Fine Aggregate Angularity

Traffic ESALs	Depth from Surface < 100 mm	> 100 mm	
10 - 30 million	45	40	Minimum
		% air voids in loose sample	

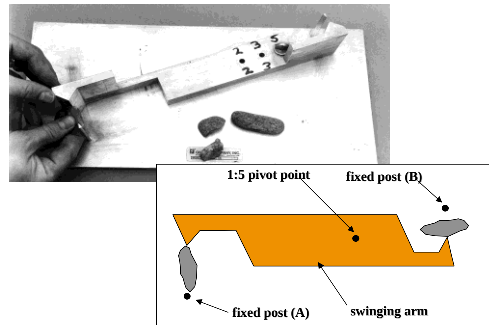
> Rounder particles pack tighter together -- less air

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.

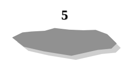
   The F&E specification varies with traffic level, and is based on 5:1 ratio.

   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.

Flat, Elongated Particles



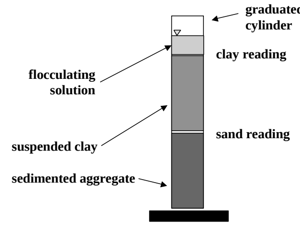
Traffic ESALs	Percent	
.	.	
10 - 30 million	10	Maximum
.	.	
.	.	

percentage
of flat and elongated particles

4. Clay content is measured using the sand 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



   Clay content varies with traffic level.

Clay Content

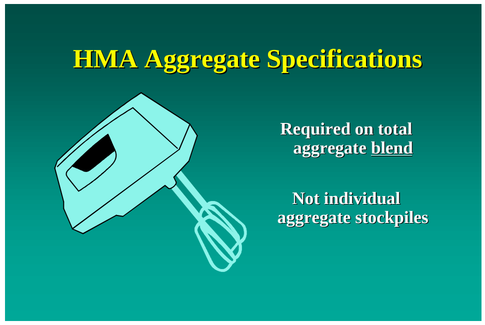
Traffic ESALs	Percent	
.	.	
$10 - 30 \times 10^6$	45	Minimum
.	.	
.	.	

sand equivalent value

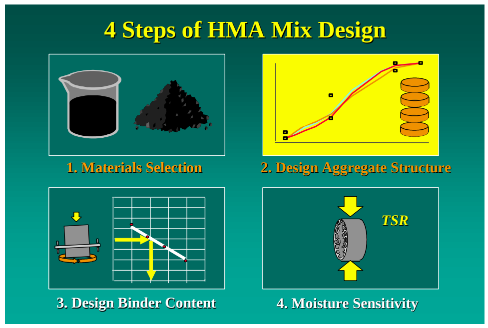
> More sand - Less clay
Clay on aggregate particles
reduces binder adhesion

In HMA, the <u>Specification</u> of the aggregate properties is on total blend; estimates of pass/fail results can be made on stockpile tests.

Illinois specifies the aggregate properties on individual sources.



The second step in HMA mix design is selection of the design aggregate structure.



I. Illinois Friction Policy

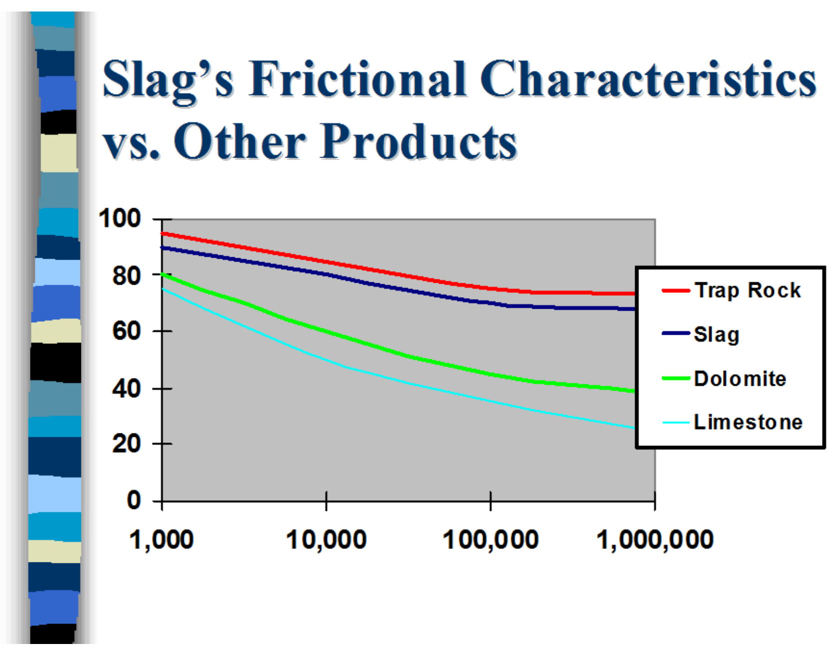
In 2000, Illinois developed a new friction policy for the four friction aggregate mixtures. Although the Department's TRA-16, "Skid-Accident Reduction Program", dictates their use. The following defines their use:

High or Low ESAL Mixture C:ADT ≤ 5,000

High ESAL Mixture D:
- 2 lanes: ADT > 5,000
- 4 lanes: 5,001≤ ADT ≤ 25,000
- 6 lanes: ADT ≤ 60,000

High ESAL Mixture E:
- 4 lanes: 25,001≤ ADT ≤ 100,000
- 6 lanes: 60,001≤ ADT ≤ 100,000

High ESAL Mixture F:ADT > 100,000



II. 0.45 POWER CURVE - A TOOL TO AID IN BLENDING

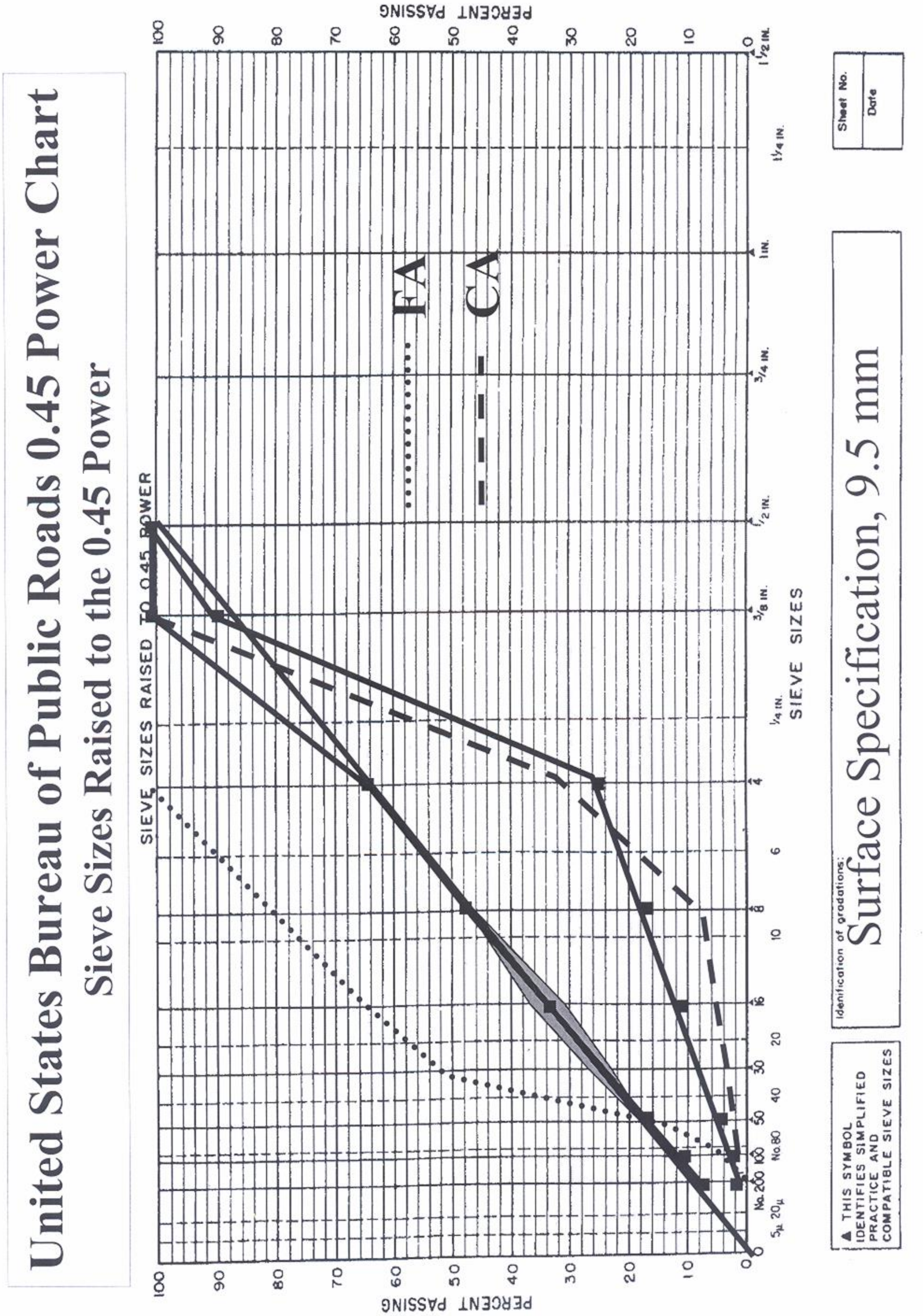


Figure 5-1

II. 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.

See Figure 5.2

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.

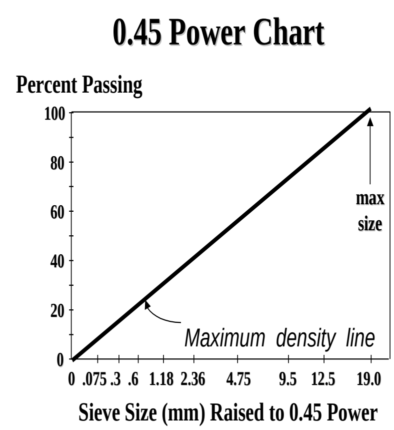
1. Asphalt mixtures do not use round rocks of the same specific gravities.

2. There are numerous philosophies as to where the top of the line should be drawn.

See Figure 5.3

Following is a table showing the maximum and nominal maximum size designations for IDOT mixtures.

IDOT Mixture	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")

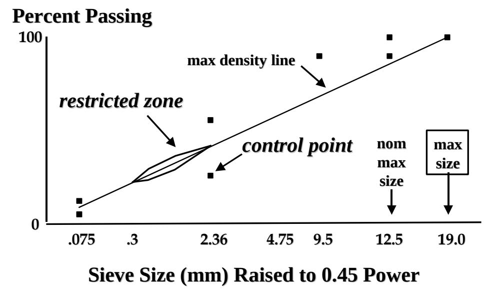


1. Illinois has developed "high-type" gradation bands for each of these mix sizes, plus finer "low-volume" gradations for the 19.0 and 9.5 mm mixes.

2. Illinois "recommends" that gradations not pass through the restricted zone.

3. Illinois HMA gradations are contained in the January 1, 2012 Standard Specification for Road and Bridge Construction

Control points and the restricted zone are used as gradation boundaries.

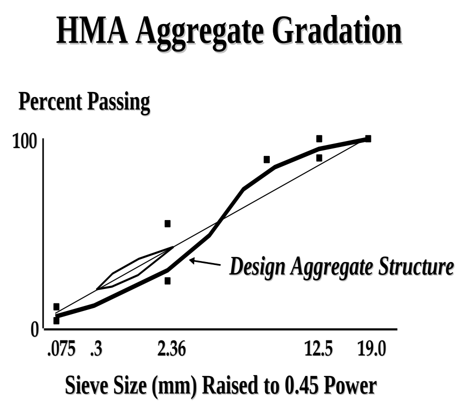


Illinois believes current specs comply with the intent of HMA gradations.

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 for both binder and surface mixtures are located primarily below the maximum density line on the 0.45 curve chart. This ensures coarse aggregate interlock. For HMA mixtures with Ndesign ≥ 90, the mixture composition shall not exceed 40% passing the 4.75mm (#4) sieve for binder mixtures and 40% passing the 2.36mm (#8) sieve for surface mixtures.

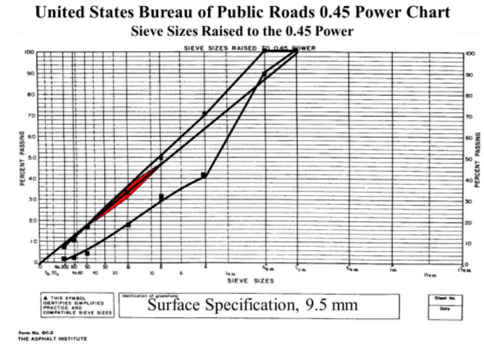
See Figure 5.4

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.



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.

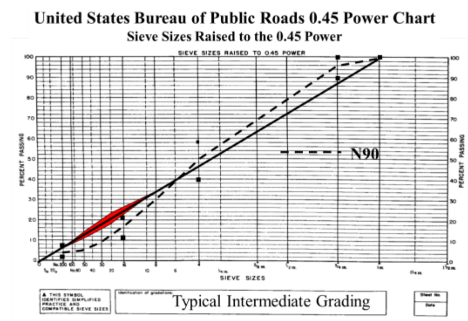
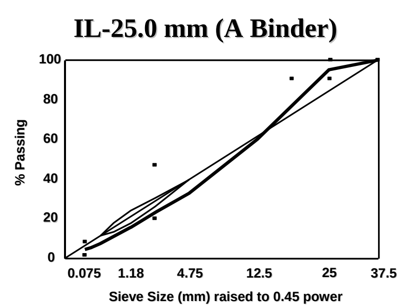


Figure 5-5

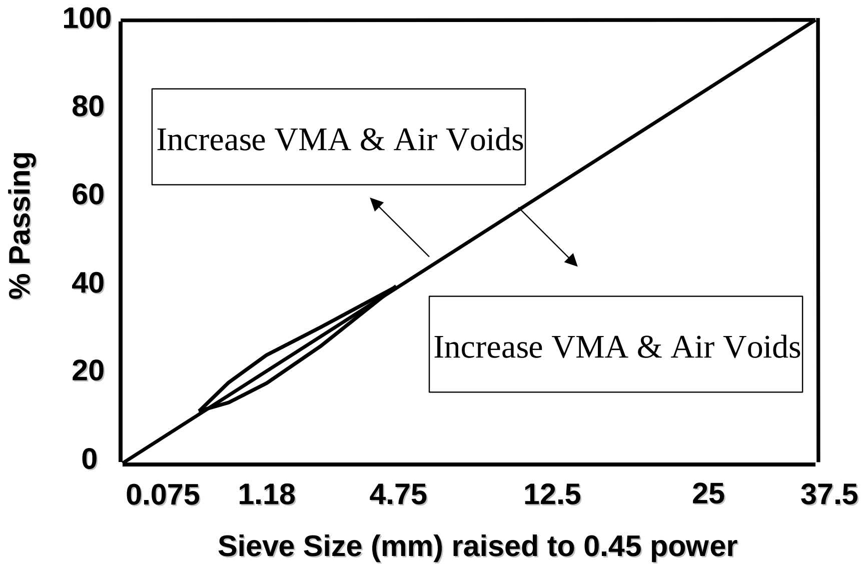
This is the middle of the spec gradation for the 25.0 mm binder mix.

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%

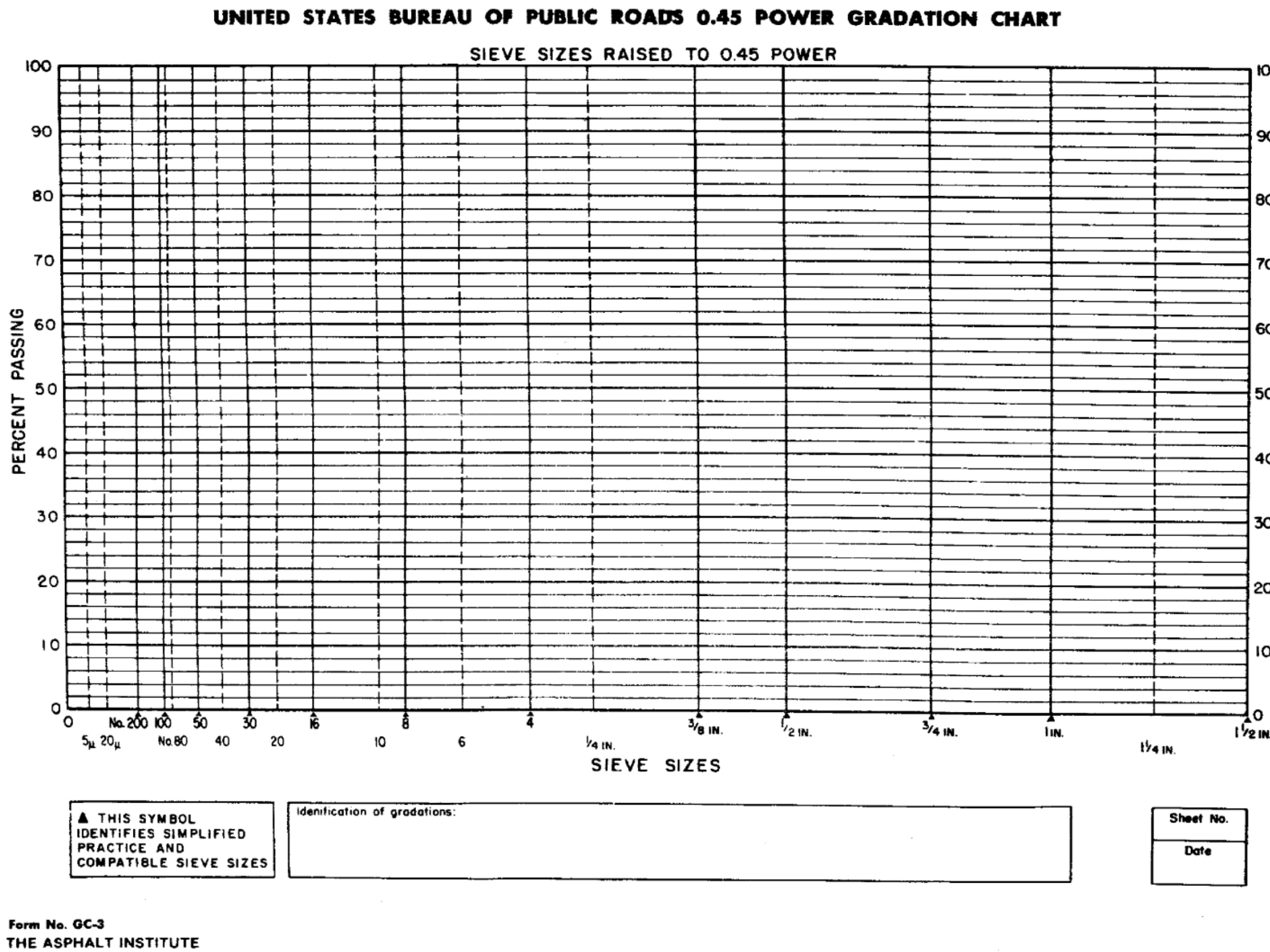
   600 µm (No. 30) sieve ± 2%

   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.

Superpave 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

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.

See Figure 5.15

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 compliance. 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

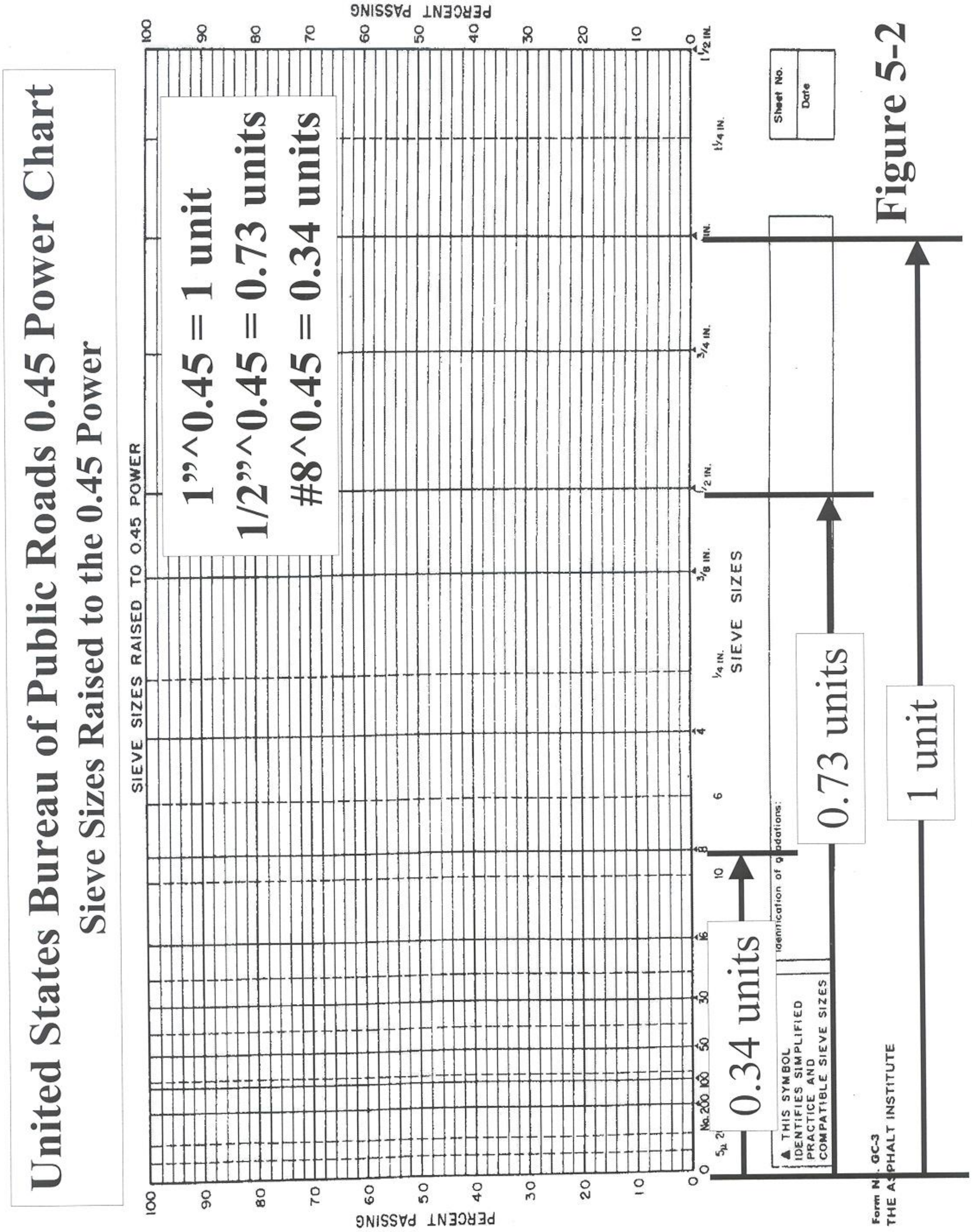
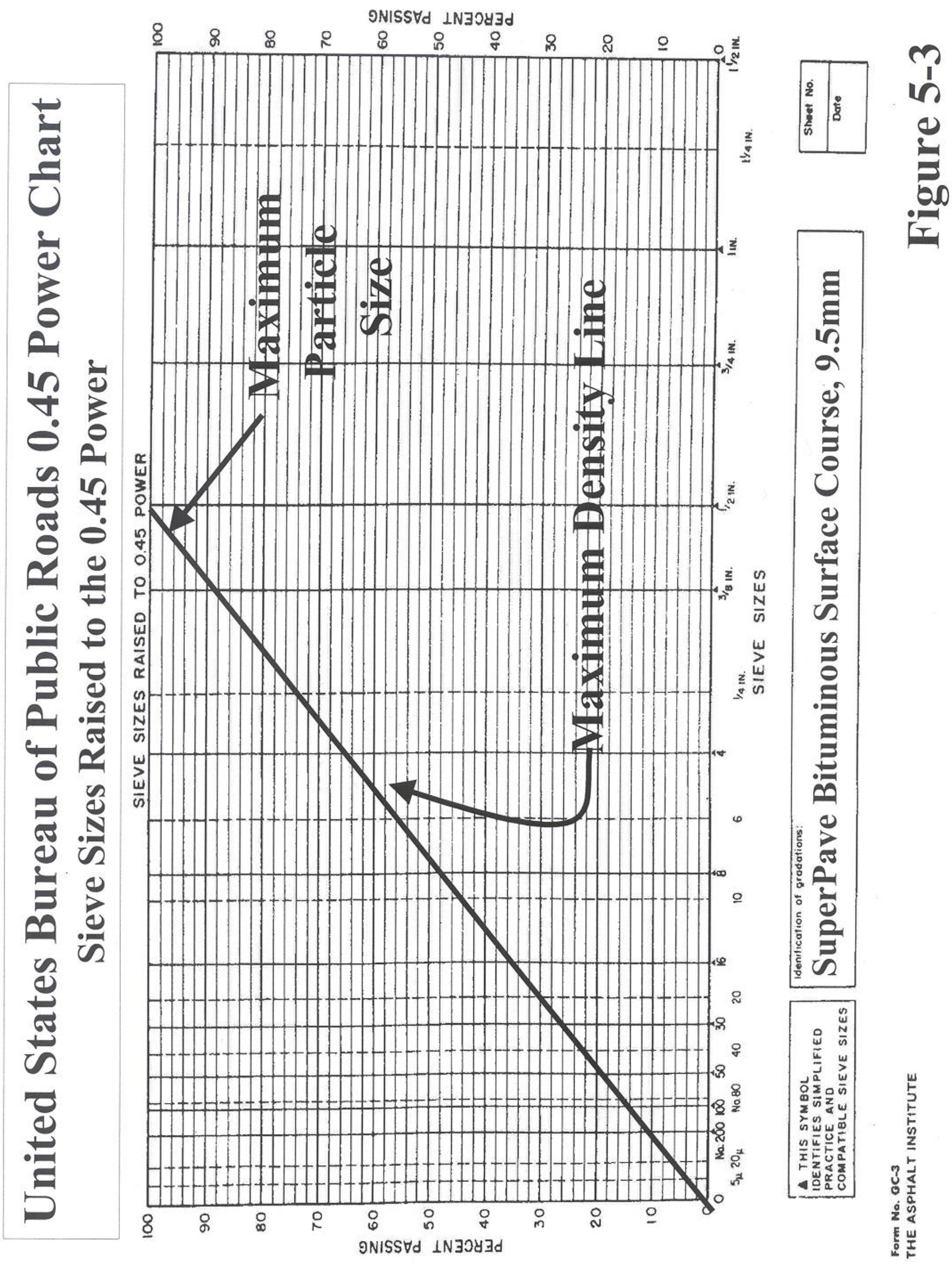

United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
1"^0.45 = 1 unit
1/2"^0.45 = 0.73 units
#8^0.45 = 0.34 units
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
SIEVE SIZES
0.34 units
0.73 units
1 unit
Sheet No.
Date
THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND 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
SIEVE SIZES
Identification of gradations:
SuperPave Bituminous Surface Course, 9.5mm
Sheet No.
Date
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Form No. GC-3
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Figure 5-3

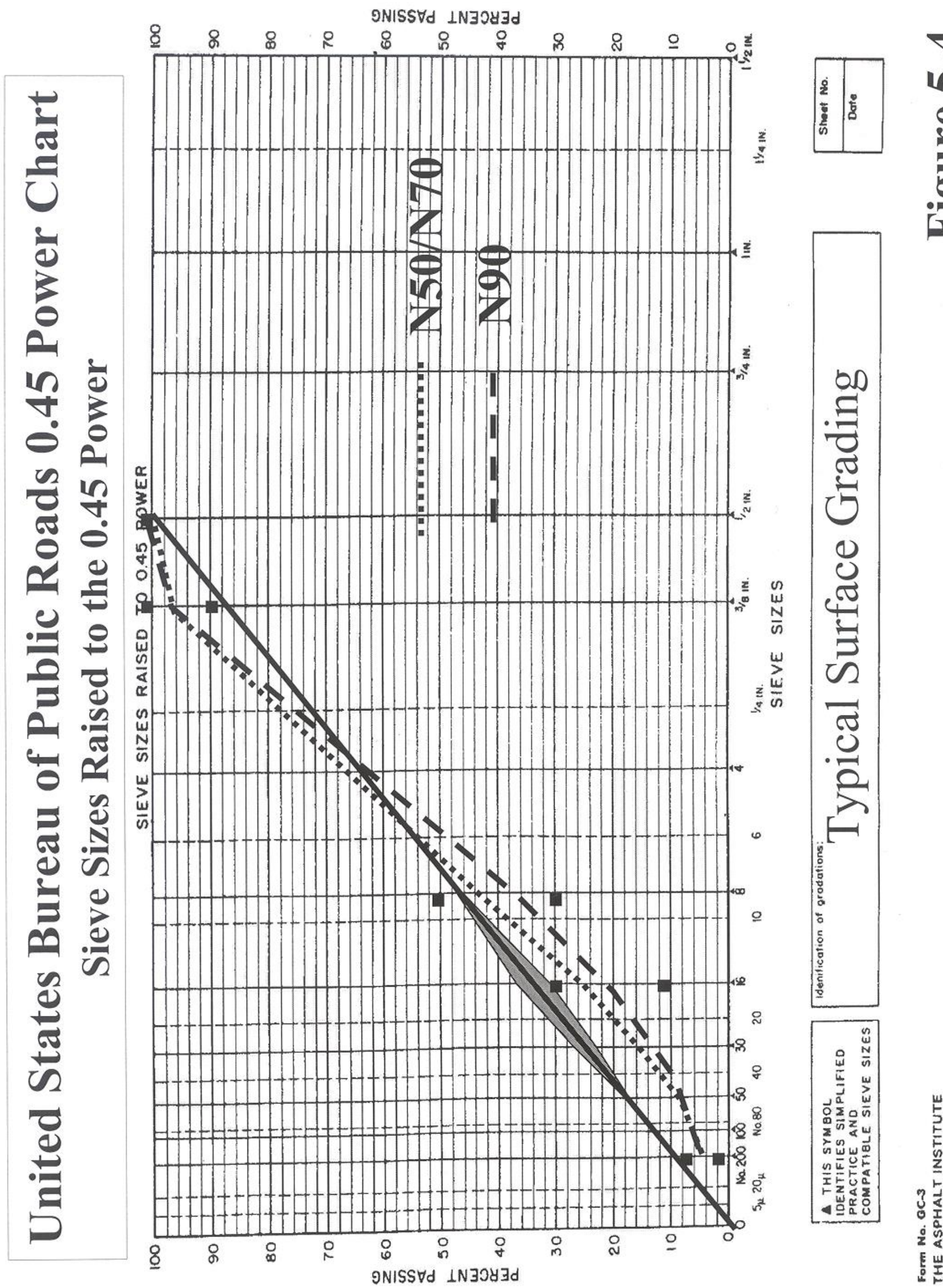
United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
SIEVE SIZES
N50/N70
N90
Identification of gradations:
Typical Surface Grading
▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Sheet No.
Date
Form No. GC-3
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Figure 5-4

United States Bureau of Public Roads 0.45 Power Chart

Sieve Sizes Raised to the 0.45 Power

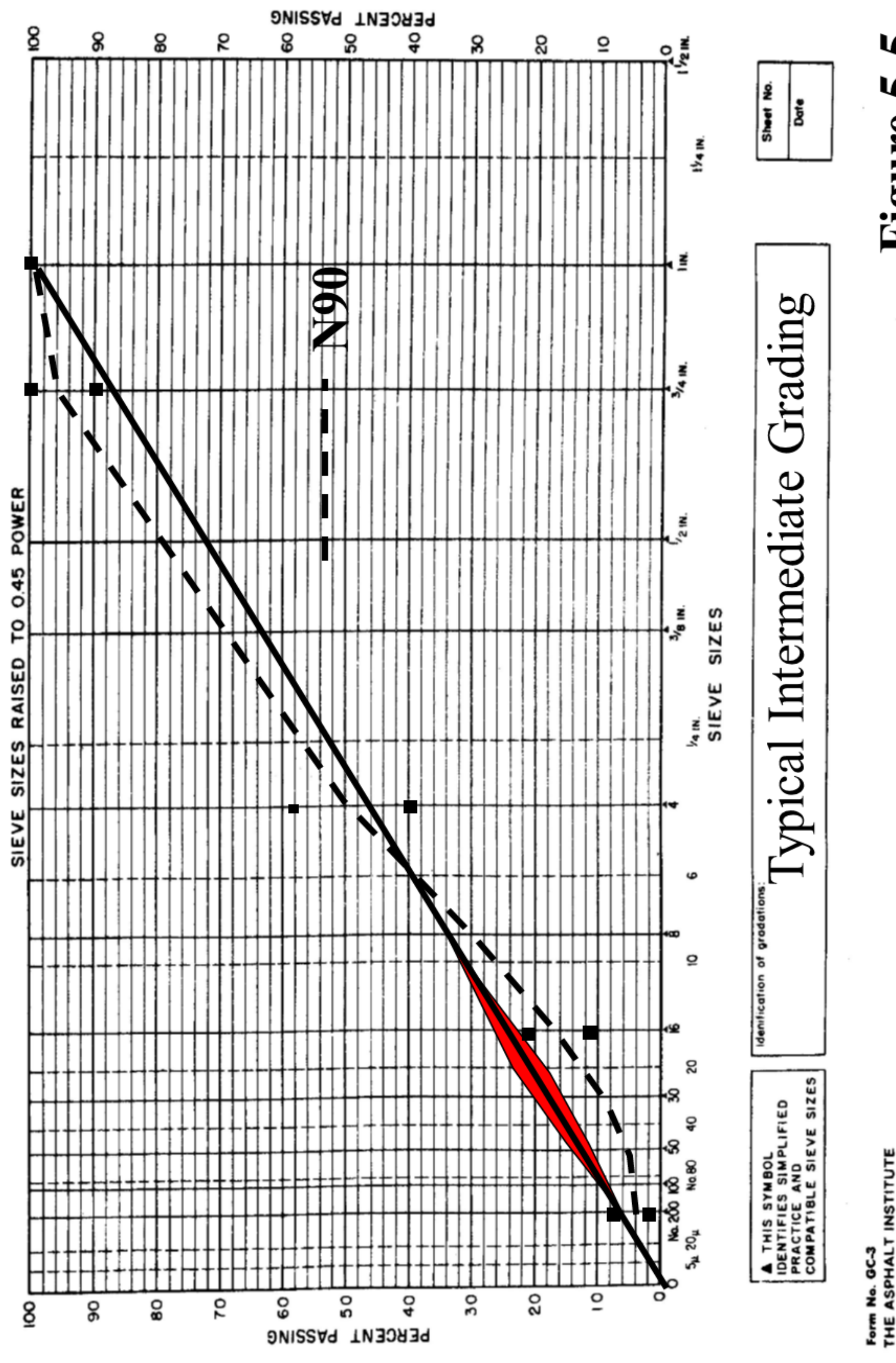

Figure 5-5

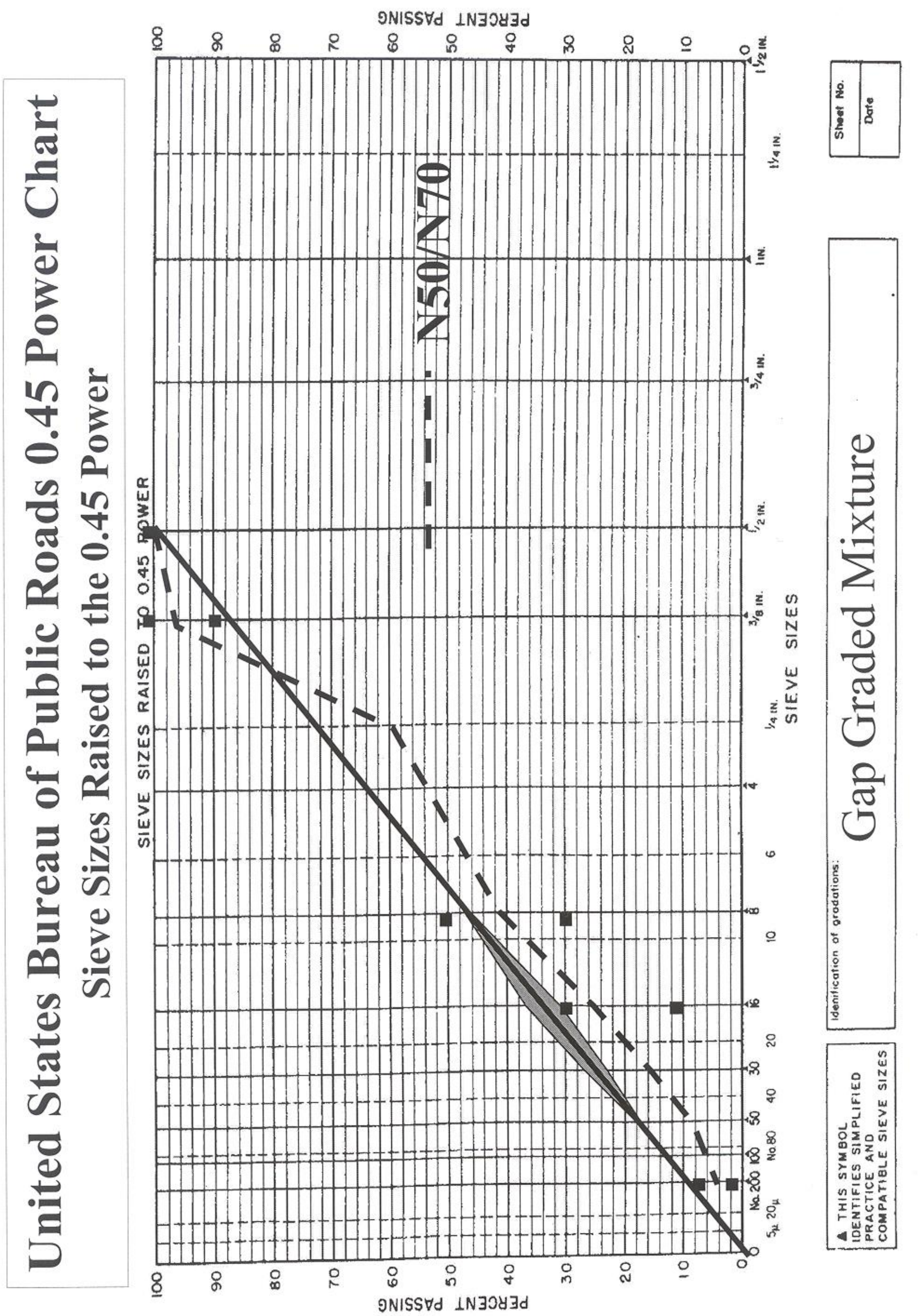
United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
SIEVE SIZES RAISED TO 0.45 POWER
N50/N70
PERCENT PASSING
SIEVE SIZES
Gap Graded Mixture
Identification of gradations:
Sheet No.
Date
▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Form No. GC-3
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Figure 5-6

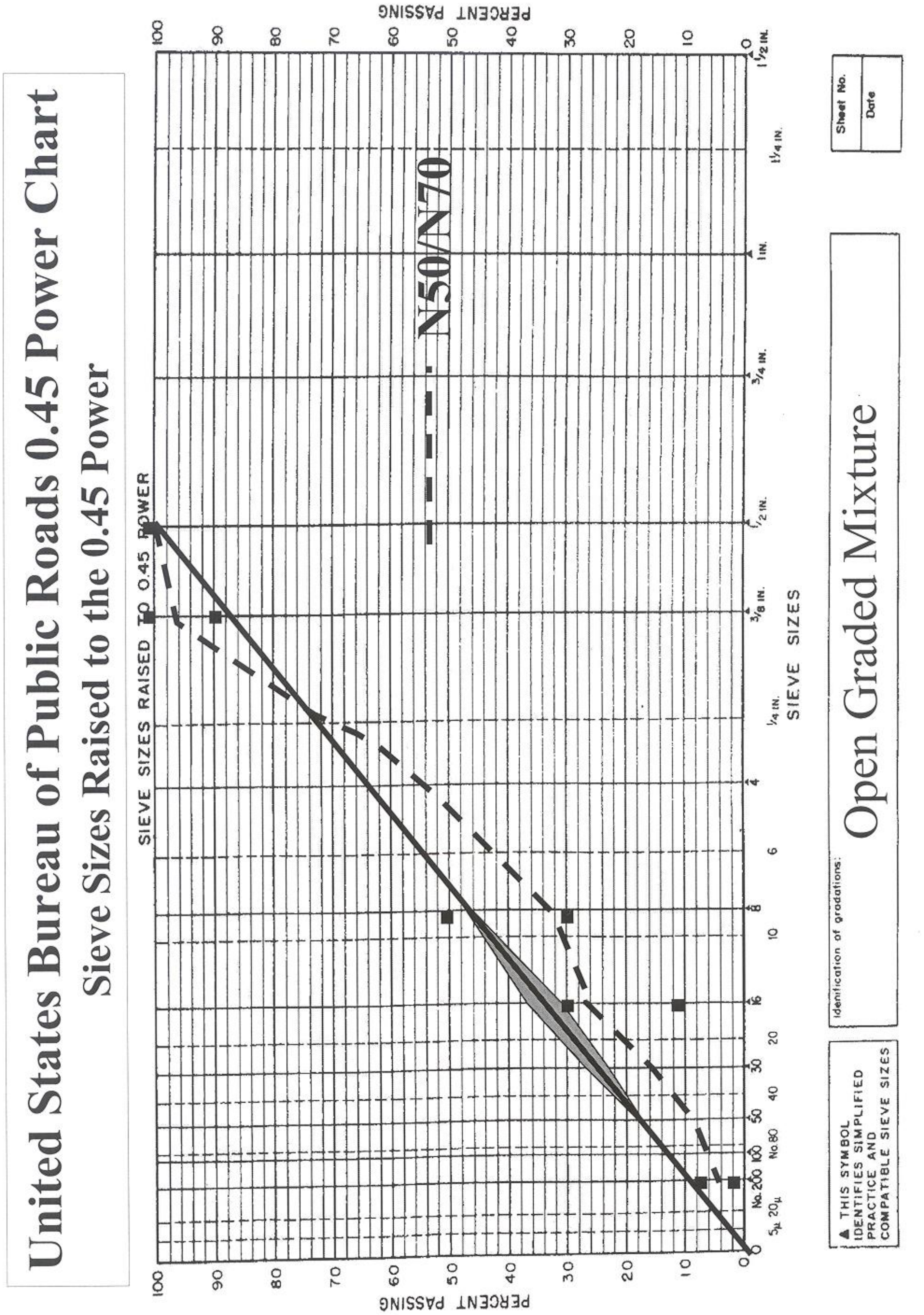
United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
N50/N70
SIEVE SIZES
Open Graded Mixture
Identification of gradations:
Sheet No.
Date
THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Form No. GC-3
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Figure 5-7

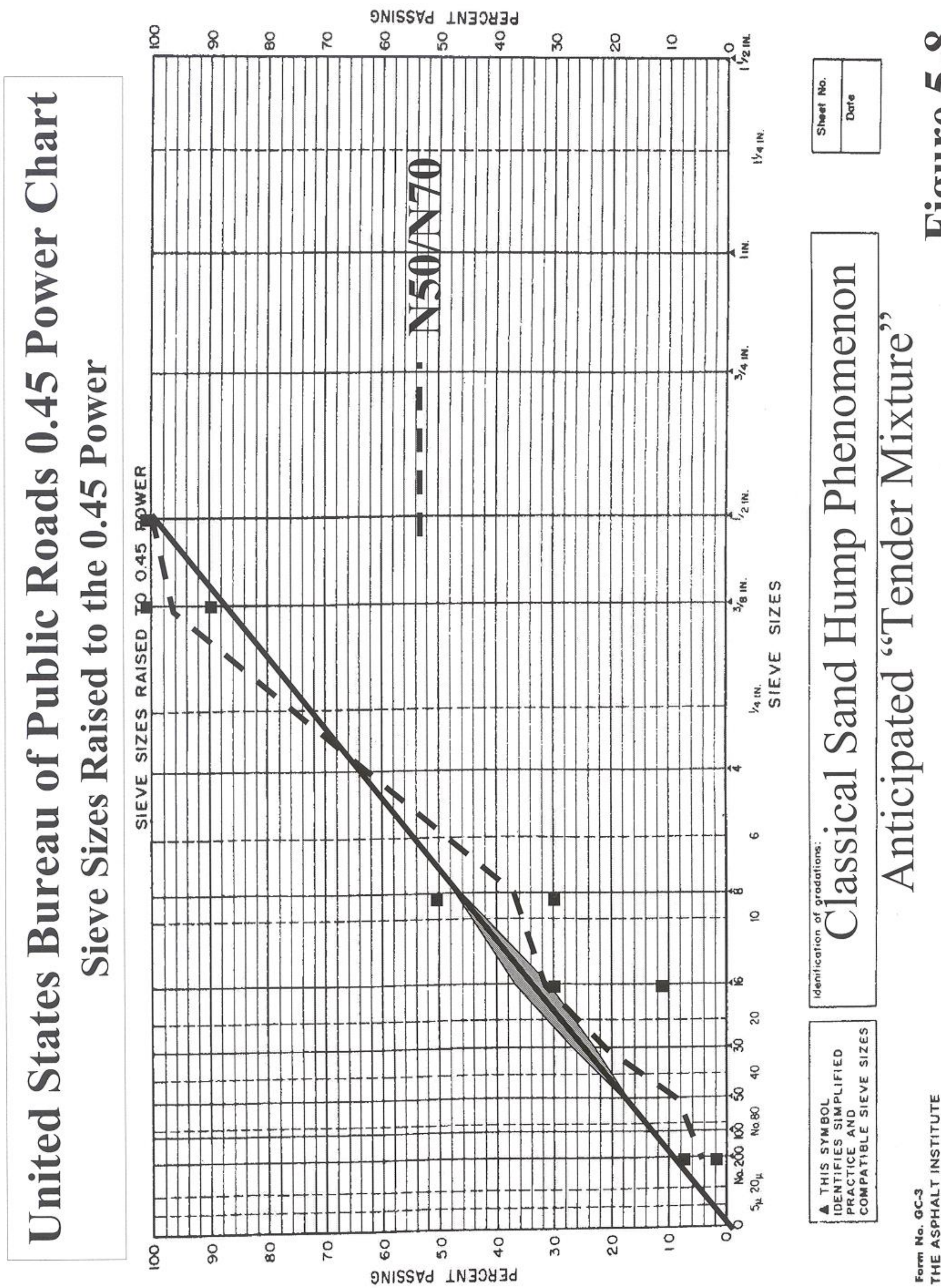

United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
N50/N70
SIEVE SIZES
No.200 No.80 50 40 30 20 16 10 8 6 4 1/4 IN. 3/8 IN. 1/2 IN. 3/4 IN. 1 IN. 1 1/4 IN. 1 1/2 IN.
THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Identification of gradations:
Classical Sand Hump Phenomenon
Anticipated "Tender Mixture"
Sheet No.
Date
Form No. QC-3
THE ASPHALT INSTITUTE

Figure 5-8

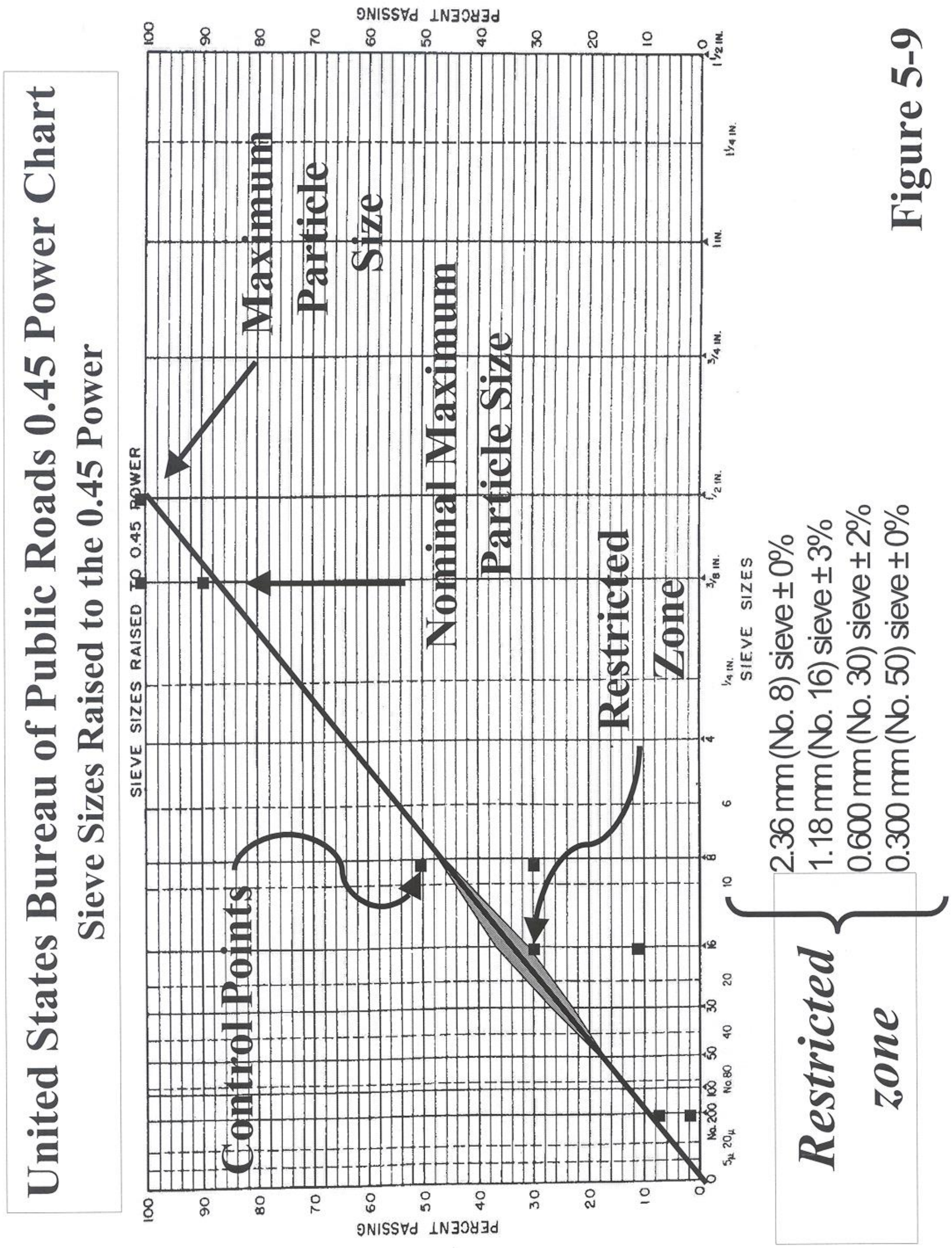
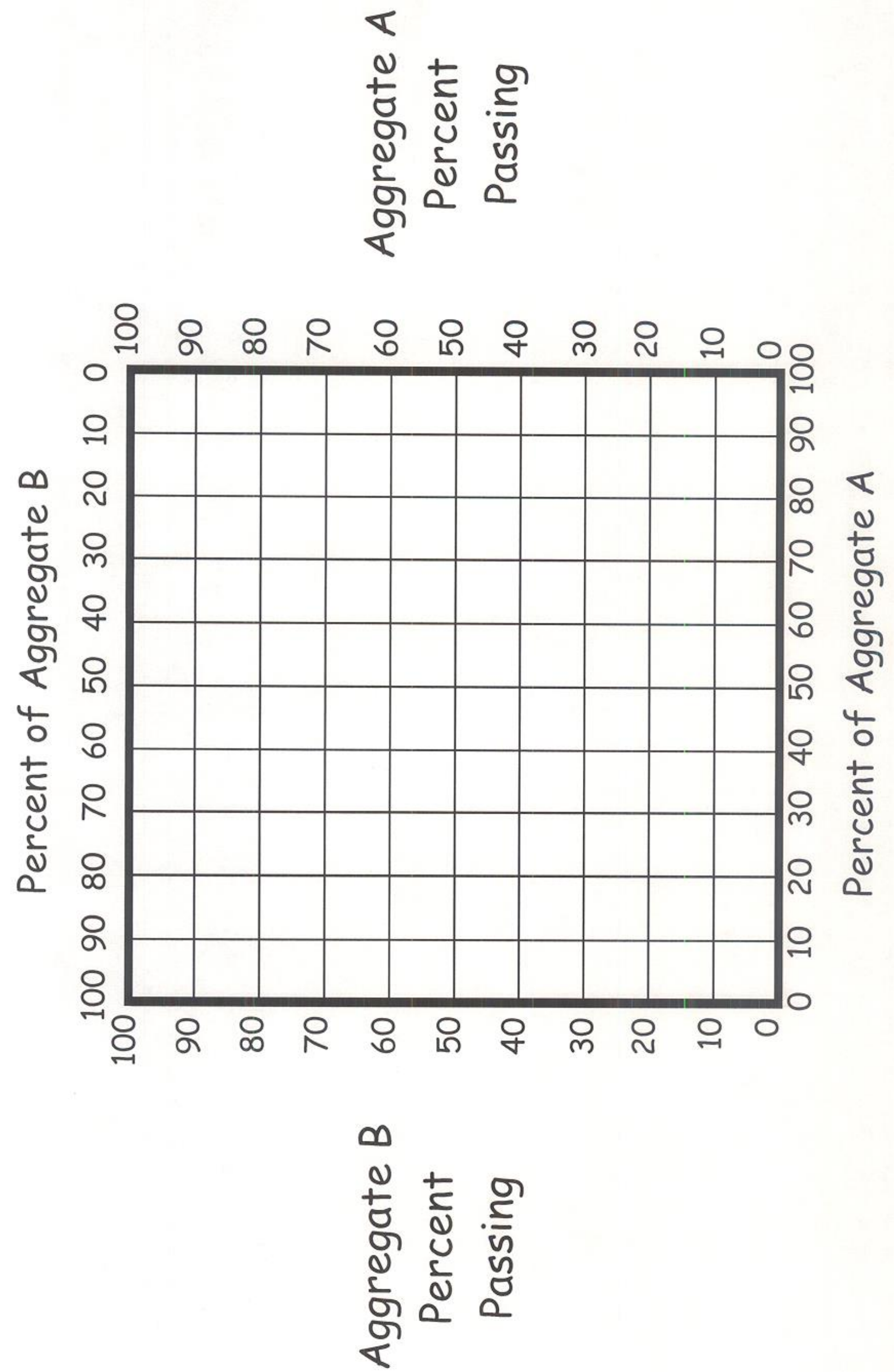

United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
SIEVE SIZES
Maximum Particle Size
Nominal Maximum Particle Size
Restricted Zone
Control Points
Restricted zone
2.36 mm (No. 8) sieve ± 0%
1.18 mm (No. 16) sieve ± 3%
0.600 mm (No. 30) sieve ± 2%
0.300 mm (No. 50) sieve ± 0%

Figure 5-9

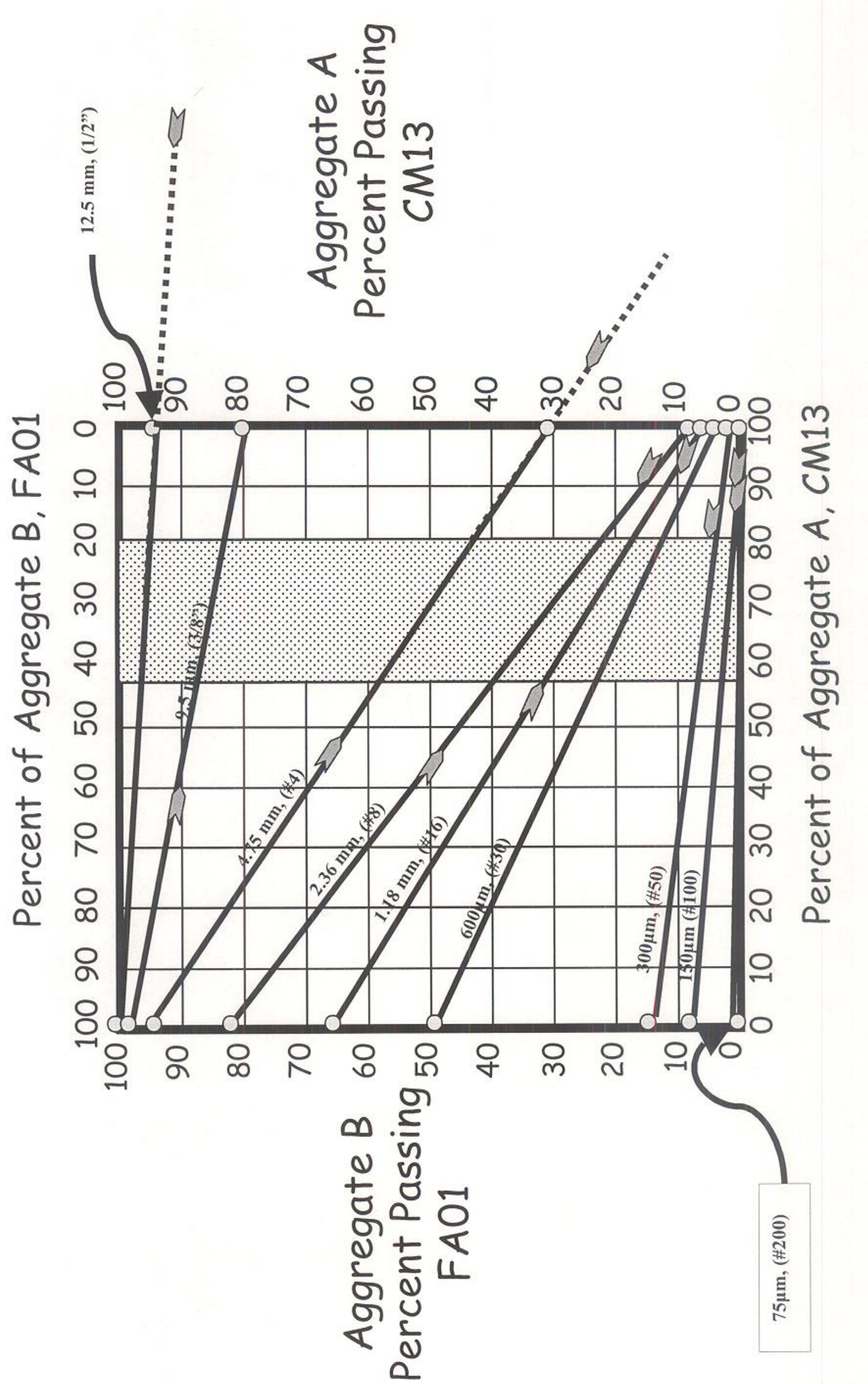
Figure 5-10 Surface Design, N50, 9.5mm

Material	CM			FA					
Source									
Percent Used			%			%	Combined Gradation	Target Value	Spec. 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



Proportioning Two Aggregates

FIGURE 5-12

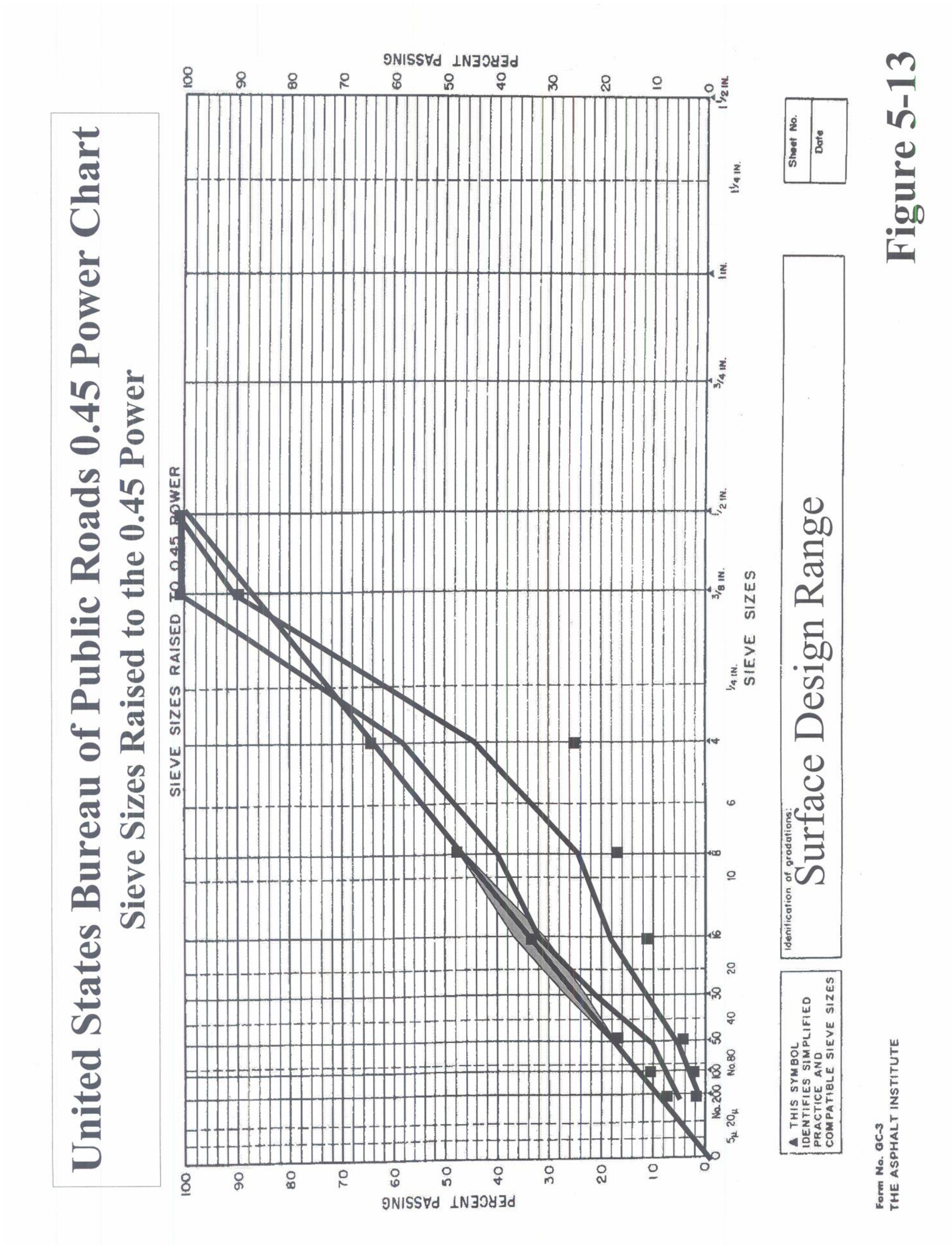

United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
SIEVE SIZES
5µ 20µ No.200 100 No.80 50 40 30 20 16 10 8 6 4 1/4 IN. 3/8 IN. 1/2 IN. 3/4 IN. 1 IN. 1 1/4 IN. 1 1/2 IN.
▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Identification of gradations:
Surface Design Range
Sheet No.
Date
Form No. GC-3
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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

BINDER DESIGN:

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

SURFACE DESIGN:

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

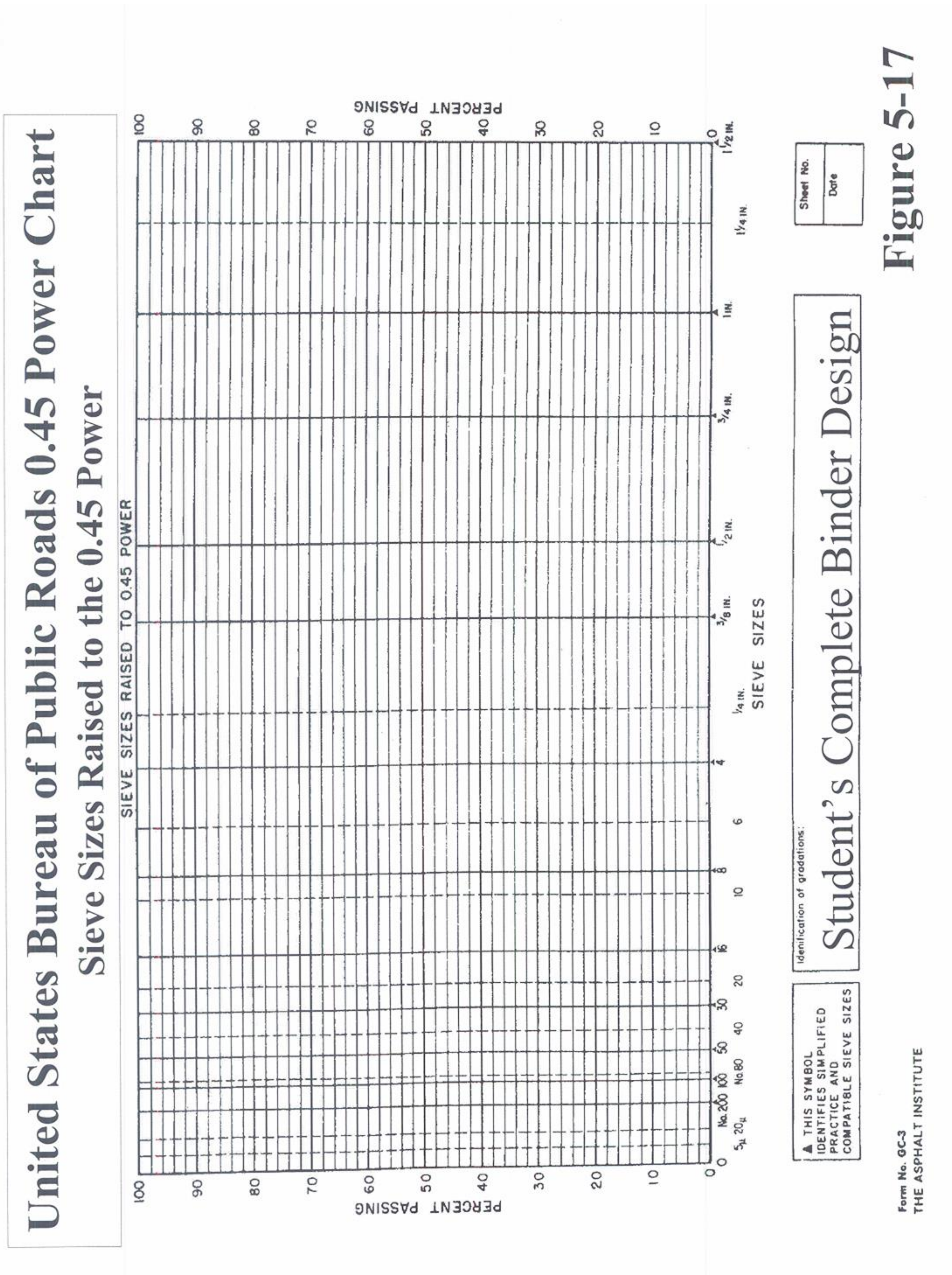

United States Bureau of Public Roads 0.45 Power Chart
Sieve Sizes Raised to the 0.45 Power
SIEVE SIZES RAISED TO 0.45 POWER
PERCENT PASSING
SIEVE SIZES
▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Identification of gradations:
Student's Complete Binder Design
Sheet No.
Date
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			Combined Gradation %	Target Value	Spec. Limits
Source																		
Percent Used	_____%			_____%			_____%			_____%			_____%					
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

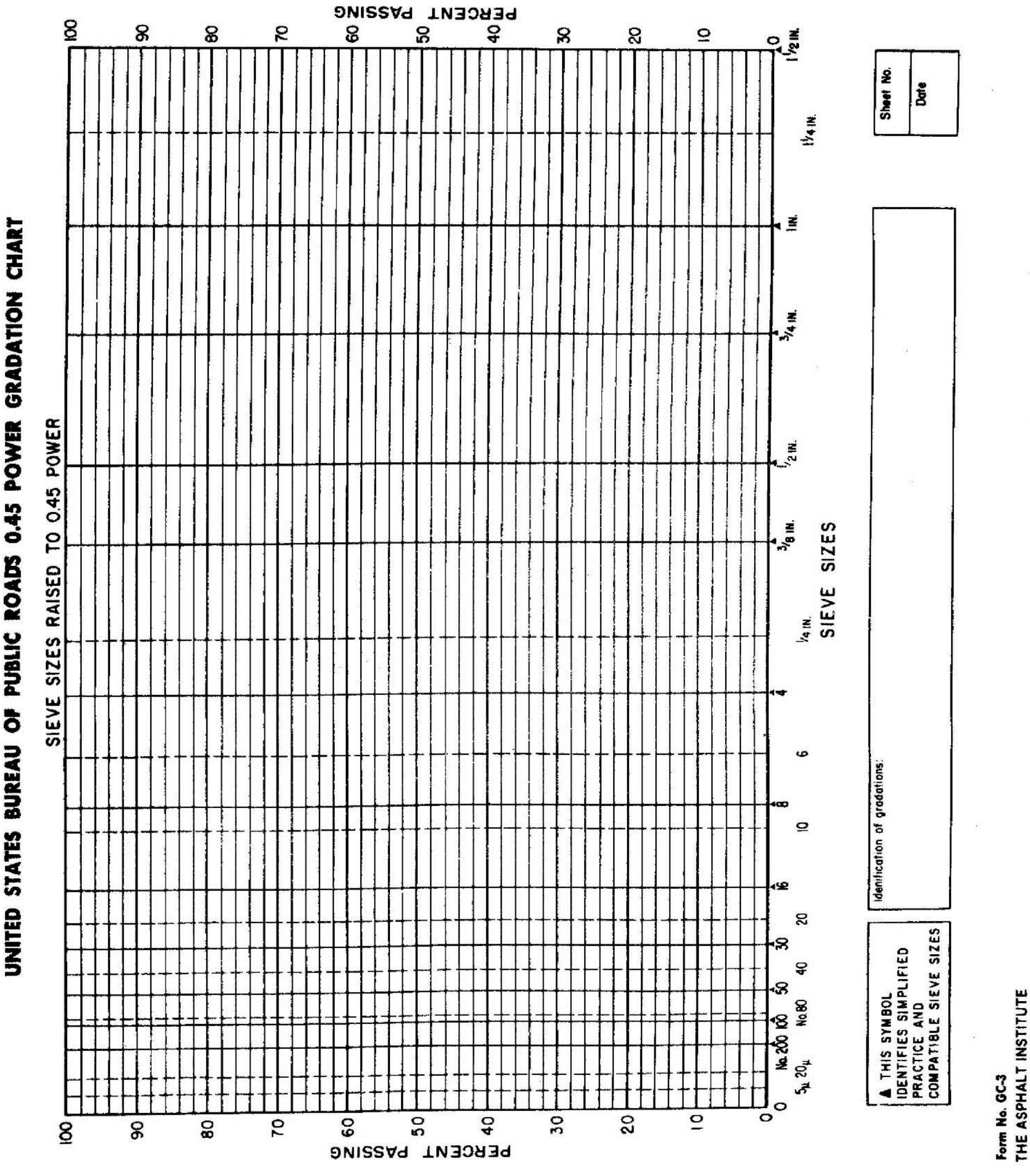
Contract Level III Class
Mixture HMA, Surface, N70

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																		
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

A. Splitting Aggregates

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 performed 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.

See Figure 5.19FA & 5.19CA

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.

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:

$$P_{bi} = \frac{G_b \text{ x} \left(V_{be} + V_{ba}\right)}{\left(G_b \text{ x} \left[V_{be} + V_{ba}\right]\right) + W_s} \text{ x} 100$$

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:

$$V_{ba} = \frac{P_s \text{ x} \left(1 - V_a\right)}{\frac{P_b}{G_b} + \frac{P_s}{G_{sb}}} \quad \text{x} \quad \left(\frac{1}{G_{sb}} - \frac{1}{G_{se}}\right)$$

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

% RAP	0
% RAP AC	0
RAP Wt. =	0

BATCH SIZE	**12,000**

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

BATCH SIZE	**12,000**

% RAP	0
% RAP AC	0
RAP Wt. =	0

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

<u>Test Data</u>

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%.

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Hot-Mix Asphalt Mix Design
Procedure for Dust Correction Factor Determination
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(continued)
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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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Procedure for Dust Correction Factor Determination
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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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B) RAP Mix Design

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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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.

DCF	Washed	RJMF
75μm (No. 200)	4.3	3.4

DCF = 4.3 - 3.4 = 0.9

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Procedure for Dust Correction Factor Determination
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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	

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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.

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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			

	#2	#3	#4	#5
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			

	#1	#2	#3	#4	#5
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:---								

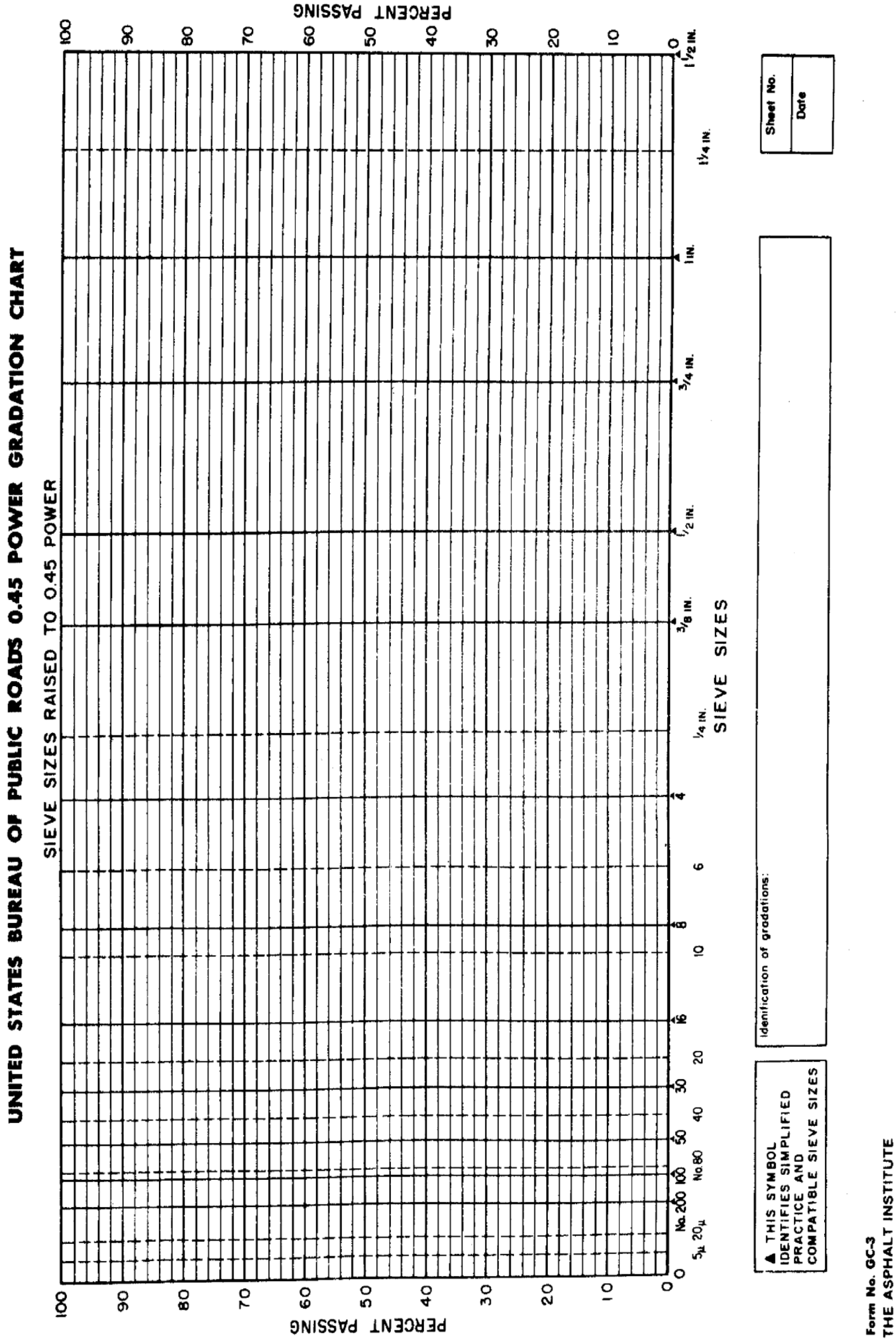
REMARKS:

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. 1¼ IN. 1½ 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 AC

- 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.

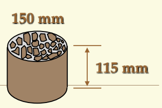
Empty 5-gallon Bucket

- Discharge quickly,
- Thoroughly clean walls,
- Split evenly for test specimens according to agency specifications.

HMA Splitter

- Remix,
- Split,
- Watch "Rice" sample size.

Specimen Preparation

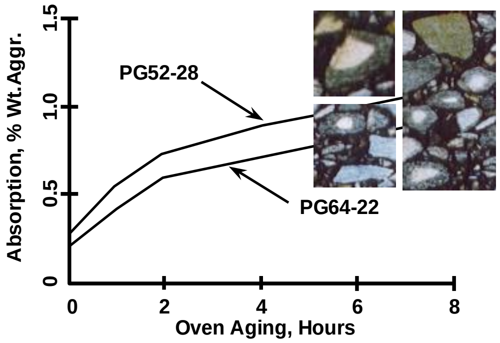


- Specimen Height & Mass
  - 115 mm ± 5 mm
  - Approximately 4850 g of mix required (4600 g of natural aggregate),
  - 5150 g for 50/50 mass of steel slag,
  - 4750 g for 50/50 mass of ACBF slag.

Conditioning in oven

- Place samples in oven at compaction temperature for specified time,
- "Rice" in oven for highly absorptive aggregates.

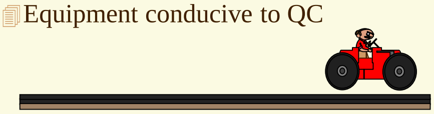
Effect of Absorption, I



Gyratory Compactors

Goals of HMA Compaction Method

- Simulate field densification
  - traffic
  - climate
- Accommodate large aggregates
- Measure mix compactability
- Equipment conducive to QC



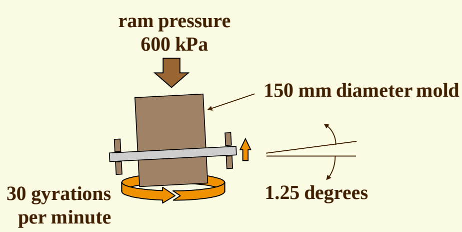
Prepare the SGC

- Perform regular calibrations,
- Review compaction temperature requirement,
- Set N_{design} or N_{max} depending on your specification.

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 degree external angle.

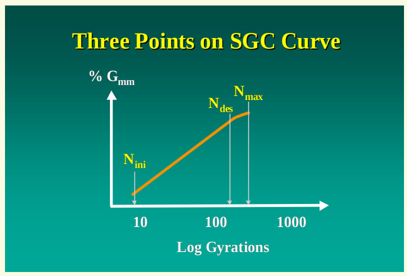
Extrude specimen

- Fairly quickly for coarse graded mixtures,
- After a little cooling for fine graded mixtures to avoid deformation.

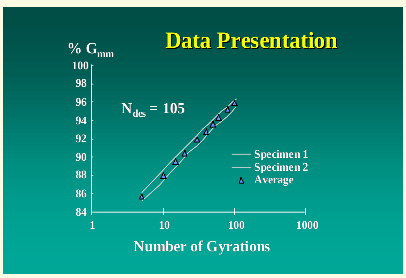
Identify specimens

- Asphalt Binder content,
- Test specimen number,
- Design number, etc.

Compaction Data



Compaction of 2-Specimens



Bulking Specimens

- Bulk specific gravity (G_{mb}) specimens
  - Highly absorptive aggregates cured for 2 hrs.
  - Non-absorptive aggregates brought to compaction temperature.
  - No conditioning for plant mix specimens.

Bulking Specimens

		4.0A	4.0B
BRICK NO.			
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
  - Highly absorptive aggregates cured for 2 hrs.
  - Non-absorptive aggregates crumbled and cooled.
  - No conditioning for plant mix specimens.

"Rice" Gravity

1. Weight of Pycnometer w/o lid + Sample _______
2. Weight of Pycnometer w/o lid _______
3. Dry sample weight (1-2) A _______
4. Averaged calibrated Pycnometer weight (Pycnometer + lid + water) D _______
5. Vacuumed sample weight (Pycnometer + lid + water + sample) E _______
6. Maximum Specific Gravity, [A/(A+D-E)] _______

(report to 3 places, [2.xxx])

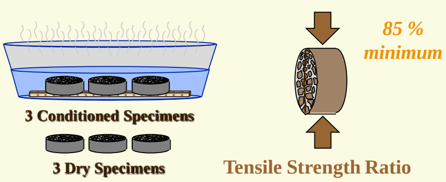
Test Data Interpretation

HMA Mixture Requirements

- Specimen Height
- Mixture Volumetrics
  - Air Voids
  - Voids in the Mineral Aggregate (VMA)
  - Voids Filled with Asphalt (VFA)
  - Mixture Density Characteristics
- Dust Proportion
- Moisture Sensitivity

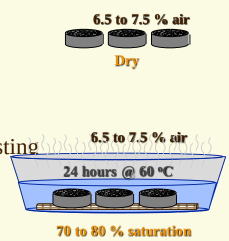
Moisture Sensitivity; Modified AASHTO T283-07

- Measured on Proposed Aggregate Blend and Asphalt Binder Content



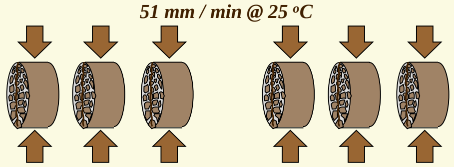
AASHTO T283-07 Modified

- Two subsets with equal voids
  - one - "dry"
  - one - saturated
- One set conditioned
  - 24 hrs @ 60ºC
  - 2 hrs @ 25ºC before testing



AASHTO T283-07 Test Procedure

51 mm / min @ 25 ºC

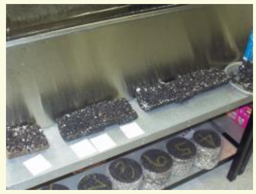


Avg Dry Tensile Strength **Avg Wet Tensile Strength**

$$TSR = \frac{Wet}{Dry} \geq 85\ \%$$

Stripping Pass/Fail

- Test Data,
- Specification Requirements,
- Cracked rock vs. stripped rock.
- Visual Ratings.

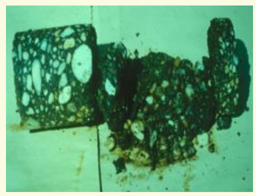


Laboratory Requirements

- 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 166-10, Modified

E. Maximum Theoretical Specific Gravity (G_{mm}) - AASHTO T 209-05, Modified

F. Tensile Strength Ratio (TSR) - AASHTO T 283-07

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
Short-Term Aging Temperature	295±5°F	305±5°F	*295±5°F	*305±5°F	PP-2

* High Absorptive Aggregate & Slag Only

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 moisture sensitivity. 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. 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 154° C (310° F) oven to a temperature at approximately the mixing temperature of 146° ± 3° C (295° ± 5° F). 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 PG58-22. 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 are placed in the oven at 154° C (310° F) for a minimum of 1 hour. The two maximum theoretical specific gravities (G_{mm}) are left out and allowed to cool. 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 heated to a temperature between 93° C (200° F) and 149° C (300° F), 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 Section 9 of Illinois Modified AASHTO TP4.

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 angle of 22.0 ± 0.35 mrad (1.16 ± 0.02°) 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.

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).

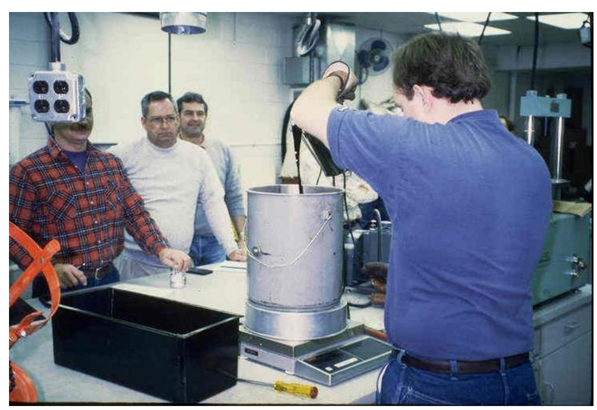
A. At this point, the batched aggregate should be in the oven, dried, and heated to no more than the mixing temperature. The asphalt binder should be at the mixing temperature of 295° ± 5° F (146° ± 3° C).

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.

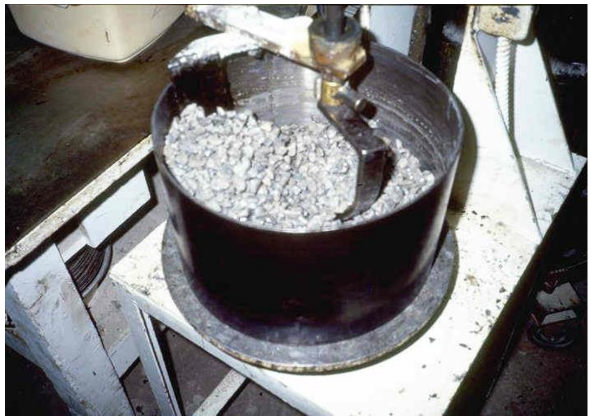
C. Introduce the heated aggregate into the mixing bowl. Check the batch weight of aggregate. Dry-mix the aggregate thoroughly.

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.

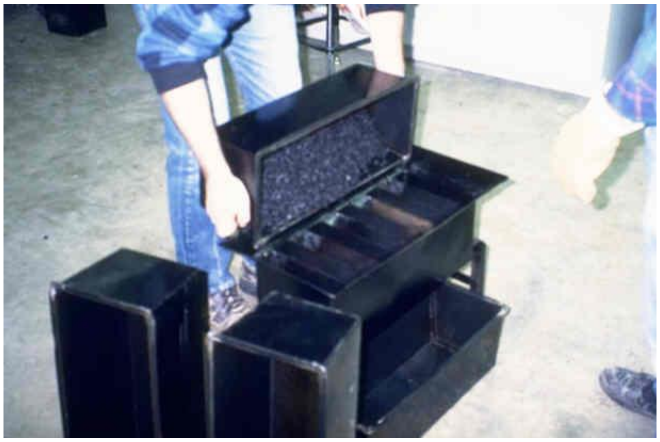


G. Remove the mix from the mixing bowl. Thoroughly clean the inside of the bowl and all the utensils used during this process. It should be noted to start with the batch containing the highest percent asphalt in an effort to butter the bowl. Repeat this mixing process for the remainder of the batches. 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.

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 PP2 covers mixture conditioning.

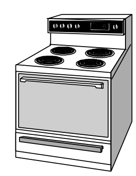
   Conditioning temperatures are as follows:

   - 295±5 °F for unmodified asphalt
   - 305±5 °F for modified asphalt

See Figure7.1

Mixture Conditioning

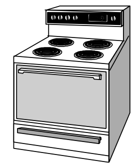
- **Bulk specific gravity (G_{mb}) specimens**
  - **Absorptive aggregates - 2 hours at compaction temperature**
  - **Non-absorptive - 1 hour at compaction temperature**
  - **No conditioning for plant mix specimens**



3. Once the bulk specific gravity (G_{mb}) specimens are at their compaction temperature any-time after this initial cure, they shall be compacted. The maximum theoretical specific gravity (G_{mm}) sample is allowed to cool after being split unless, as stated previously, aggregates with absorption's greater than 2.5% or slag aggregates are used. In this case, the sample is allowed to cool after the cure time is reached. Once cooled, this test procedure can continue.

Mixture Conditioning

- **Max specific gravity (G_{mm}) specimens**
  - **Absorptive aggregates - 2 hours at compaction temperature**
  - **Non-absorptive aggregates - no conditioning needed**
  - **No conditioning for plant mix specimens**



C. Compaction

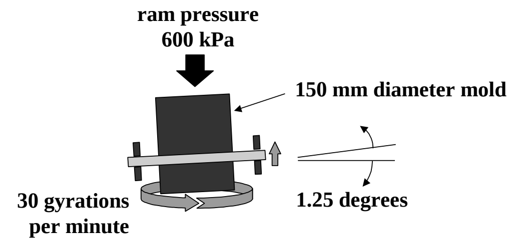
The goals of the HMA Compaction Method are as follows:

- 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.



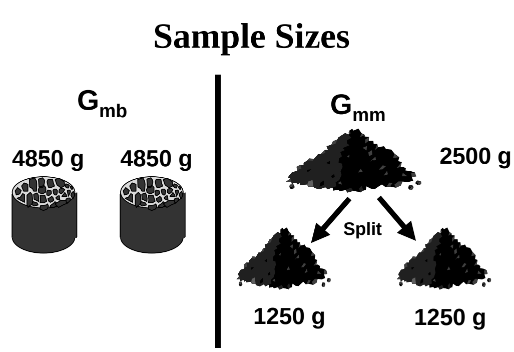
- The 150mm mold allows for up to 37.5mm (1.5 inch) maximum aggregate size.
- Recording of the height of the mixture in the mold during the compaction process is an important feature.

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.

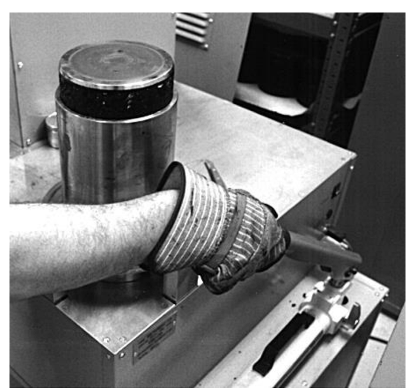
4. Place a paper disk in the bottom of the mold.

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.

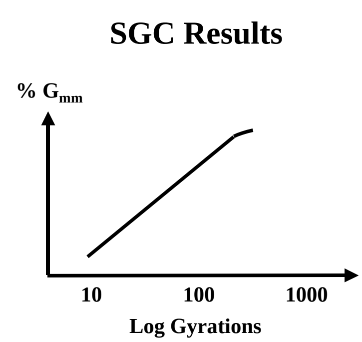


9. Remove the paper disks.

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.

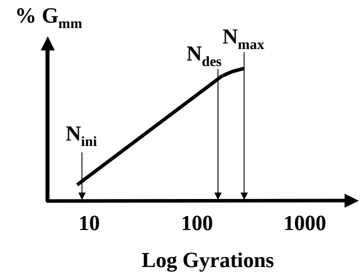


Previously, compaction was carried out to N_{max}, and the density of the mix was determined at N_{max}, N_{des}, and N_{ini}.

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.

Illinois Design Compaction

- **Based on traffic:**

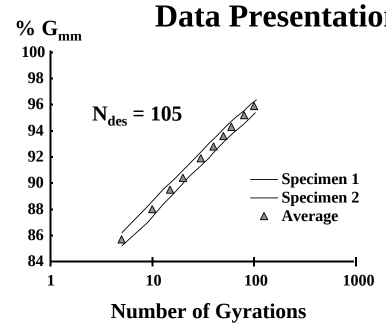
Design ESALs (millions)	Illinois N_{des}	
< 0.3	30	(Low volume)
0.3 to 3	50	
3 to 10	70	(Major state roads)
10 to 30	90	
≥ 30	105	(Heavy Interstates)

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



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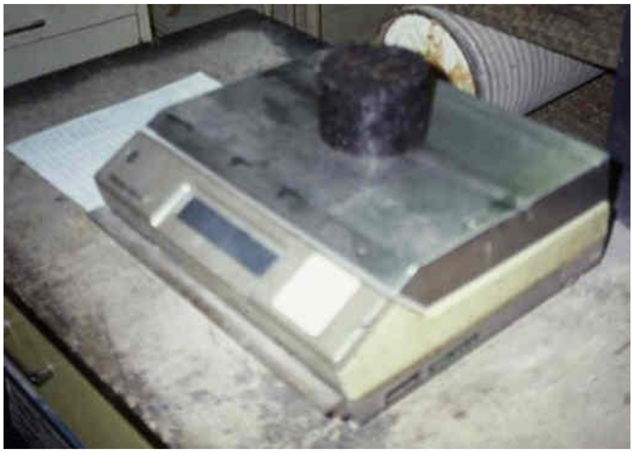
D. Bulk Specific Gravity (G_{mb}) - AASHTO T 166-10, Illinois Modified

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).

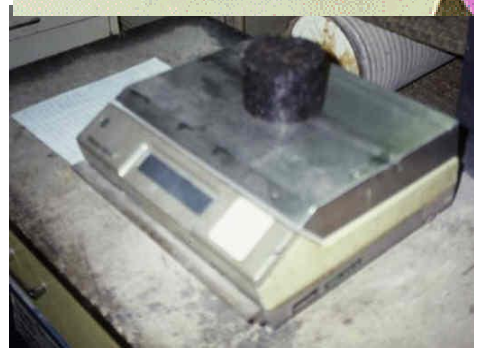


3. Determine the specimen's original dry weight to the nearest 0.1 gram.

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 submerged 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).

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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	________	________	________

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E. Maximum Theoretical Specific Gravity (G_{mm}) - AASHTO T 209-05, 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.

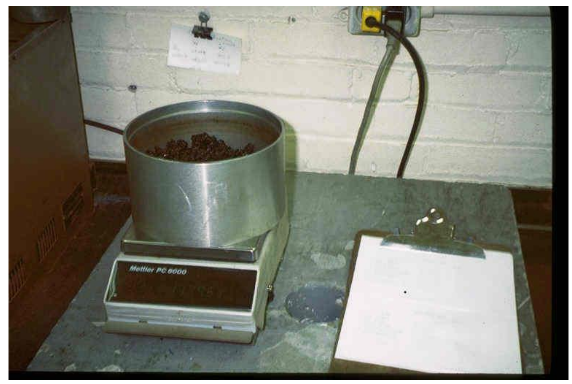
   (b) Place the lid on the pycnometer; seat firmly, pressing out excess water and entrapped air.

   (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 pyc-nometer and cover with water.



5. Remove entrapped air by sub-jecting 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

Name______________________________

		Sample			
		1	2	3	4
1. Weight of Pycnometer w/o lid + Sample		________	________	________	________
2. Weight of Pycnometer w/o lid		________	________	________	________
3. Dry sample weight (1-2)	A	________	________	________	________
4. Averaged calibrated Pycnometer weight (Pycnometer + lid + water)	D	________	________	________	________
5. Vacuumed sample weight (Pycnometer + lid + water + sample)	E	________	________	________	________
6. Maximum Specific Gravity (report to 3 places, [2.xxx]) $\frac{A}{A + D - E}$		________	________	________	________

Average G_{mm}(D) ________ (2.xxx)

Pyc. Calibration Weights

1. __________
2. __________
3. __________

QC2

A = Dry sample weight

D = Calibrated Pycnometer weight

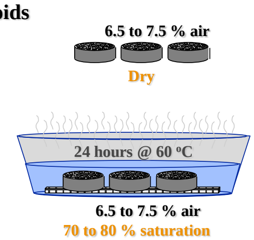
E = Vacuumed sample + Pyc., lid, & water

F. Tensile Strength Ratio (TSR) - AASHTO T 283-07, Illinois Modified

This will be reviewed in Chapter 13

IL Modified AASHTO T 283-07 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.

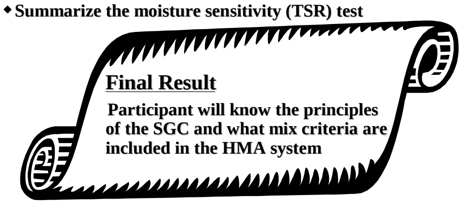
HMA Example

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

Class example.

Superpave Gyratory Compaction and Mixture Requirements

- Section Objectives
  - Describe the Superpave Gyratory Compactor
  - Review the HMA mixture requirements
  - Summarize the moisture sensitivity (TSR) test



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.

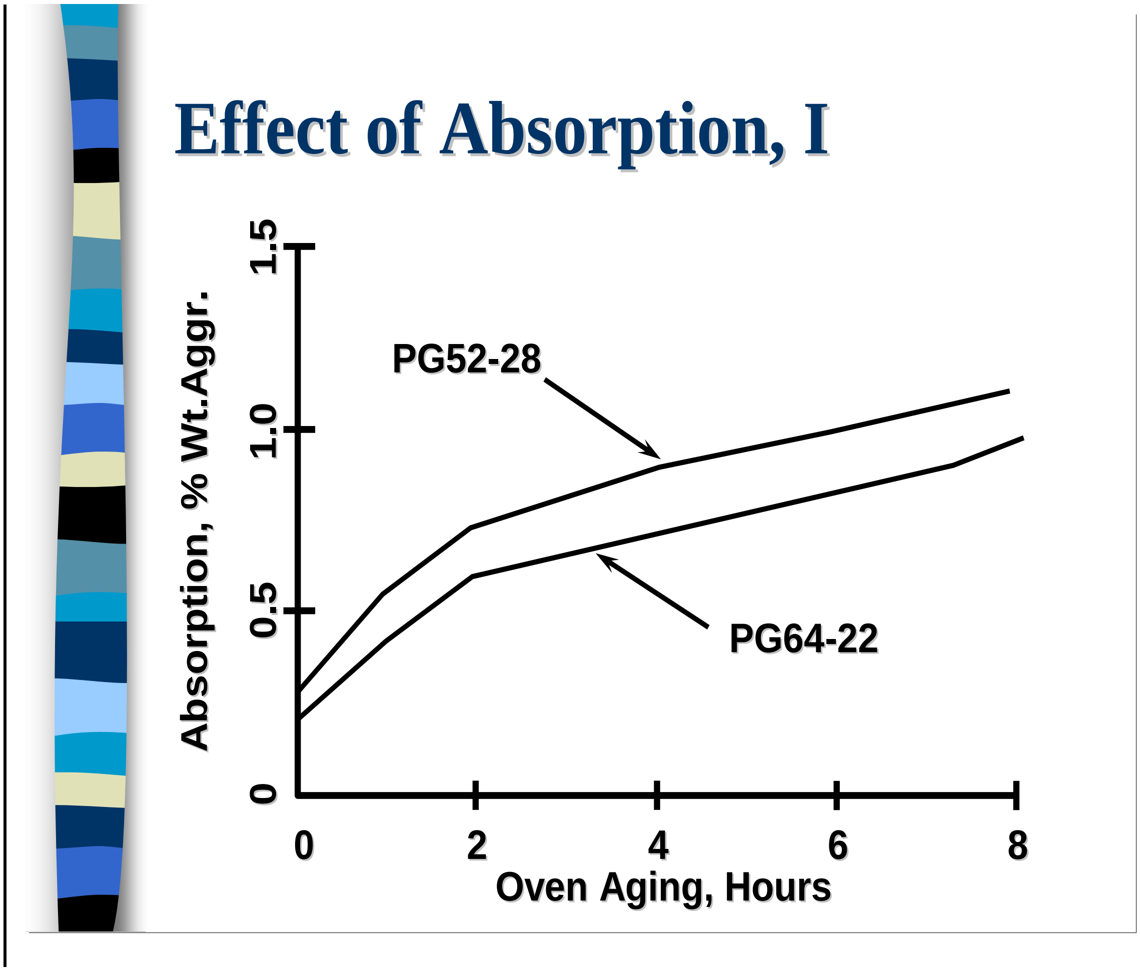

Effect of Absorption, I
Absorption, % Wt.Aggr.
0
0.5
1.0
1.5
PG52-28
PG64-22
0
2
4
6
8
Oven Aging, Hours

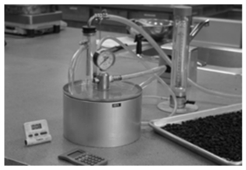
Figure 7.1

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

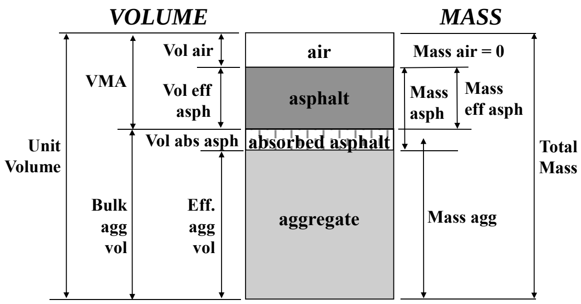
Final Result

Participant will understand the basis of the volumetric mix design determinations.

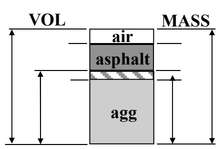
Volumetric Nomenclature

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)

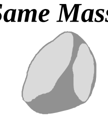
specific gravity of object (G)

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

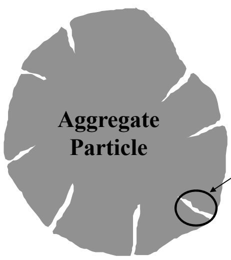


Different Volumes

Aggregate Bulk Specific Gravity

"SSD" Level

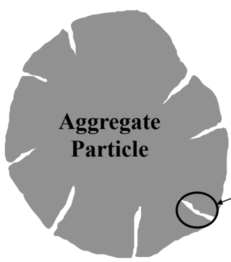
$$G_{sb} = \frac{\text{Dry Mass}}{\text{Bulk Vol}} \Big/ 1.000 \text{ g/cm}^3$$



Bulk Volume = solid volume + water permeable pore volume

Aggregate Apparent Specific Gravity

$$G_{sa} = \frac{\text{Dry Mass}}{\text{App Vol}} \Big/ 1.000 \text{ g/cm}^3$$

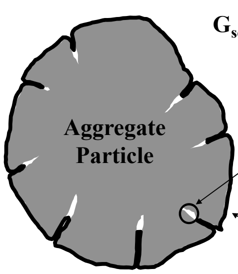


Apparent Volume = volume of solid aggregate particle only

Pores not included

Aggregate Effective Specific Gravity

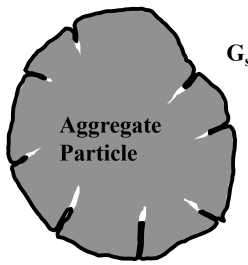
$$G_{se} = \frac{\text{Dry Mass}}{\text{Eff Vol}} \Big/ 1.000 \text{ g/cm}^3$$



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

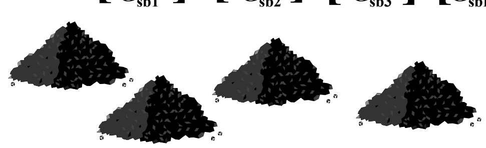
G_b: measured

Aggregate Specific Gravities

- G_{sb} - largest volume, lowest value
- G_{se} - in-between volume, middle value
- G_{sa} - smallest volume, highest value

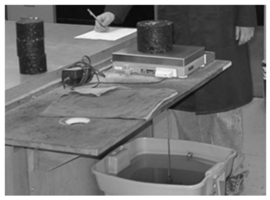
Combined Aggregate Bulk Specific Gravity

$$G_{sb}\text{ (combined)} = \frac{100}{\left[\frac{P_1\%}{G_{sb1}}\right] + \left[\frac{P_2\%}{G_{sb2}}\right] + \left[\frac{P_3\%}{G_{sb3}}\right] + \left[\frac{P_{RAP}\%}{G_{sbRAP}}\right]}$$



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



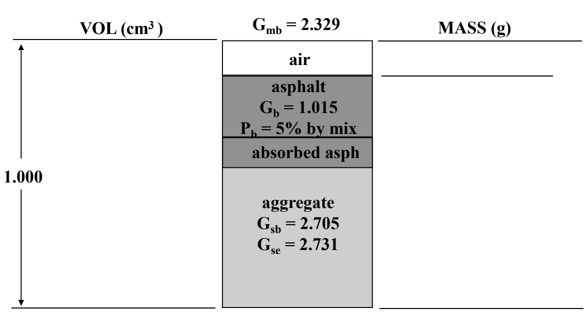
$$G_{mb} = \frac{\text{Dry Mass}}{\text{Bulk Volume}}$$

Bulk Volume = SSD Mass-Weight In Water

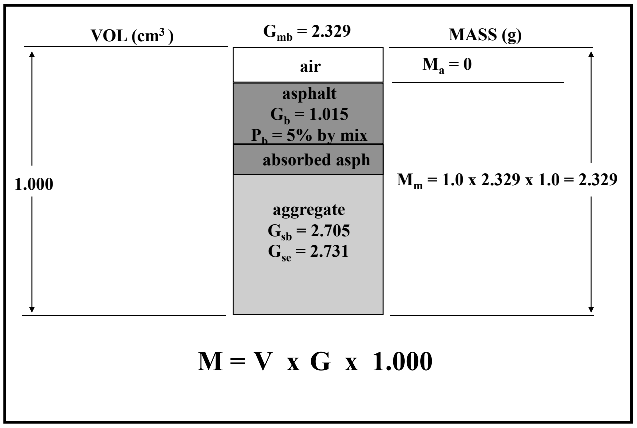
Maximum Theoretical Specific Gravity - Mix

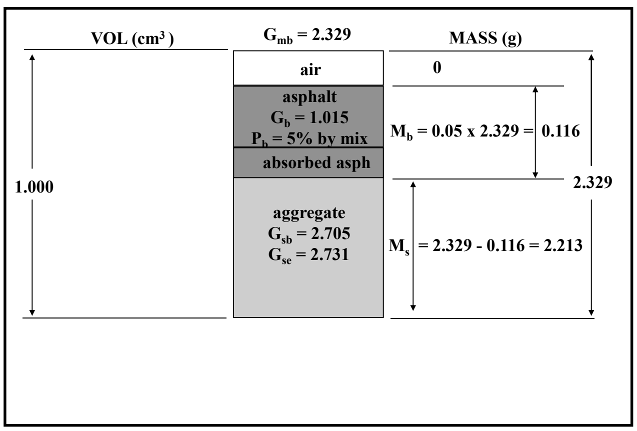
- **Definition**
  - mass per volume of material containing no air voids, compared to unit volume of water
- **Use G_{mm}**

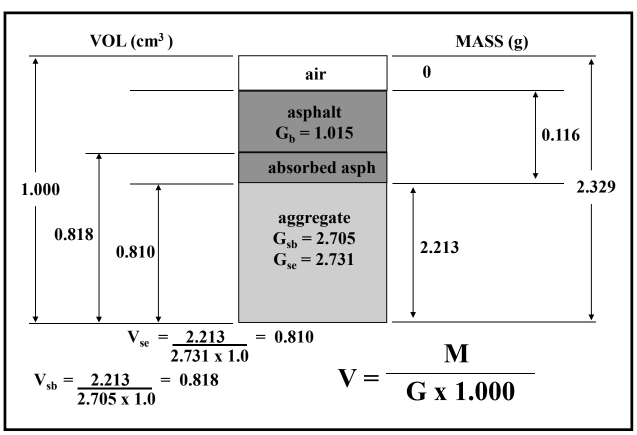
$$G_{mm} = \frac{\text{Dry Mass}}{\text{Voidless Volume}}$$

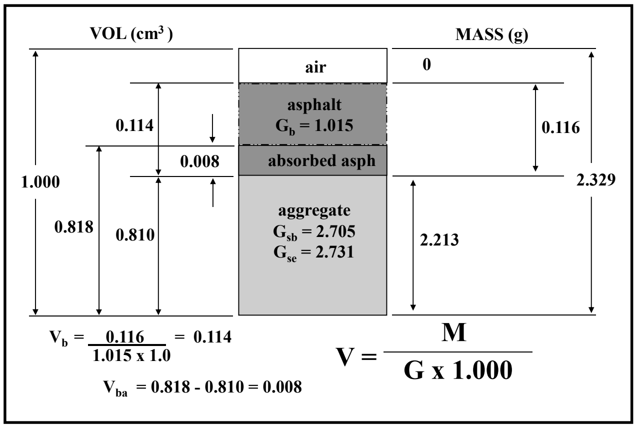


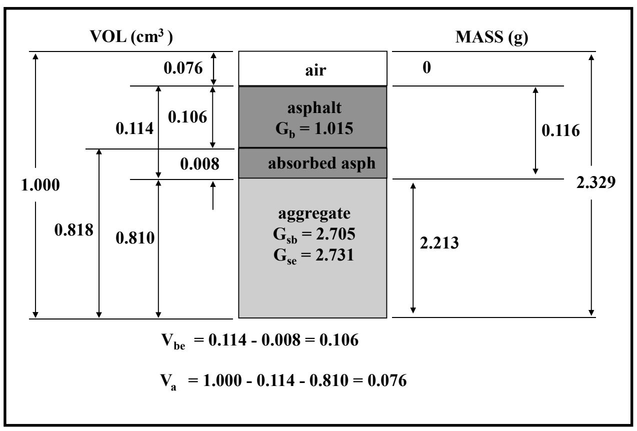
$$G = [\,M / V\,] / \gamma_{H_2O}$$

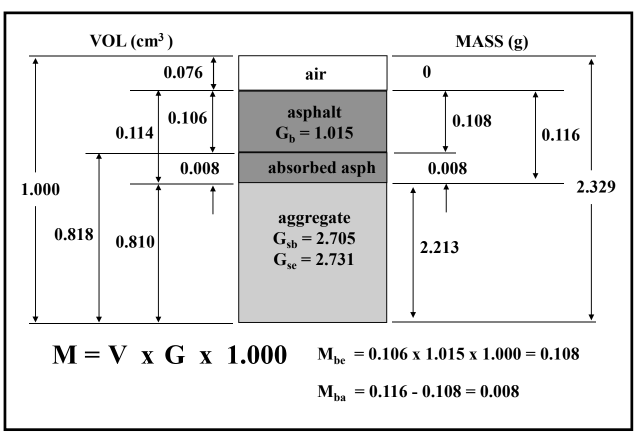

VOL (cm³)
G_{mb} = 2.329
MASS (g)
air
M_a = 0
asphalt
G_b = 1.015
P_b = 5% by mix
absorbed asph
1.000
M_m = 1.0 x 2.329 x 1.0 = 2.329
aggregate
G_{sb} = 2.705
G_{se} = 2.731
M = V x G x 1.000

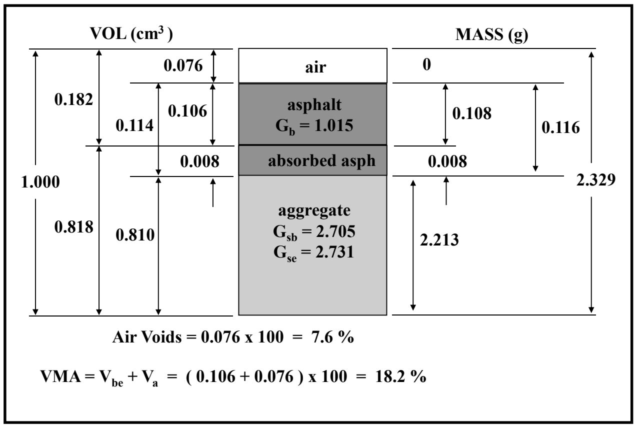

VOL (cm³)
G_{mb} = 2.329
MASS (g)
air
0
asphalt
G_b = 1.015
P_b = 5% by mix
M_b = 0.05 x 2.329 = 0.116
absorbed asph
1.000
2.329
aggregate
G_{sb} = 2.705
G_{se} = 2.731
M_s = 2.329 - 0.116 = 2.213

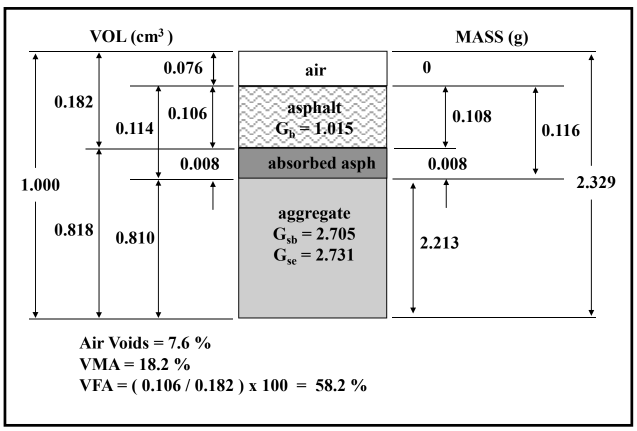

VOL (cm³)
MASS (g)
air
0
asphalt
G_b = 1.015
0.116
absorbed asph
1.000
2.329
0.818
0.810
aggregate
G_{sb} = 2.705
G_{se} = 2.731
2.213
$V_{se} = \frac{2.213}{2.731 \times 1.0} = 0.810$
$V_{sb} = \frac{2.213}{2.705 \times 1.0} = 0.818$
$V = \frac{M}{G \times 1.000}$

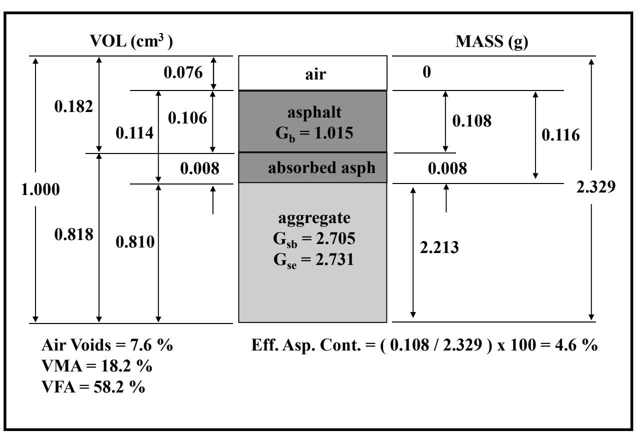

VOL (cm³)
MASS (g)
air
0
asphalt
Gb = 1.015
absorbed asph
aggregate
Gsb = 2.705
Gse = 2.731
0.114
0.008
1.000
0.818
0.810
0.116
2.329
2.213
Vb = 0.116 / 1.015 x 1.0 = 0.114
Vba = 0.818 - 0.810 = 0.008
V = M / G x 1.000

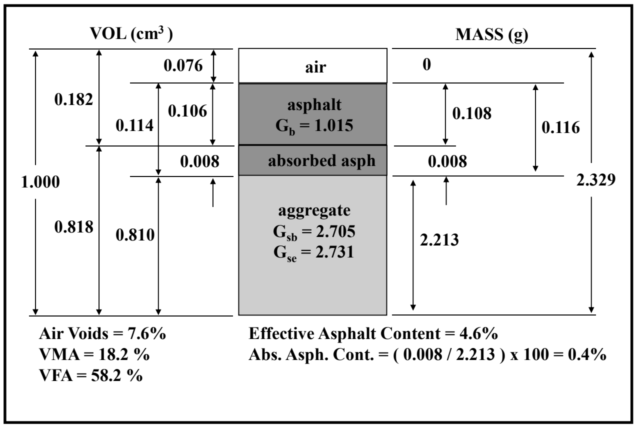

VOL (cm³)
MASS (g)
air
0
asphalt
Gb = 1.015
absorbed asph
aggregate
Gsb = 2.705
Gse = 2.731
0.076
0.106
0.114
0.008
1.000
0.818
0.810
0.116
2.329
2.213
Vbe = 0.114 - 0.008 = 0.106
Va = 1.000 - 0.114 - 0.810 = 0.076

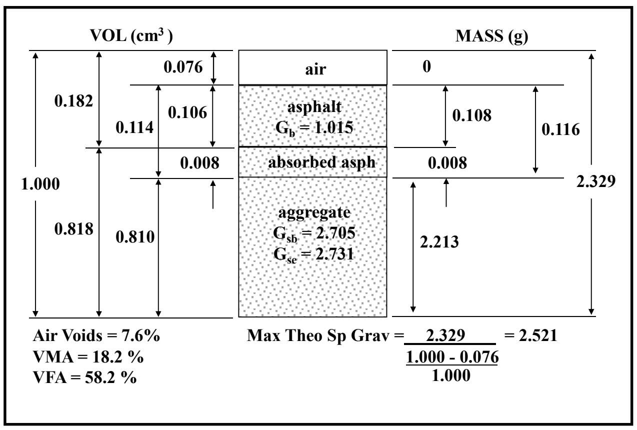

VOL (cm³)
MASS (g)
air
0
asphalt
Gb = 1.015
absorbed asph
aggregate
Gsb = 2.705
Gse = 2.731
0.076
0.106
0.114
0.008
1.000
0.818
0.810
0.108
0.008
0.116
2.329
2.213
M = V x G x 1.000
Mbe = 0.106 x 1.015 x 1.000 = 0.108
Mba = 0.116 - 0.108 = 0.008

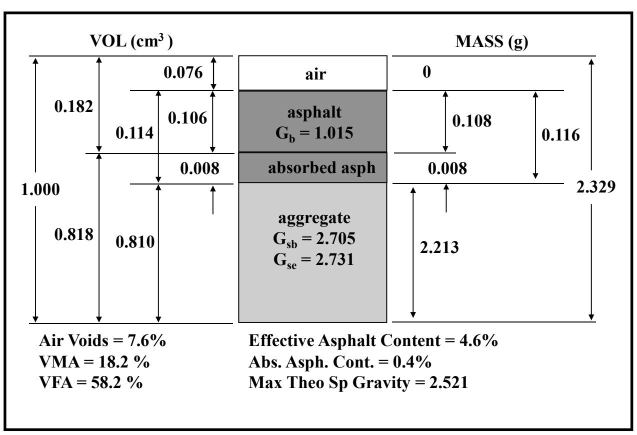

VOL (cm³)
MASS (g)
0.076
air
0
0.182
0.106
asphalt
Gb = 1.015
0.108
0.114
0.116
0.008
absorbed asph
0.008
1.000
2.329
aggregate
Gsb = 2.705
Gse = 2.731
0.818
0.810
2.213
Air Voids = 0.076 x 100 = 7.6 %
VMA = Vbe + Va = (0.106 + 0.076) x 100 = 18.2 %


VOL (cm³)
MASS (g)
0.076
air
0
0.182
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
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
0.106
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
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)
0.076
air
0
0.182
0.114
0.106
asphalt
Gb = 1.015
0.108
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
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)
0.076
air
0
0.182
0.114
0.106
asphalt
Gb = 1.015
0.108
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
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)
0.076
air
0
0.182
0.114
0.106
asphalt
Gb = 1.015
0.108
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
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

$$G_{mm} = \frac{100}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

$$V_a = \left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right) x\ 100$$

$$VMA = 100 - \frac{G_{mb}\ x\ P_s}{G_{sb}}$$

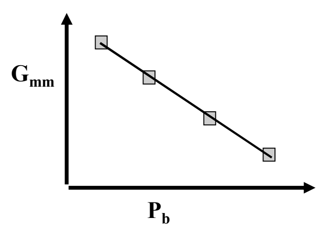
$$VFA = \left(\frac{VMA - V_a}{VMA}\right) x\ 100$$

$$P_{be} = P_b - \frac{P_{ba}\ x\ P_s}{100}$$

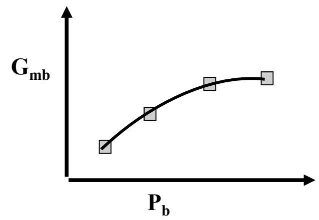
$$P_{ba} = 100\ x \left(\frac{G_{se} - G_{sb}}{G_{se}\ x\ G_{sb}}\right) x\ G_b$$

$$Eff.\ Vol. = VMA - V_a$$

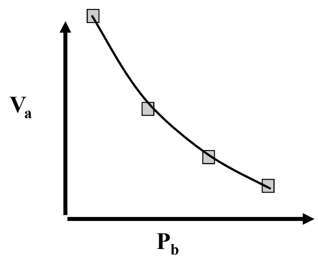
Maximum Theoretical Specific Gravity at Other Asphalt Binder Contents



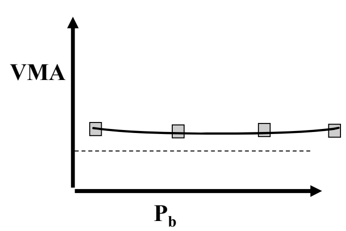
Bulk Specific Gravity at Other Asphalt Binder Contents



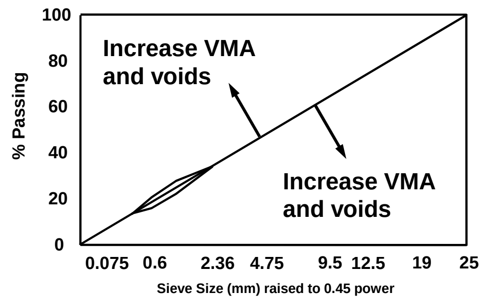
Air Void Content



Voids in the Mineral Aggregate



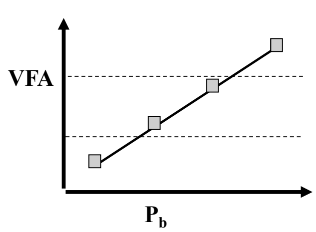
Voids in the Mineral Aggregate



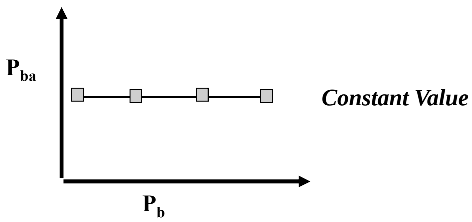
VMA Adjustments

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**

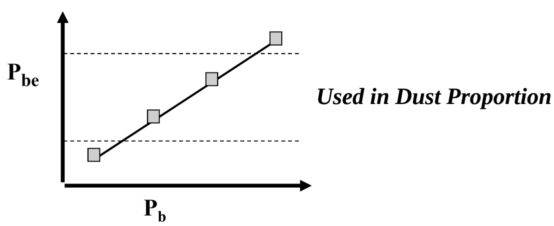
Voids Filled With Asphalt



Absorbed Asphalt Binder Content

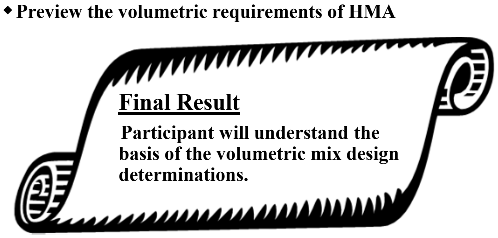


Effective Asphalt Binder Content



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



Volumetrics Problem

Reference last page of Chapter…

BINDER HOMEWORK PROBLEM
SUMMARY – COMPACTED MIX PROPERTIES

Pb	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 (Pages 9-13 and 9-14). 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:

$$D = G \text{ x} \left(1 g / cm^3\right)$$

where: D = density of material in grams per cubic centimeter,

G = specific gravity of material,

and $1g/cm^3$ = 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:

$$V = \frac{W}{G \text{ x} \left(1 g / cm^3\right)}$$

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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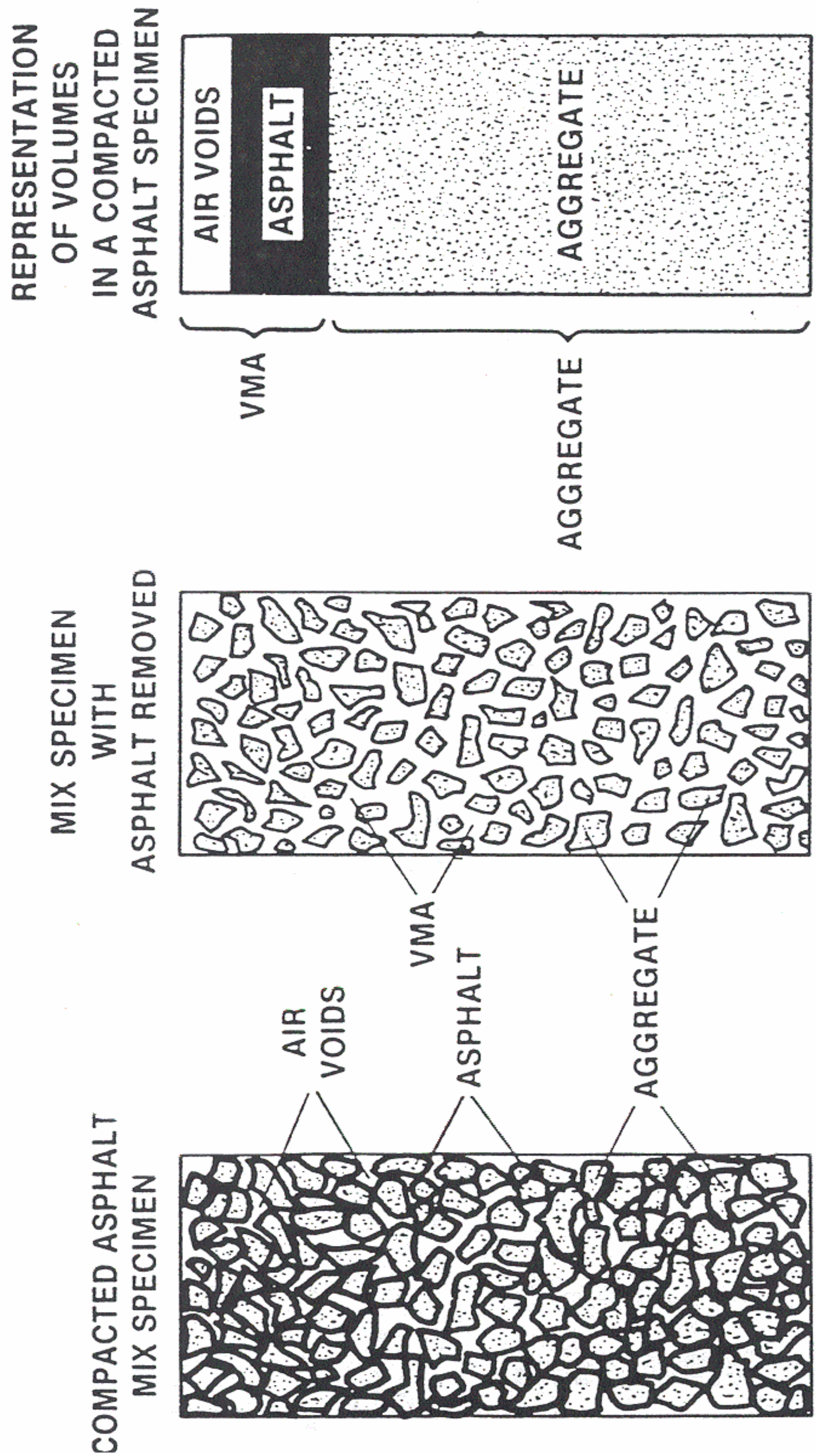
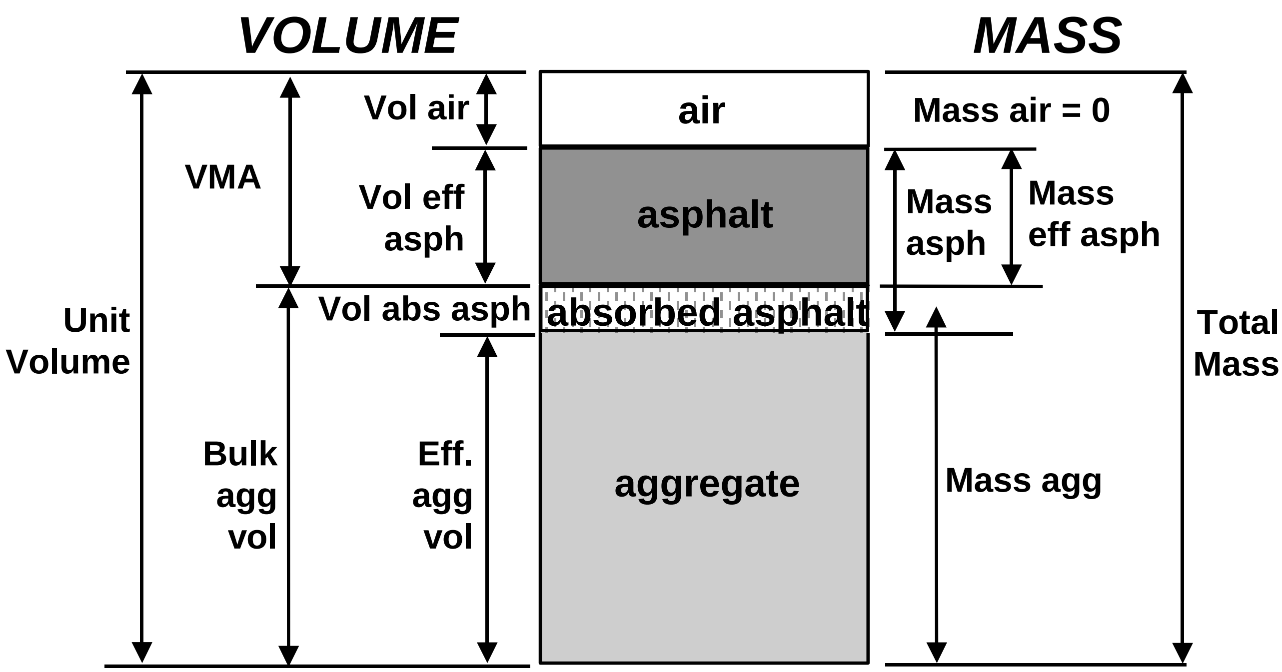


FIGURE 3.1—Illustration of VMA in a Compacted Mix Specimen (Note: For simplification the volume of absorbed asphalt is not shown).

II. VOLUME / WEIGHT RELATIONSHIP



Asphalt Mixture Component Diagram

Given: Total Volume of Mixture = 1 cm^3

Mix Bulk Specific Gravity = 2.329

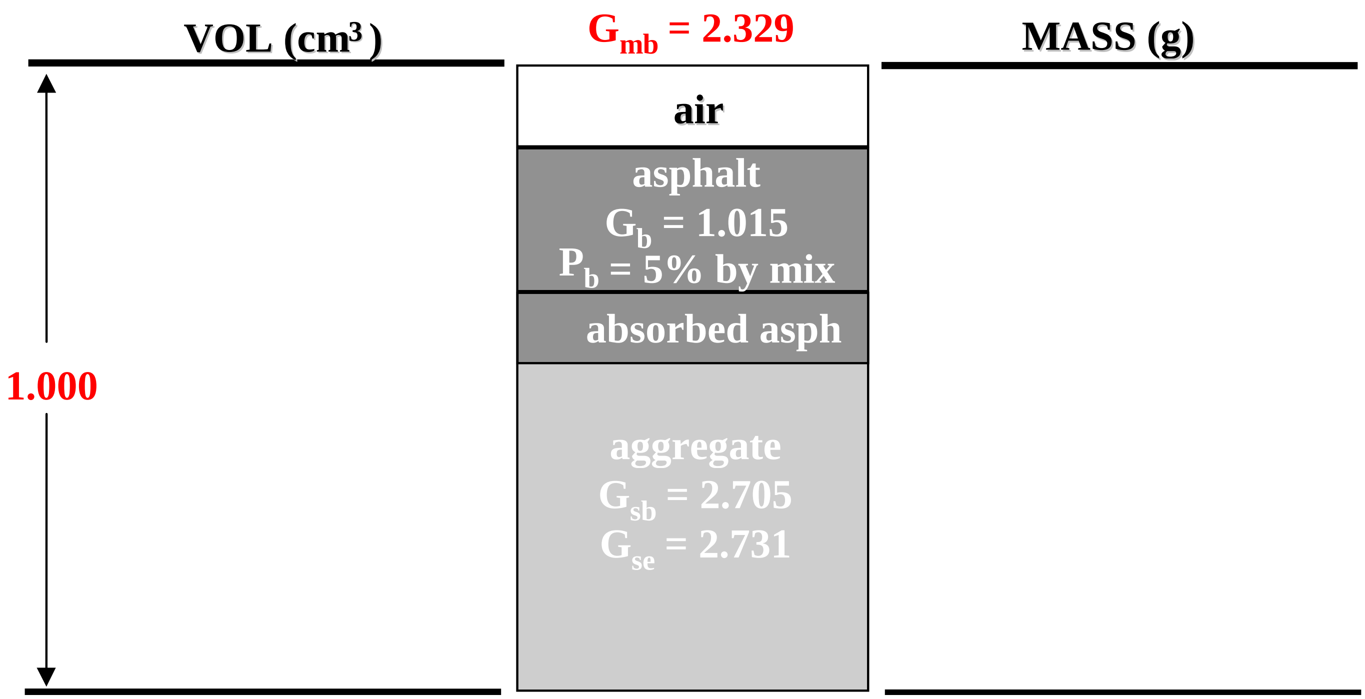
Aggregate Bulk Specific Gravity = 2.705

Aggregate Effective Specific Gravity = 2.731

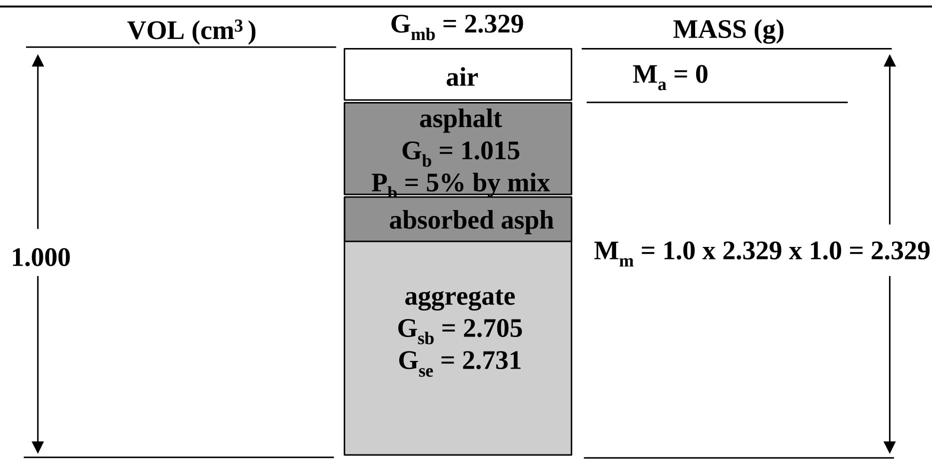
Asphalt Binder Specific Gravity = 1.015

Asphalt Binder Content (Pb) = 5.0% (weight total mix)

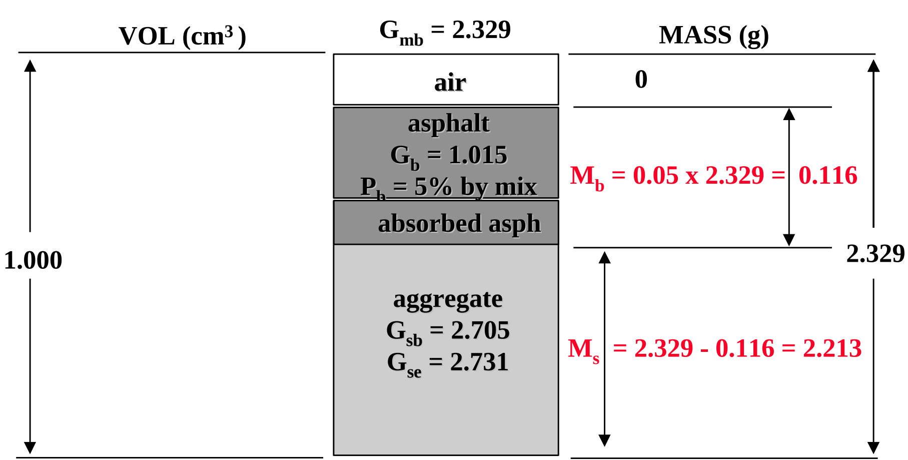
Find: Air Void Content, VMA, VFA, Maximum Theoretical Specific Gravity of Mix

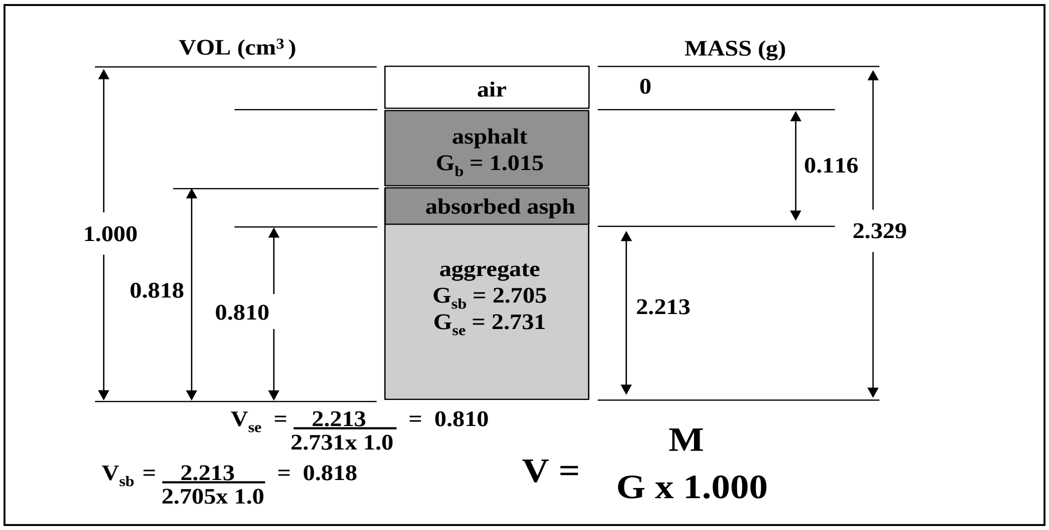

VOL (cm³)
Gmb = 2.329
MASS (g)
air
asphalt
Gb = 1.015
Pb = 5% by mix
absorbed asph
1.000
aggregate
Gsb = 2.705
Gse = 2.731

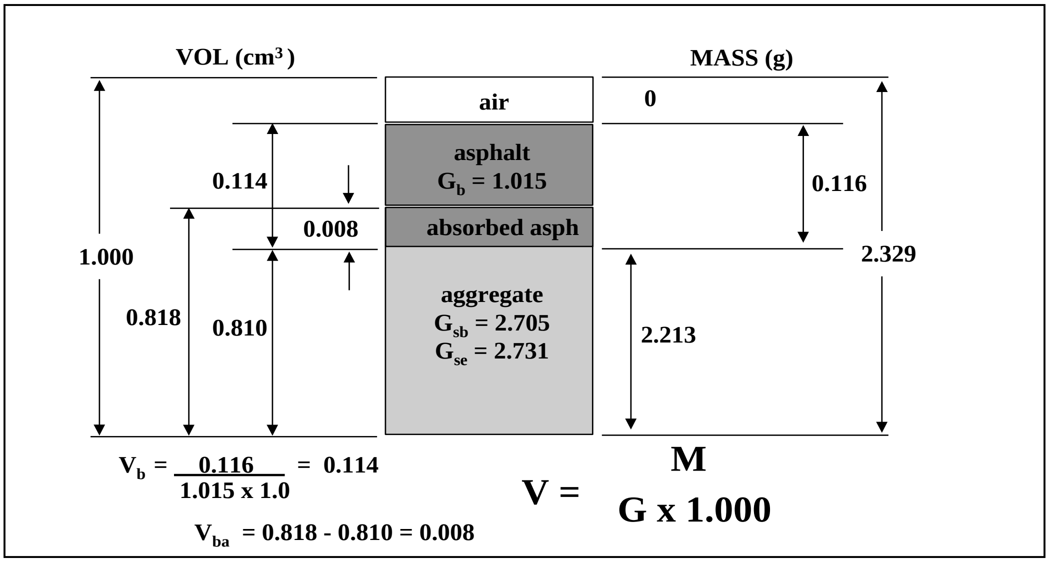
- **With these specific gravities used for "bridges", all of the volume and weight properties can be calculated using the component diagram.**
  - **G_{mb}**
  - **G_b**
  - **G_{sb}**
  - **G_{se}**
  - **P_b**
- **To start, assume the volume equals 1.000**

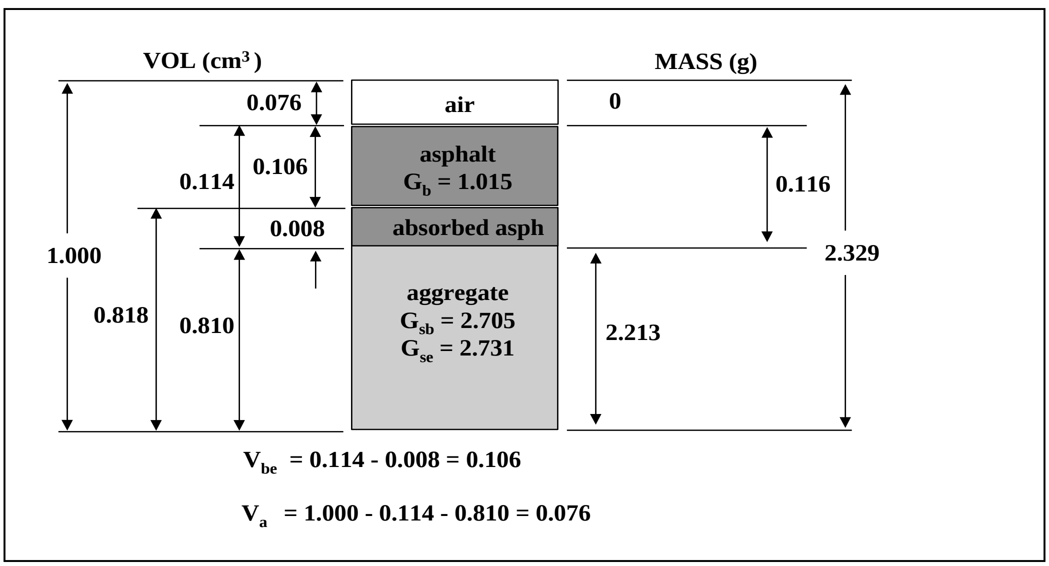


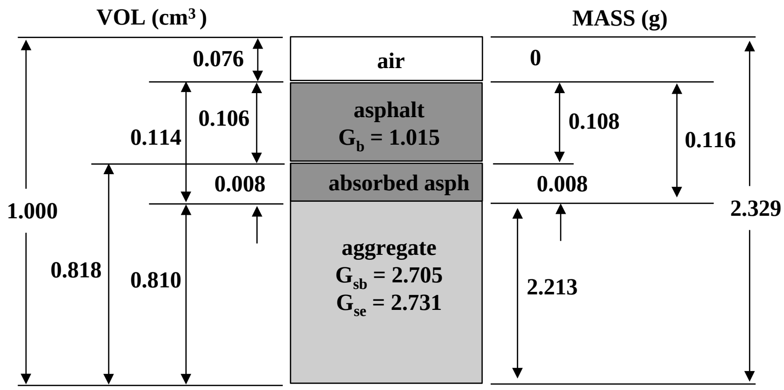
$$M = V \times G \times 1.000$$




VOL (cm³)
MASS (g)
air
0
asphalt
Gb = 1.015
0.116
absorbed asph
1.000
2.329
0.818
aggregate
Gsb = 2.705
Gse = 2.731
0.810
2.213
Vse = 2.213 / 2.731x 1.0 = 0.810
Vsb = 2.213 / 2.705x 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
Vba = 0.818 - 0.810 = 0.008
V = M / G x 1.000

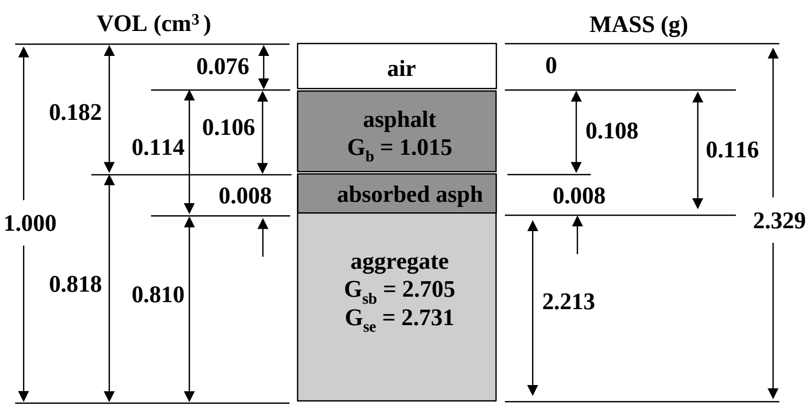

VOL (cm³)
MASS (g)
0.076
air
0
asphalt
Gb = 1.015
0.106
0.114
0.116
0.008
absorbed asph
1.000
2.329
aggregate
Gsb = 2.705
Gse = 2.731
0.818
0.810
2.213
Vbe = 0.114 - 0.008 = 0.106
Va = 1.000 - 0.114 - 0.810 = 0.076



M = V x G x 1.000

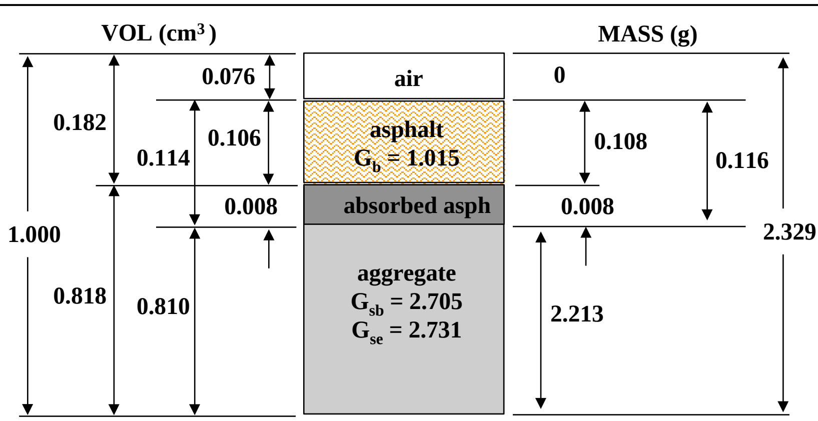
M_{be} = 0.106 x 1.015 x 1.000 = 0.108

M_{ba} = 0.116 - 0.108 = 0.008

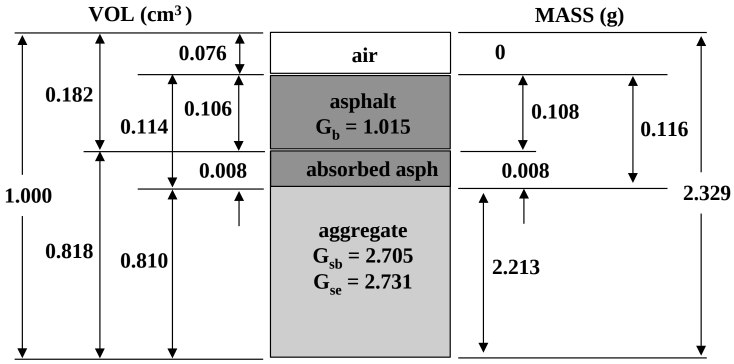


Air Voids = 0.076 x 100 = 7.6 %

VMA = $V_{be} + V_a$ **= (0.106 + 0.076) x 100 = 18.2 %**

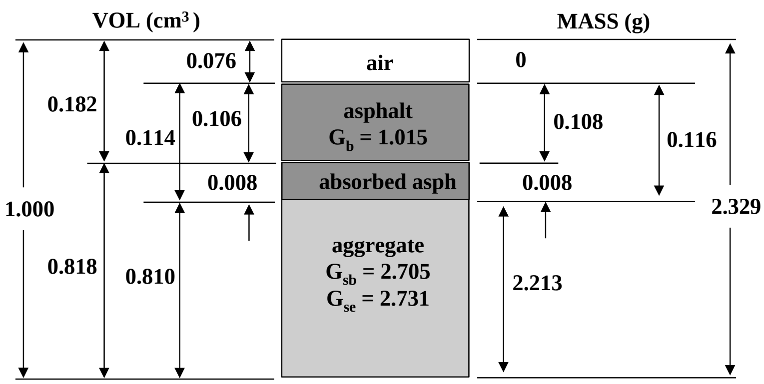


Air Voids = 7.6 %
VMA = 18.2 %
VFA = (0.106 / 0.182) x 100 = 58.2 %



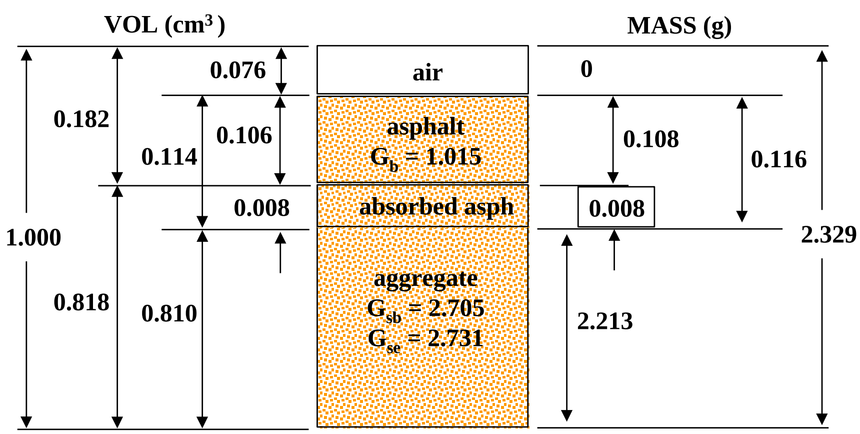
Air Voids = 7.6 %
VMA = 18.2 %
VFA = 58.2 %

Eff. Asp. Cont. = (0.108 / 2.329) x 100 = 4.6 %



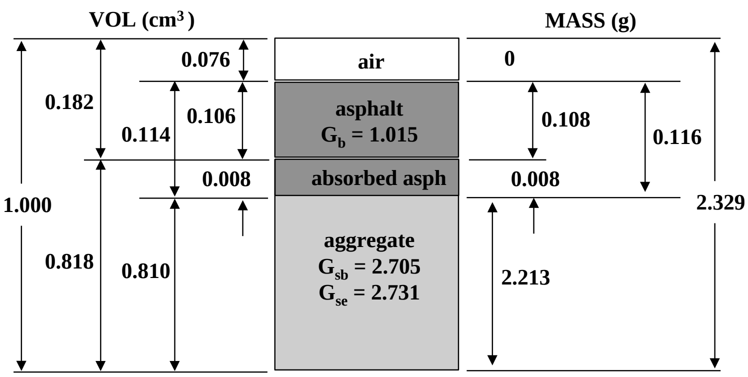
Air Voids = 7.6%
VMA = 18.2 %
VFA = 58.2 %

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 = $\dfrac{2.329}{\dfrac{1.000 - 0.076}{1.000}}$ **= 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. Calculating G_{se} (Effective Specific Gravity of Aggregate)

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:

$$P_{ba} = 100 \text{ x } \frac{(G_{se} - G_{sb})}{(G_{se} \text{ x } G_{sb})} \text{ x } G_b$$

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 conte nt 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:

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

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.

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

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	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	100
19.0 (3/4)	94.3	100.0	100.0	100.0	100.0	100.0	97.2	82	100	97	97	97
12.5 (1/2)	40.0	100.0	100.0	100.0	100.0	100.0	70.3	50	85	70	64	76
9.5 (3/8)	17.9	96.9	100.0	100.0	100.0	100.0	58.7	--	--	59	--	--
4.75 (#4)	4.9	30.8	97.7	96.8	100.0	100.0	37.9	24	40	38	33	43
2.36 (#8)	3.0	7.7	66.8	80.8	100.0	100.0	25.1	16	36	25	20	30
1.18 (#16)	2.7	4.9	36.9	64.8	100.0	100.0	17.7	10	25	18	18	18
600µm (#30)	2.6	4.1	20.1	48.4	100.0	100.0	12.8	--	--	13	--	--
300µm (#50)	2.5	3.7	11.6	18.5	100.0	100.0	7.7	4	12	8	4	12
150µm (#100)	2.4	3.5	7.9	3.1	99.0	100.0	5.2	3	9	5	5	5
75µm (#200)	2.0	3.0	4.8	1.5	88.0	100.0	4.0	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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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

HOMEWORK #4
(Page 2 of 2)

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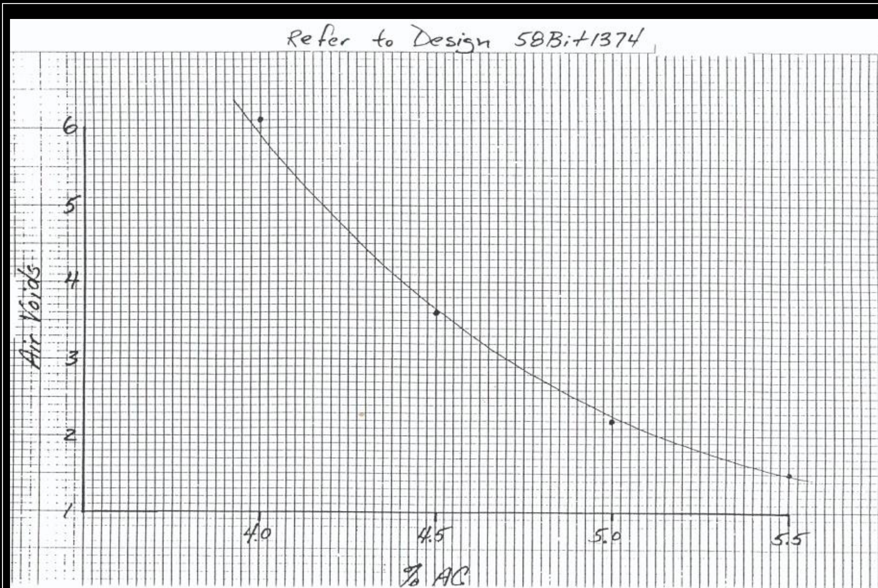
Optimum Design Asphalt Concepts

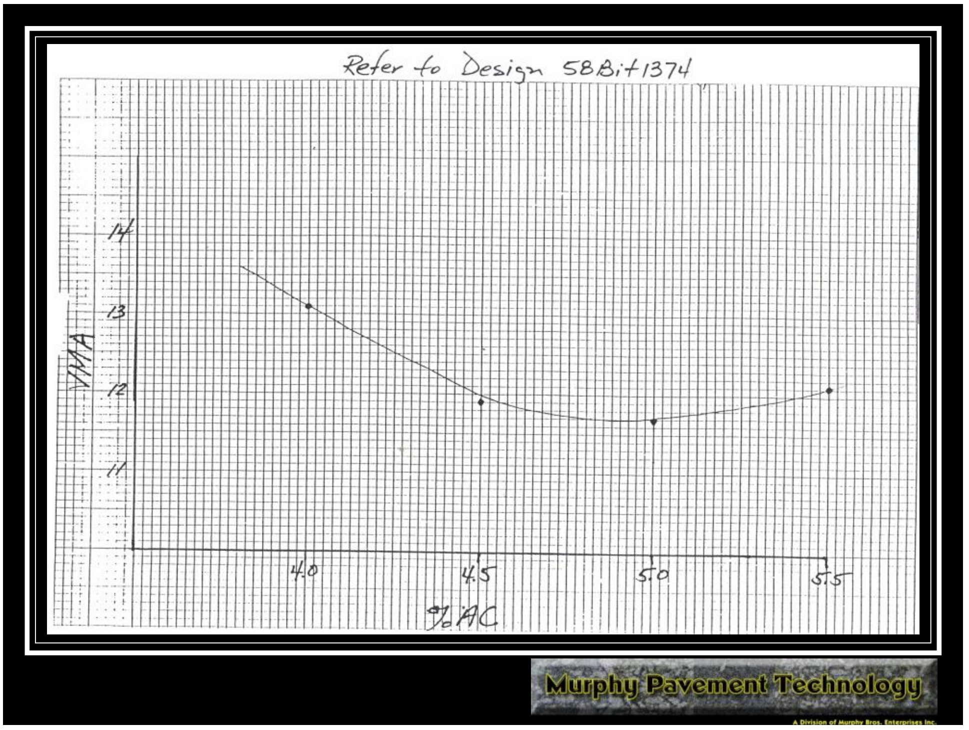
- P_b @ 4.0% Voids
- Care-AC vs. Best-Fit-Curves
- Judgment of values chosen

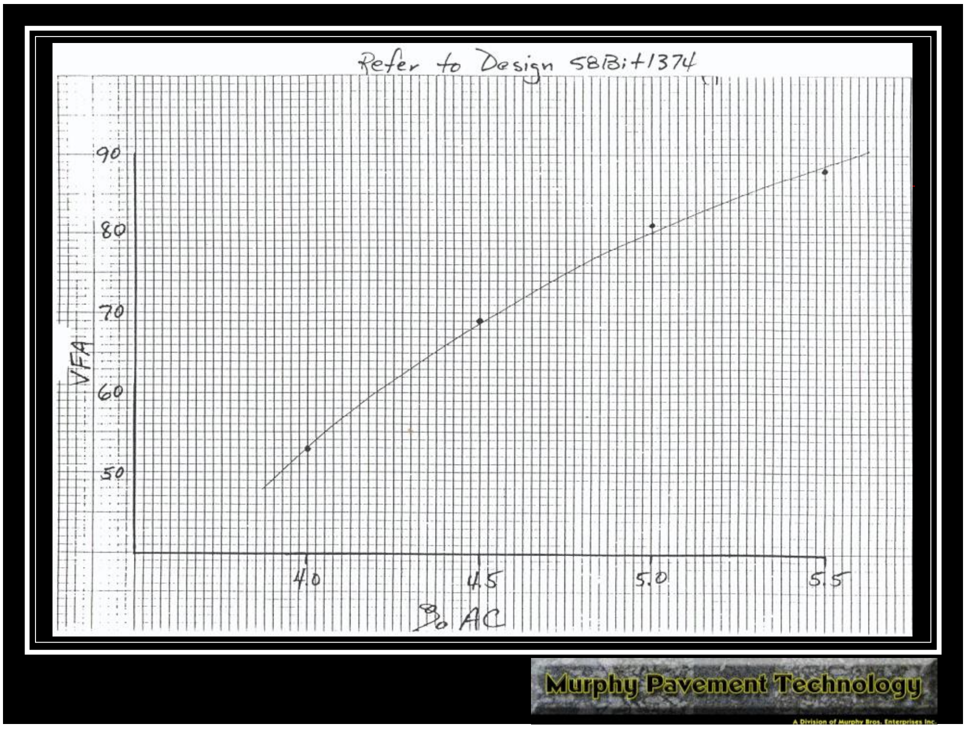
Timothy R. Murphy, P.E.
President

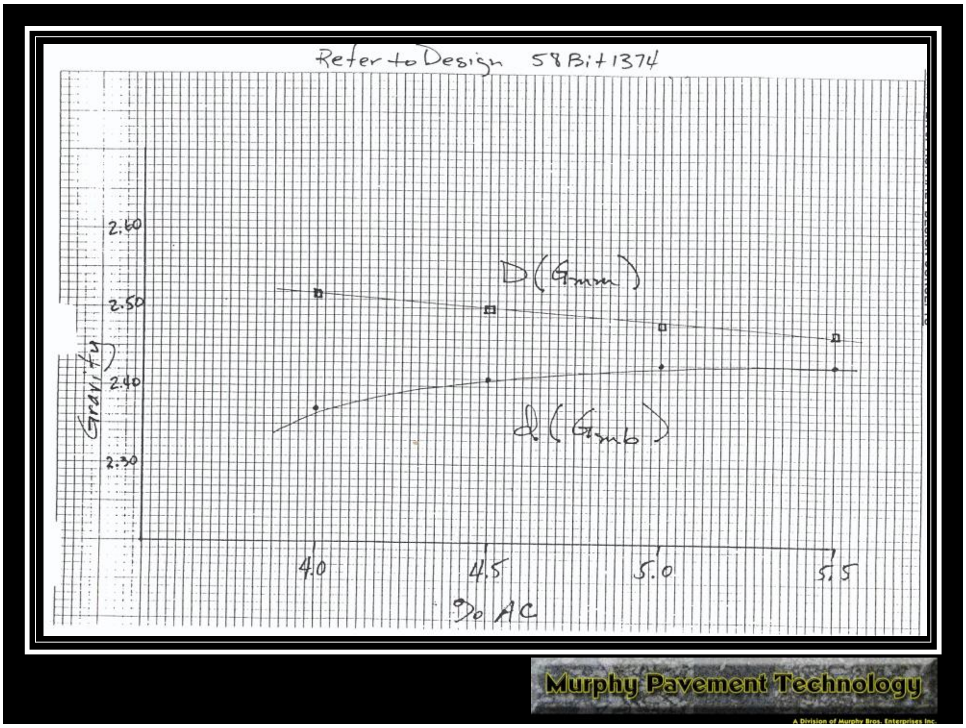
Murphy Pavement Technology



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



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%

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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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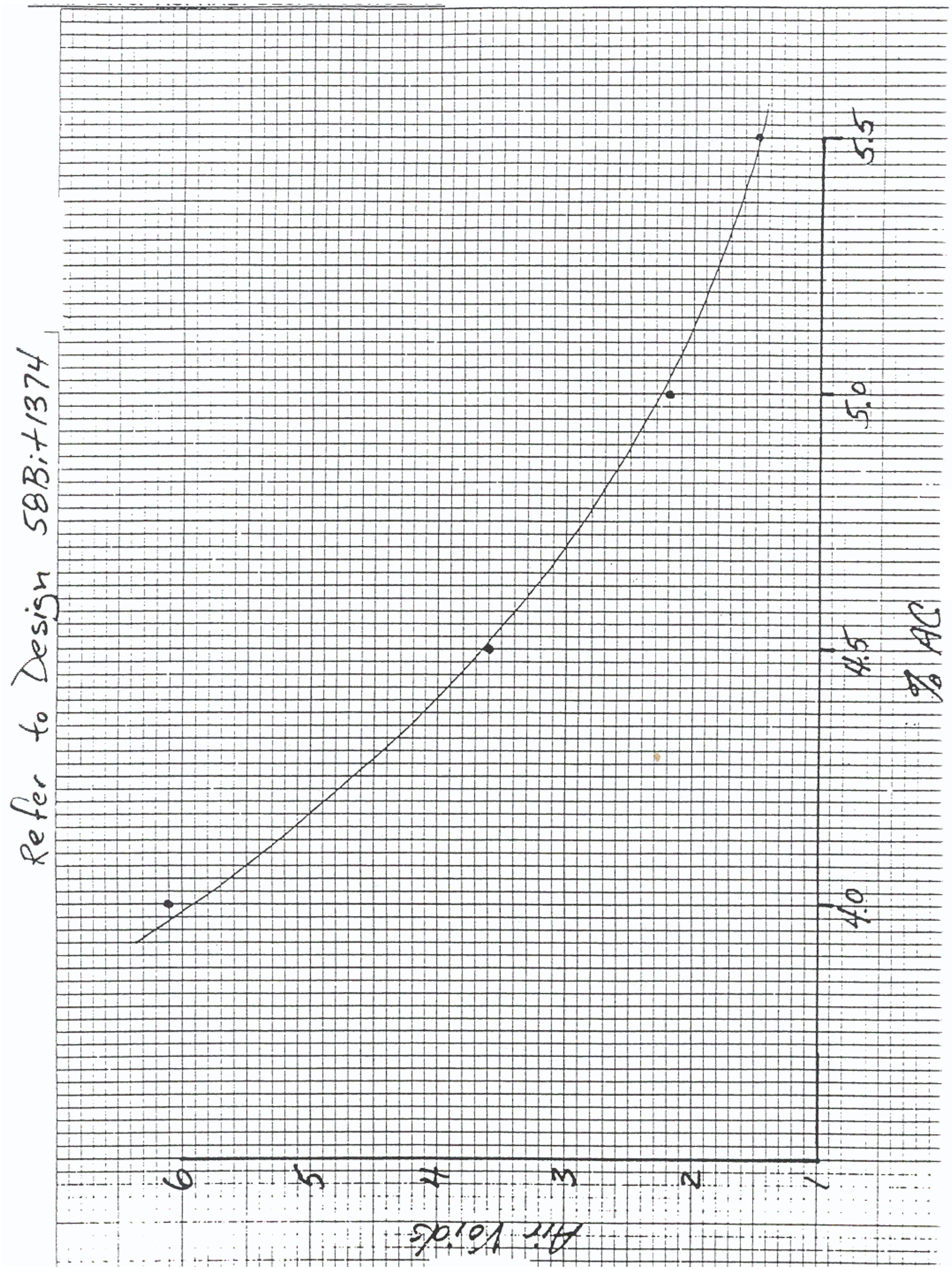
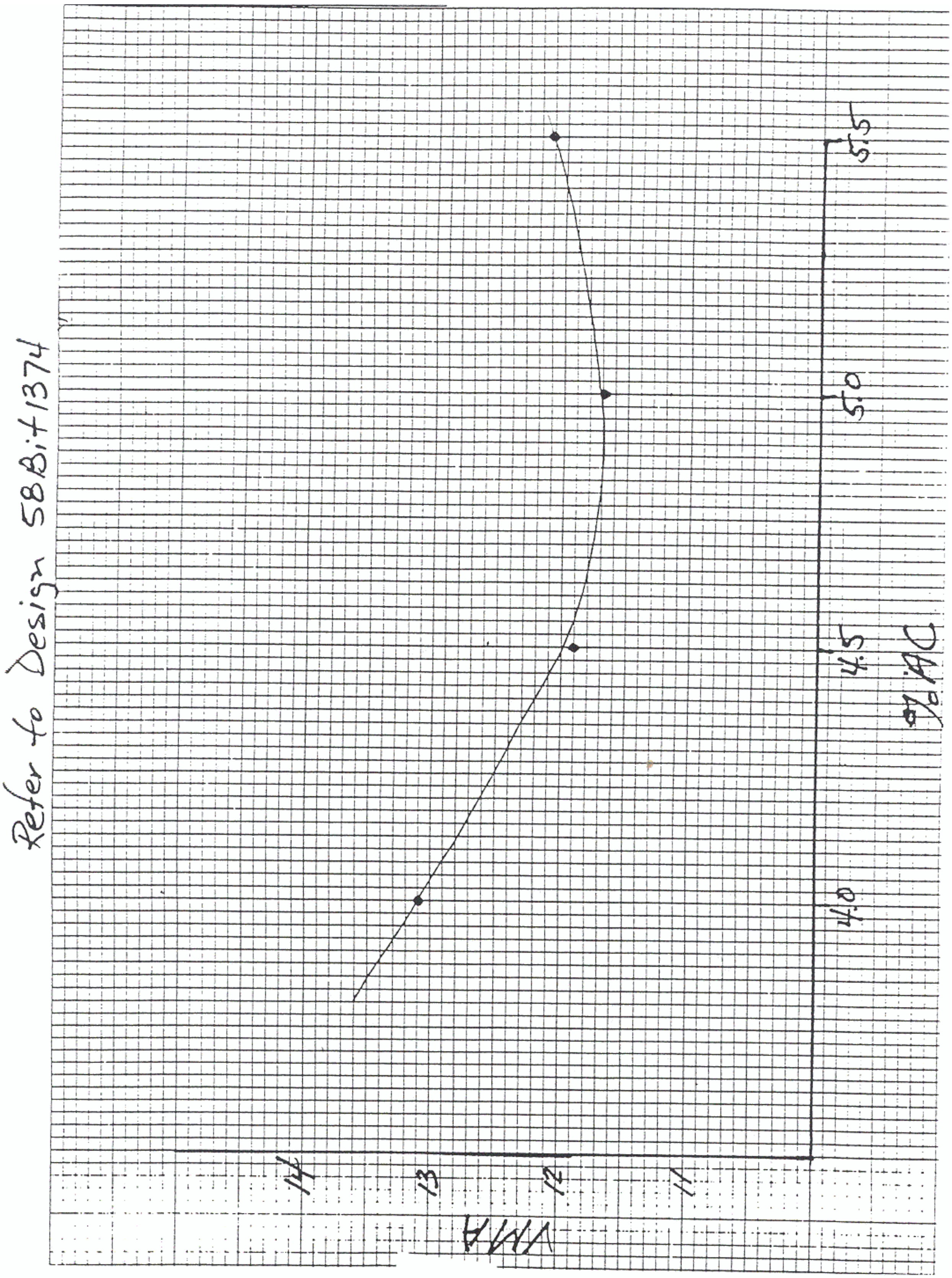
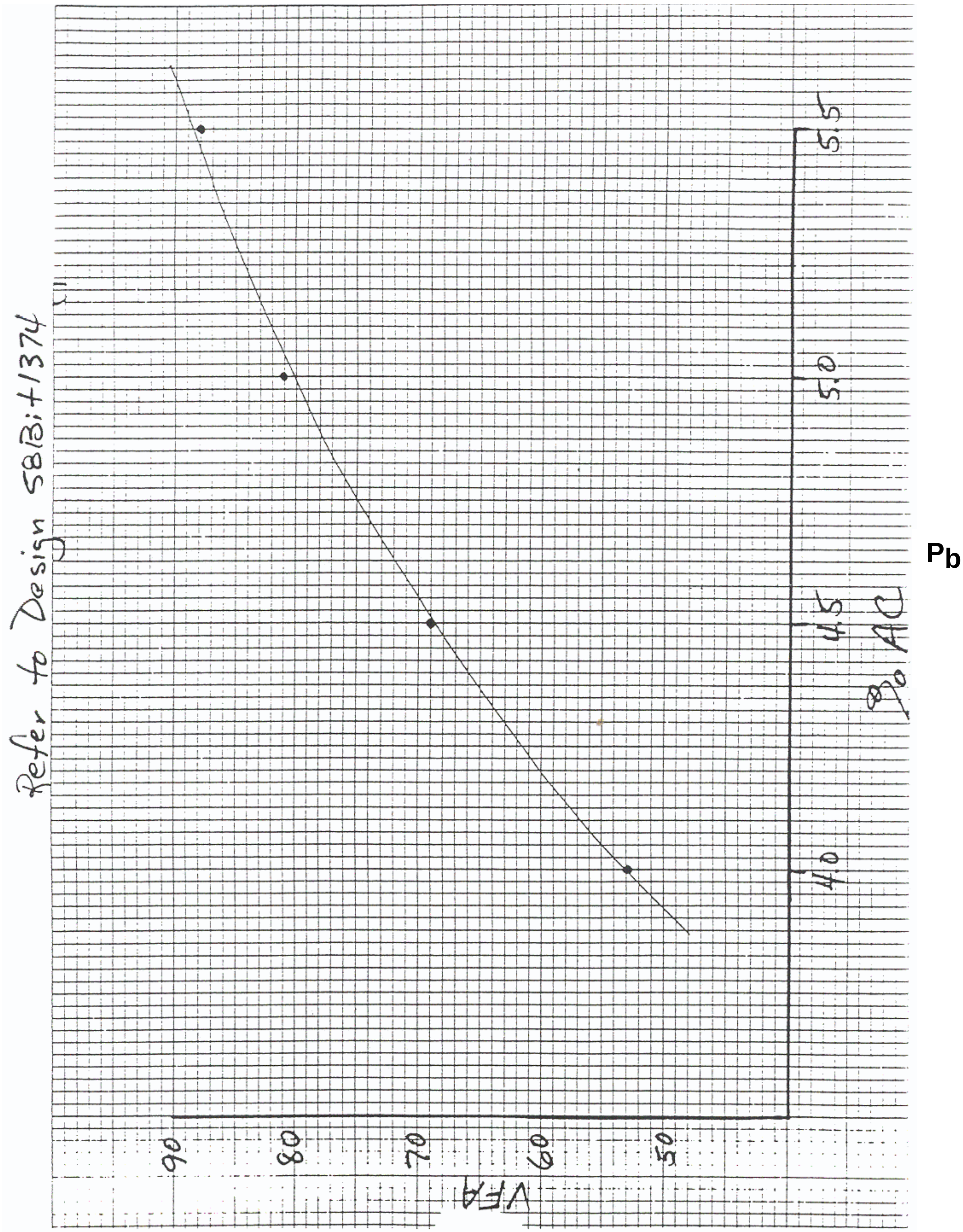
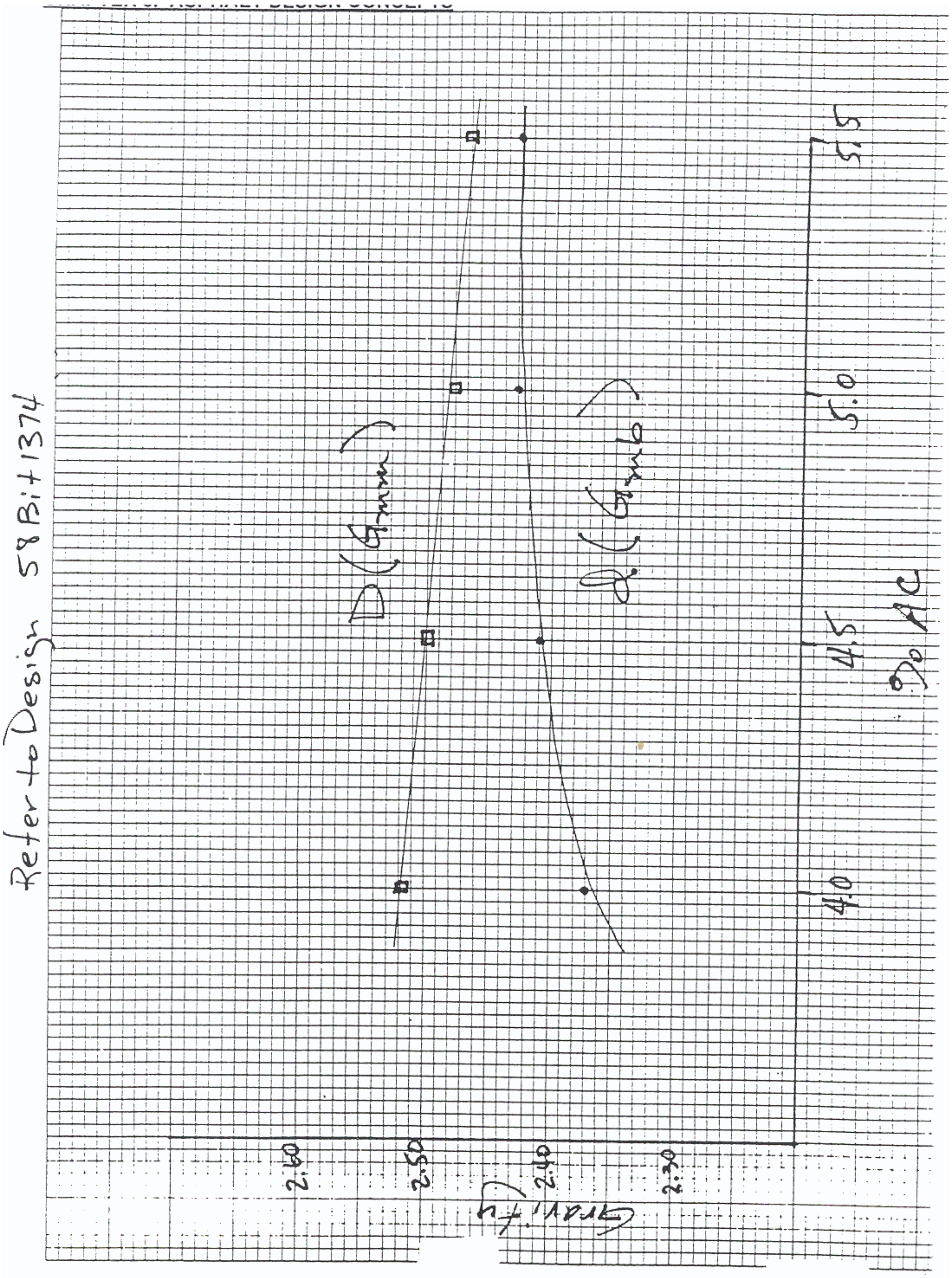


Pb

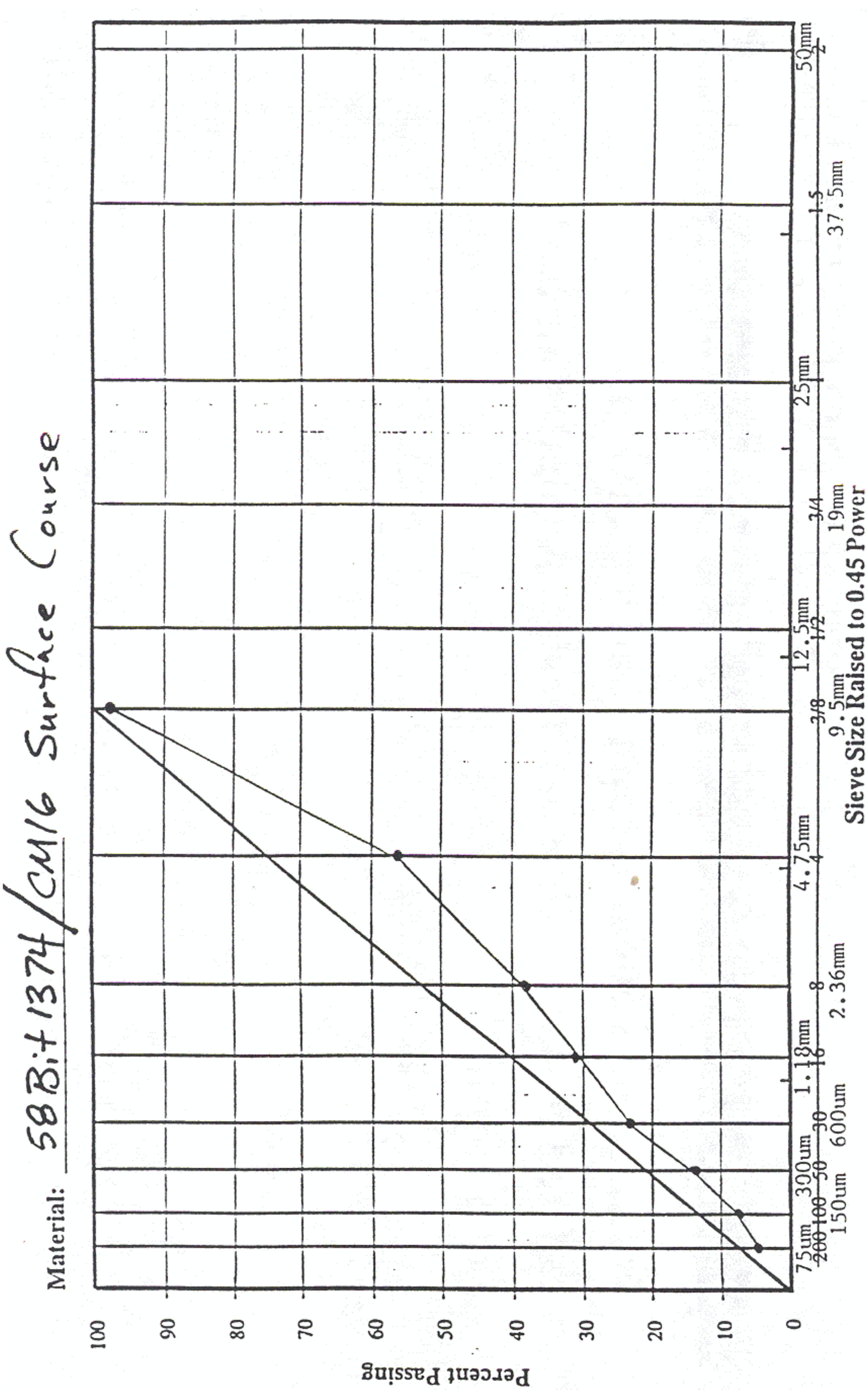


Pb


Refer to Design 58Bit 1374
VFA
90
80
70
60
50
4.0
4.5
5.0
5.5
% AC
Pb


Refer to Design 58 Bit 1374
D (Gmm)
d (Gmb)
5.5
5.0
4.5
4.0
% AC
2.60
2.50
2.40
2.30
Gravity

Pb


Material: SBit 1374/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 1
37.5mm 1.5
50mm 2

INTERPOLATION

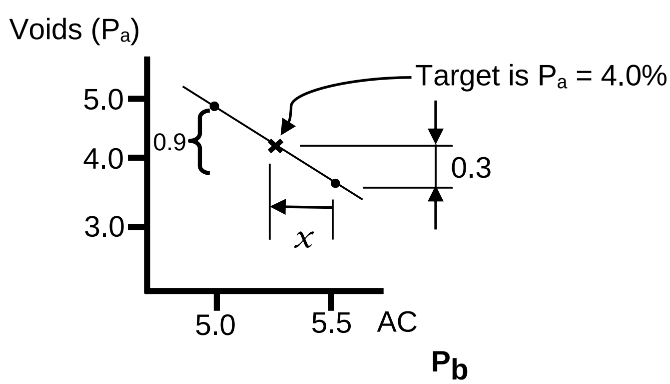
- Based on Linear Graphs and y = mx + b
- Used to Approximate a Design Asphalt Binder Content
- Example:

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%**

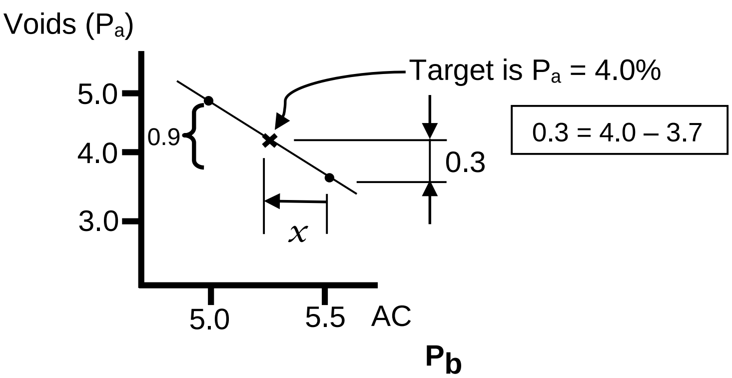


- **Plot actual points on graph and create a line**
- **Determine P_b at P_a = 4.0% from the line**

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

$$\left(\frac{0.9}{0.5}\right) = 0.3$$

$$x = 0.3\left(\frac{0.9}{0.5}\right) = 0.17$$

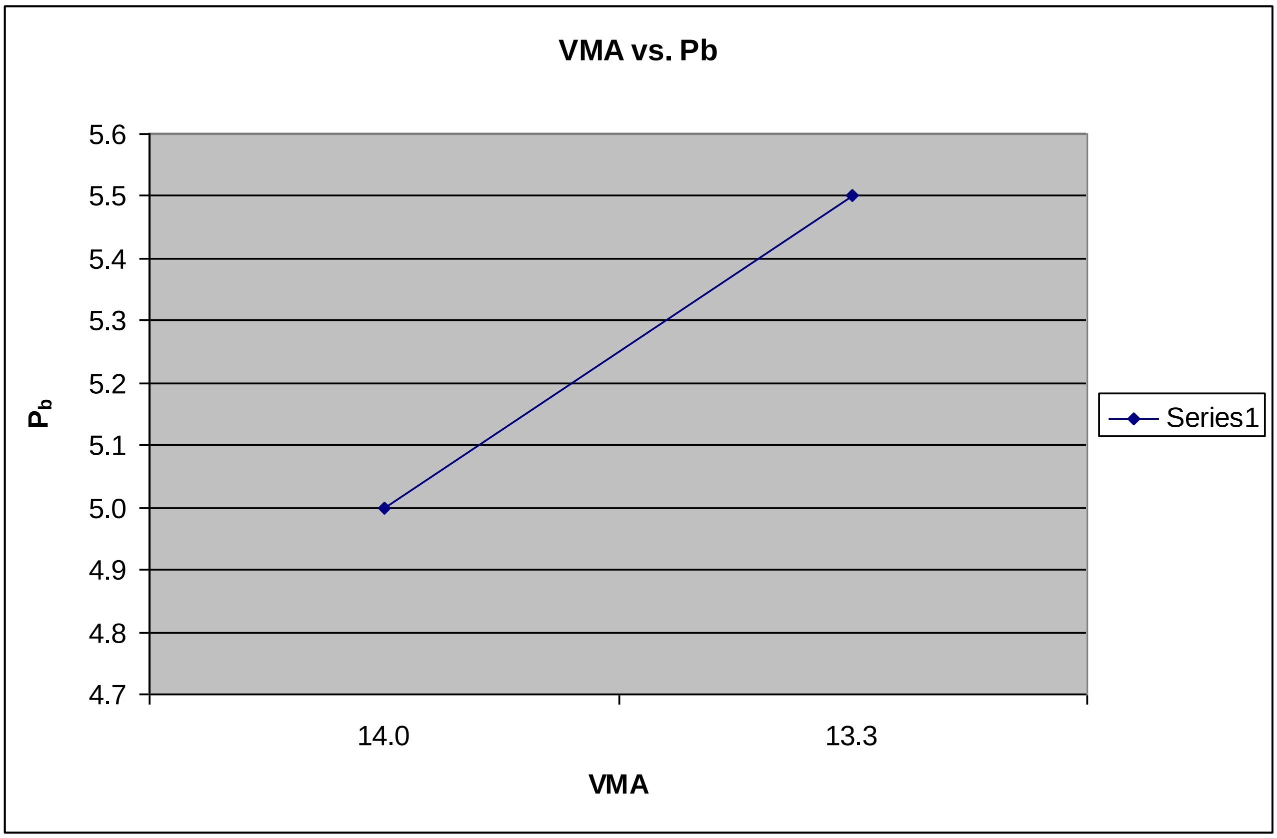
5.5% AC – 0.17% = 5.33% or
5.3% AC @ 4.0% Air Voids

- **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**

$$\left.\frac{0.7}{0.5} = \frac{X}{0.3}\right\} \quad 0.42 = X$$

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.

2

Use and Designing With RAP

- **Benefits of Using RAP**
- **RAP in Mix Design**
  - **RAP characterization**
  - **Blending asphalt**
  - **Batching procedures**
- **Class Problem**

3

Benefits of using RAP

- Recycling of construction material
- Savings of non-renewable resource
- Cost savings

4

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.

5

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.

6

The impact of 'green government'

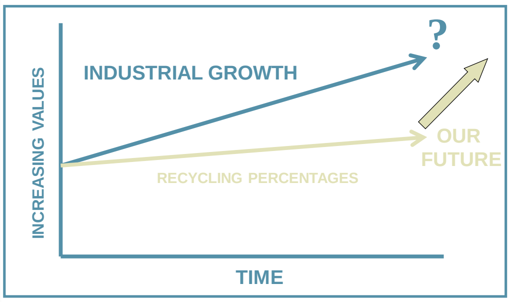
Today, governments at all levels — Federal, state, county and municipal — are seeking to incorporate environmental considerations into their activities.

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.

7

Growth vs. Recycling over Time



8

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 [illegible]	RAP w/5% AC ($8/ton)	Mix
94% = $11.28	6% = $33.00		Cost = $4[illegible].28
[illegible]% = $9.00	[illegible]% = $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?

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Savings of $23,652 / mile

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.] / 9 sq. ft. / sq. yd. = 17,600

Tons = 17,600 s. yds. x 4" x Asphalt density = 3,942

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Asphalt plant quality inputs

Look at the Volumes!!!

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Raw feed; recycled asphalt

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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

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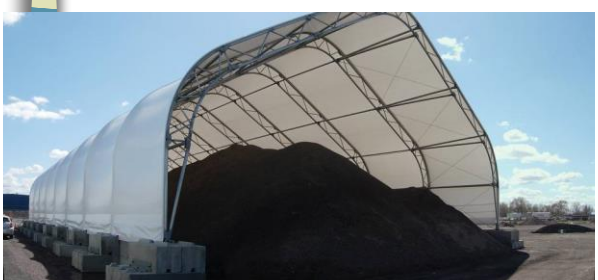
RAP storage is suggested



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RAP in Mix Design

- RAP characterization
- Blending asphalt
- Batching procedures

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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)

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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

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RAP Characterization

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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.

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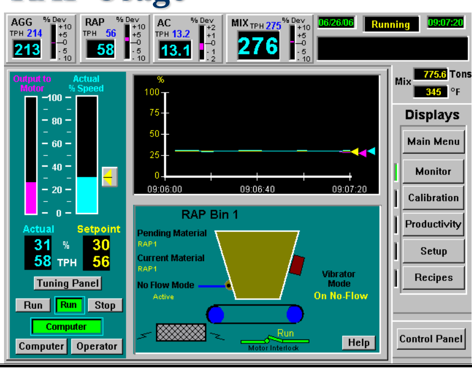
RAP Usage



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Updated RAP Stockpiles

- Fractionated Rap (FRAP)
- Homogeneous (Binder / Surface)
- Conglomerate
- Conglomerate "D" Quality (DQ)
- Non - Quality

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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.

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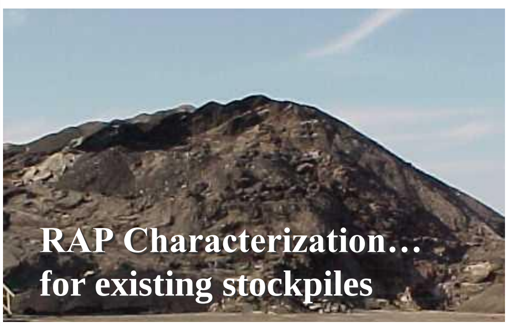

RAP Characterization… for existing stockpiles

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FRAP / Homogeneous / Conglomerate RAP Tolerances

Parameter		Tolerance, %
½"	(12.5 mm)	± 8
#4	(4.75 mm)	± 6
#8	(2.36 mm)	± 5
#16	(0.600 mm)	± 5
#200	(0.075 mm)	± 2.0
	AC	± 0.4[1]
	G_{mm}	± 0.02[2]

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Homogeneous / Conglomerate / Frap RAP Tolerances

Note 1 –

Tolerance for FRAP is ± 0.3%.

Note 2 –

If applicable when variation of the G_{mm} exceed the ± 0.020 tolerance, a new stockpile of shall be created which will also require an additional mix design.

This is a consistency rewarding specification.

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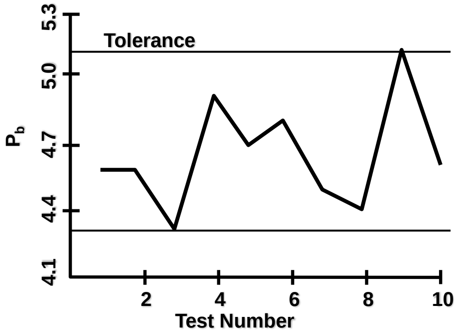
RAP Characterization



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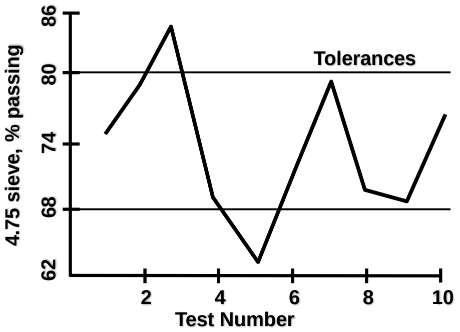
RAP Characterization



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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.

Class Participation: WHY?

Extra Credit: Is there a difference between full-depth and overlay applications?

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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.**

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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.

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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.

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New Maximum FRAP & RAS in HMA

N_{des}	Binder/Leveling	Surface
30	30 / 35 / 40 / 50	30 / 35 / 40
50	25 / 30 / 40	15 / 25 / 35
70	15 / 25 / 25 / 30 / 40	10 / 15 / 20 / 30
90	10 / 20 / 30 / 40	10 / 15 / 20 / 30

10% RAP allowed in dense graded polymer modified mixtures; 20% in SMA; 30% in 4.75-mm mixture.

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RAP Batching Example

Given: RAP asphalt = 4.8%
Optimum Binder Content = 5.0%
Batch Mass = 10,000 g

Blend %
RAP = 25.0%
CM11 = 42.0%
CM16 = 16.5%
FA20 = 16.5%

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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

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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

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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

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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

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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

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RAP Batching Example

Calculate mass of virgin binder needed:

(Total Binder Needed) - (Binder in RAP)

526 g – 126 g = 400 g

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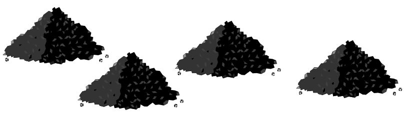
RAP Batching Example

Students perform work on pages 10.1-17 & 10.1-19

Combined Aggregate Bulk Specific Gravity

$$G_{sb}\text{ (comb.)} = \frac{100}{\left(\frac{P_1\%}{G_{sb1}}\right) + \left(\frac{P_2\%}{G_{sb2}}\right) + \left(\frac{P_3\%}{G_{sb3}}\right) + \left(\frac{RAP\%}{G_{sbRAP}}\right)}$$



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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.**

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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%		

9) Determine Aggregate Mass
(Blend %) x (Aggregate Batch Weight) =

10) Determine Aggregate & Recycle Binder Mass of Recycle
(Aggregate Batch Size) x (% of RAP (in decimal form)) / (1.0 – Rcycle Binder Content (in decimal form)) =

11) Determine Mass of Binder in Recycle
(Aggregate & Recycle Binder Mass) – (Recycle Aggregate Mass) =

12) Determine Mass of Batch (Binder Included)
(Aggregate Batch Size) / ((1.0 – (Optimum Binder Content (in decimal form))) =

13) Determine Mass of Binder
(Mass of Batch (Binder Included)) – (Aggregate Batch Size) =

14) Determine Mass of New Binder
(Mass of Binder) – (Mass of Binder in Recycle) =

15) 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

16) Determine Asphalt Binder Replacement (% ABR)
(Percent of Recycle Binder) / (Percent Optimum Binder Content) x 100

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SECTION 1031. RECLAIMED ASPHALT PAVEMENT

1031.01 Description. RAP is reclaimed asphalt pavement resulting from cold milling or crushing of an existing dense graded hot-mix asphalt (HMA) pavement. The Contractor shall supply written documentation that the RAP originated from routes or airfields under federal, state or local agency jurisdiction.

1031.02 Stockpiles. The Contractor shall construct individual, sealed RAP stockpiles meeting one of the following definitions. No additional RAP shall be added to the pile after the pile has been sealed.

(a) Homogeneous. Homogeneous RAP stockpiles shall consist of RAP from Class I, Superpave (High ESAL), HMA (High ESAL), or equivalent, mixtures only and represent; 1) the same aggregate quality, but shall be at least C quality or better; 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 “homogenous”, with a quality rating dictated by the lowest coarse aggregate quality present in the mixture. Stockpiles shall meet the testing requirements of Article 1031.07. Stockpiles not meeting these requirements may be processed (crushing and screening) and retested.

(b) Conglomerate. Conglomerate RAP stockpiles shall consist of RAP from Class I, Superpave (High ESAL), HMA (High ESAL), or equivalent, mixtures only. The coarse aggregate in this RAP shall be crushed aggregate only and may represent more than one aggregate type and/or quality but shall be at least C quality or better. This RAP may have an inconsistent gradation and/or asphalt binder content prior to processing. All 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. Stockpiles shall not contain steel slag or other expansive material as determined by the Department. Stockpiles shall meet the testing requirements of Article 1031.07.

(c) Conglomerate “D” Quality (DQ). Conglomerate DQ RAP stockpiles shall consist of RAP containing coarse aggregate (crushed or round) that is at least D quality or better. Conglomerate DQ RAP stockpiles shall not contain steel slag or other expansive material as determined by the Department. Conglomerate DQ RAP shall meet the testing requirements of Article 1031.07.

Reclaimed Superpave (Low ESAL)/HMA (Low ESAL) IL-19.0L binder and IL-9.5L surface mixtures shall be placed in conglomerate DQ RAP stockpiles due to potential of rounded aggregate.

(d) Other. RAP stockpiles that do not meet the requirements of the stockpile categories listed above shall be classified as “Other”. “Other” RAP stockpiles shall not be used in HMA.

1031.03 Contaminants. RAP containing contaminants, such as earth, brick, sand, concrete, sheet asphalt, bituminous surface treatment (i.e. chip seal), pavement fabric, joint sealants, etc., will be unacceptable unless the contaminants are removed to the satisfaction of the Engineer. Sheet asphalt shall be stockpiled separately.

1031.04 Quality Designation of Aggregate in RAP. The use of RAP in HMA shall be set by the lowest quality of coarse aggregate in the RAP stockpile and are designated as follows.

(a) RAP from Class I, Superpave (High ESAL) or HMA (High ESAL) surface mixtures are designated as containing Class B quality coarse aggregate only.

(b) RAP from Superpave (Low ESAL)/HMA (Low ESAL) IL-19.0L binder and IL-9.5L surface mixtures are designated as Class C quality coarse aggregate only.

(c) RAP from Class I, Superpave (High ESAL), or HMA (High ESAL) binder mixtures, bituminous base course mixtures, and bituminous base course widening mixtures are designated as containing Class C quality coarse aggregate only.

(d) RAP from bituminous stabilized subbase and BAM shoulders are designated as containing Class D quality coarse aggregate only.

The Contractor shall supply written documentation that the RAP meets the above quality designations.

Any mixture not listed above shall have the designated quality determined by the Department.

1031.05 RAP in HMA. The use of RAP in HMA shall be as follows.

(a) 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 using RAP.

(b) Steel Slag Stockpiles. RAP stockpiles containing steel slag or other expansive material, as determined by the Department, shall be homogeneous and will be approved for use in HMA (High ESAL and Low ESAL) surface mixtures only.

(c) Use in High and Low ESAL Mixtures. RAP stockpiles for use in HMA mixtures (High ESAL and Low ESAL) shall be either homogeneous or conglomerate, except conglomerate stockpiles shall not be used in HMA surface mixture Ndesign 50 or greater.

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

1031.06 RAP in Aggregate Surface Course and Aggregate Shoulders. The use of RAP in Aggregate Surface Course and Aggregate Shoulders shall be as follows.

Art. 1031.06 Reclaimed Asphalt Pavement

(a) Stockpiles. RAP stockpiles may be any of those listed in Article 1031.02.

(b) 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.

(c) Exclusion. The requirements of Article 1031.07 do not apply.

1031.07 Testing. All RAP shall be sampled and tested either during or after 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 2000 tons (1800 metric tons) and one sample per 2000 tons (1800 metric tons) thereafter. A minimum of five tests shall be required for stockpiles less than 4000 tons (3600 metric tons).

For testing existing stockpiles, the Contractor shall submit a plan for approval to the District proposing a satisfactory method of sampling and testing the RAP 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 field sample shall be split to obtain two samples for testing. One of the test samples from the final split shall be labeled and stored for Department use. The Contractor shall extract 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.

All of the extraction results shall be compiled and averaged for asphalt binder content and gradation. Individual extraction test results, when compared to the averages, will be accepted if within the tolerances listed below.

Parameter	Homogeneous / Conglomerate	Conglomerate "D" Quality
1 in. (25 mm)		± 5 %
1/2 in. (12.5 mm)	± 8 %	± 15 %
No. 4 (4.75 mm)	± 6 %	± 13 %
No. 8 (2.36 mm)	± 5 %	
No. 16 (1.18 mm)		± 15 %
No. 30 (600 µm)	± 5 %	
No. 200 (75 µm)	± 2.0 %	± 4.0 %
Asphalt Binder	± 0.4 %	± 0.5 %

If more than 20 percent of the individual sieves are out of the gradation tolerances, or if more than 20 percent of the asphalt binder content test results fall outside the appropriate tolerances, the RAP shall not be used in HMA unless the

RAP representing the failing tests is removed from the stockpile. All test data and acceptance ranges shall be sent to the District for evaluation.

If additional RAP stockpiles are tested and found that no more than 20 percent of the results are outside of the control tolerances set for the original RAP stockpile and HMA mix design, the additional RAP stockpiles may be used in the original mix design at the percent previously verified.

With the approval of the Engineer, the ignition oven may be substituted for extractions according to the Illinois Test Procedure, "Calibration of the Ignition Oven for the Purpose of Characterizing Reclaimed Asphalt Pavement (RAP)".

Illinois Department of Transportation

Memorandum

To:	Regional Engineers
From:	Omer M. Osman
Subject:	Special Provision for Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS)
Date:	January 8, 2016

This special provision was developed by the Bureau of Materials and Physical Research to combine the existing two BDE special provisions, Reclaimed Asphalt Pavement and Reclaimed Asphalt Shingles into one.

This special provision has been revised to fit with the 2016 Standard Specifications and incorporates the revision from January 2, 2015.

This special provision should be inserted in all HMA contracts.

The districts should include the BDE Check Sheet marked with the applicable special provisions for the April 22, 2016 and subsequent lettings. The Project Development and Implementation Section will include a copy in the contract.

This special provision will be available on the transfer directory January 8, 2016.

80306m

RECLAIMED ASPHALT PAVEMENT AND RECLAIMED ASPHALT SHINGLES (BDE)

Effective: November 1, 2012
Revise: April 1, 2016

Revise Section 1031 of the Standard Specifications to read:

"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 routes or airfields under federal, state, or local agency jurisdiction.

(b) Reclaimed Asphalt Shingles (RAS). Reclaimed asphalt shingles (RAS). RAS is 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, as defined in Bureau of Materials and Physical Research Policy Memorandum, "Reclaimed Asphalt Shingle (RAS) Sources", by weight of RAS. All RAS used shall come from a Bureau of Materials and Physical Research approved processing facility 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, sealed RAP stockpiles meeting one of the following definitions. No additional RAP shall be added to the pile after the pile has been sealed. 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 District 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. All FRAP shall be fractionated prior to testing by screening into a minimum of two size fractions with the separation occurring on or between the #4 (4.75 mm) and 1/2 in. (12.5 mm) sieves. Agglomerations shall be minimized such that 100 percent of the RAP shall pass the sieve size specified below for the mix into which the FRAP will be incorporated.

Mixture FRAP will be used in:	Sieve Size that 100 % of FRAP Shall Pass
IL-19.0	1 1/2 in. (40 mm)
IL-9.5	3/4 in. (20 mm)
IL-4.75	1/2 in. (13 mm)

(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. All 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) 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, bituminous surface treatment (i.e. chip seal), pavement fabric, joint sealants, 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) 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.

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 2000 tons (1800 metric tons) and one sample per 2000 tons (1800 metric tons) thereafter. A minimum of five tests shall be required for stockpiles less than 4000 tons (3600 metric tons).

(2) After Stockpiling. For testing after stockpiling, the Contractor shall submit a plan for approval to the District 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 extract the other test sample according to Department procedure. 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 Bureau of Materials and Physical Research 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 1000 tons (900 metric tons) and one sample per 250 tons (225 metric tons) thereafter. A minimum of five samples are required for stockpiles less than 1000 tons (900 metric tons). Once a ≤ 1000 ton (900 metric ton), five-sample/test stockpile has been established it shall be sealed. Additional incoming RAS or RAS blended with manufactured sand shall be stockpiled in a separate working pile as designated in the Quality Control plan and only added to the sealed stockpile when the test results of the working pile are complete and are found to meet the tolerances specified herein for the original sealed RAS stockpile.

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 Department procedures. The Engineer reserves the right to test any sample (split or Department-taken) to verify Contractor test results.

If the sampling and testing was performed at the shingle processing facility in accordance with the QC Plan, the Contractor shall obtain and make available all of the test results from start of the initial stockpile.

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

(a) 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 %
No. 4 (4.75 mm)	± 6 %
No. 8 (2.36 mm)	± 5 %
No. 16 (1.18 mm)	
No. 30 (600 µm)	± 5 %
No. 200 (75 µm)	± 2.0 %
Asphalt Binder	± 0.4 % 1/
G_{mm}	± 0.03

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

If more than 20 percent of the individual sieves and/or asphalt binder content tests 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 District for evaluation.

With the approval of the Engineer, the ignition oven may be substituted for extractions according to the ITP, "Calibration of the Ignition Oven for the Purpose of Characterizing Reclaimed Asphalt Pavement (RAP)".

(b) Evaluation of RAS and RAS Blended with Manufactured Sand 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
No. 8 (2.36 mm)	± 5 %
No. 16 (1.18 mm)	± 5 %
No. 30 (600 µm)	± 4 %
No. 200 (75 µm)	± 2.0 %
Asphalt Binder Content	± 1.5 %

If more than 20 percent of the individual sieves and/or asphalt binder content tests are out of the above tolerances, or if the percent unacceptable material exceeds 0.5 percent by weight of material retained on the # 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 District for evaluation.

1031.05 Quality Designation of Aggregate in RAP/FRAP.

(a) RAP. The aggregate quality of the RAP for homogeneous and conglomerate stockpiles shall be set by the lowest quality of coarse aggregate in the RAP stockpile and are designated as follows.

(1) RAP from Class I, Superpave/HMA (High ESAL), or (Low ESAL) IL-9.5L surface mixtures are designated as containing Class B quality coarse aggregate.

(2) RAP from Class I binder, Superpave/HMA (High ESAL) binder, or (Low ESAL) IL-19.0L binder mixtures are designated as containing Class C quality coarse aggregate.

(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 #4 (4.75 mm) sieve coarse aggregate shall have a maximum tonnage of 5000 tons (4500 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 to the District Office. The cost for this testing shall be paid by the Contractor. The District will forward the sample to the Bureau of Materials and Physical Research Aggregate Lab for MicroDeval Testing, according to ITP 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. RAP/FRAP from Conglomerate stockpiles shall be considered equivalent to limestone for frictional considerations. Known frictional contributions from plus #4 (4.75 mm) homogeneous RAP and 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 RAP 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 asphalt binder replacement shall not exceed the amounts listed in the Max RAP/RAS ABR table listed below for the given Ndesign.

RAP/RAS Maximum Asphalt Binder Replacement (ABR) Percentage

HMA Mixtures 1/, 2/	RAP/RAS Maximum ABR %		
Ndesign	Binder/Leveling Binder	Surface	Polymer Modified
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). If warm mix asphalt (WMA) technology is utilized and production temperatures do not exceed 275 °F (135 °C), the high and low virgin asphalt binder grades shall each be reduced by one grade when RAP/RAS ABR exceeds 25 percent (i.e. 26 percent RAP/RAS 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 FRAP/RAS table listed below for the given Ndesign.

FRAP/RAS Maximum Asphalt Binder Replacement (ABR) Percentage

HMA Mixtures 1/, 2/	FRAP/RAS Maximum ABR %		
Ndesign	Binder/Leveling Binder	Surface	Polymer Modified 3/, 4/
30	50	40	10
50	40	35	10
70	40	30	10
90	40	30	10

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). If warm mix asphalt (WMA) technology is utilized and production temperatures do not exceed 275 °F (135 °C), the high and low virgin asphalt binder grades shall each be reduced by one grade when FRAP/RAS ABR exceeds 25 percent (i.e. 26 percent ABR would require a virgin asphalt binder grade of PG 64-22 to be reduced to a PG 58-28).

3/ For SMA the FRAP/RAS ABR shall not exceed 20 percent.

4/ For IL-4.75 mix the FRAP/RAS ABR shall not exceed 30 percent.

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 results, as defined under "Testing" herein, 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. A RAS stone bulk specific gravity (Gsb) of 2.300 shall be used for mix design purposes.

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

(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.

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 feed system to remove or reduce oversized material. If material passing the sizing device adversely affects the mix production or quality of the mix, the sizing device shall be set at a size specified by the Engineer.

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

(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 material as a percent of the total mix to the nearest 0.1 percent.

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

(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 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.

(a) 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. RAP used shall be according to the current Bureau of Materials and Physical Research Policy Memorandum, "Reclaimed Asphalt Pavement (RAP) for Aggregate Applications".

(b) 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."

80306

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Illinois Department of Transportation

Determination of Reclaimed Asphalt Pavement (RAP)
Aggregate Bulk (Dry) Specific Gravity (Gsb)
Appendix B21

Effective: May 1, 2007
Revised: April 1, 2011

1. GENERAL

If the RAP consists of natural aggregates only, the RAP aggregate bulk specific gravity shall be as follows:

District	RAP Gsb
1 & 2	2.660
3 - 9	2.630

If the RAP contains slag aggregate the following procedure shall be used by an independent AASHTO accredited laboratory to determine the RAP aggregate bulk specific gravity (G_{sb}).

2. 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.

3. 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.

4. 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:

A. Sample pans - Large, flat and capable of holding 20,000 grams of RAP material.
B. Chopping utensil – Blade trowel or other utensil used to separate the large conglomerations of a RAP sample into a loose-flowing condition.

Illinois Department of Transportation

Determination of Reclaimed Asphalt Pavement (RAP)
Aggregate Bulk (Dry) Specific Gravity (Gsb)
Appendix B21
(continued)

Effective: May 1, 2007
Revised: April 1, 2011

5. RAP SAMPLE PREPARATIONS

   A. Transfer the entire 20,000 gram sample into a large flat pan(s).
   B. Place sample into a preheated oven at 230 ± 9° F. (110 ± 5° C.) and heat for 30 to 45 minutes.
   C. Remove the sample from the oven and begin breaking up the larger conglomerations of RAP with the chopping utensil.
   D. As the material begins to soften, blend the heated RAP by mixing the freshly chopped material with the fines in the pan.
   E. Return the RAP into the oven and continue heating for another 15 - 20 minutes.
   F. 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.
   G. 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.

6. TESTING

   A. Percent Asphalt Binder P_b:
      1. Split out a 1,500 - 2,000 gram prepared RAP sample.
      2. Dry the RAP sample to a constant weight in an oven at 230 ± 9° F. (110 ± 5° C.).
      3. Determine the P_b of the dried RAP sample according to Illinois Modified T 164. Record the P_b.

   B. Maximum Specific Gravity determination, G_{mm}:
      1. Split out one 3,000 gram prepared RAP sample.
      2. 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".
      3. Place the sample in 295° ± 5° F. (146° ± 3° C.) oven for one hour.
      4. 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.
      5. Split sample into two equal samples.
      6. Determine the G_{mm} of the prepared RAP samples according to Illinois Modified AASHTO T209.
      7. 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.

Illinois Department of Transportation

Determination of Reclaimed Asphalt Pavement (RAP) Aggregate Bulk (Dry) Specific Gravity (Gsb) Appendix B21 (continued)

Effective: May 1, 2007
Revised: April 1, 2011

7. CALCULATIONS

A. Calculate the "adjusted P_b" of the RAP to account for the addition of the 1.5 percent virgin asphalt binder as follows:

1. Calculate "mass of RAP Asphalt Cement (AC)":

$$\text{Mass of RAP AC} = Dry\ RAP\ mass \times \frac{P_b}{100}$$

2. Calculate "mass of virgin AC added":

Mass of virgin AC added = 0.015 x Dry RAP mass

3. Determine "New RAP mass":

New RAP mass = Dry RAP mass + Mass of virgin AC added

4. Calculate "Adjusted P_b":

$$\text{Adjusted } P_b = \frac{Mass\ of\ RAP\ AC + Mass\ of\ virgin\ AC\ added}{New\ RAP\ Mass} \times 100$$

B: Calculate the effective specific gravity (G_{se}) of the RAP:

$$G_{se}\ (RAP) = \frac{(100 - Adjusted\ P_b)}{\left(\frac{100}{G_{mm}} - \frac{Adjusted\ P_b}{1.040}\right)}$$

C. Calculate the stone bulk gravity (G_{sb}) of the RAP:

$$G_{sb}\ (RAP) = G_{se}\ (RAP) - 0.100$$

Example w/ 1.5% virgin asphalt binder added:

- Dry RAP mass = 3,000 g
- 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

Illinois Department of Transportation

Determination of Reclaimed Asphalt Pavement (RAP)
Aggregate Bulk (Dry) Specific Gravity (Gsb)
Appendix B21
(continued)

Effective: May 1, 2007
Revised: April 1, 2011

- 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":

$$\text{Adjusted } P_b = \frac{\text{Mass of RAP AC} + \text{Mass of virgin AC added}}{\text{New RAP Mass}} \times 100$$

$$= \frac{147 \text{ grams} + 45 \text{ grams}}{3{,}045 \text{ grams}} \times 100 = 6.3\%$$

- 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}:

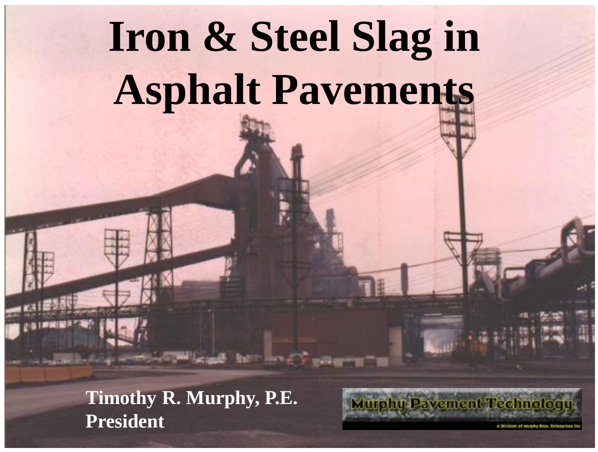
$$G_{sb} = G_{se} - 0.10 = 2.772 - 0.10 = 2.672$$

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

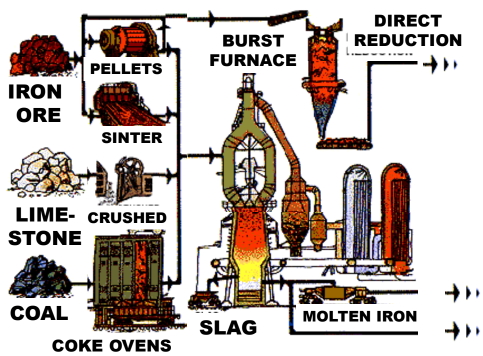


SLAG MIX DESIGNS

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.

BLAST FURNACE SLAG MANUFACTURING



Iron Ore + Limestone + Coal into Blast Furnace = Iron + Slag

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.

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 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

Physical Properties:

Specific Gravity	2.3 to 2.9
Absorption	2.0 to 5.0
Abrasion	N/A

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).

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

Again, chemistry is fairly consistent.

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

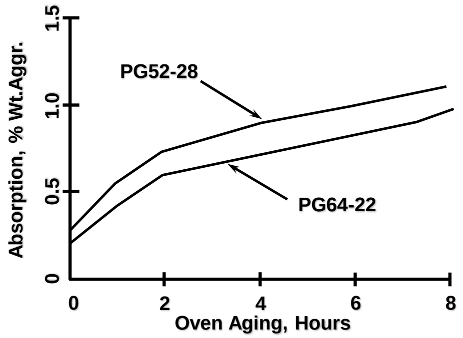
Aggregate	G_{SB}	Water Abs
Steel Slag	3.10 - 3.53	1.9 - 3.5%
Dolomite	2.62 - 2.64	2.1 - 2.3%
ACBF Slag	2.33 - 2.38	2.4 - 4.6%

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

Effect of Absorption



Results are from Kandhal and Khatri, AAPT, 1991.

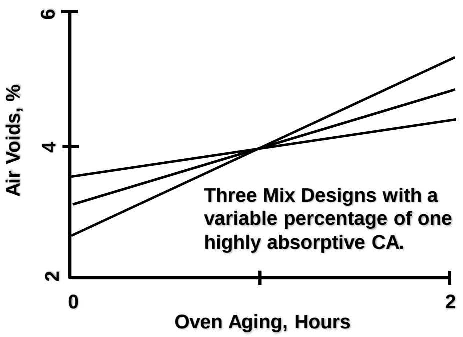
Study on performed on mineral aggregates.

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 II



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.

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
25.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
12.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0
9.5	79.0	98.0	100.0	100.0	100.0	100.0	92.9
4.75	14.0	27.0	100.0	99.0	100.0	100.0	48.4
2.36	8.0	8.0	88.0	82.0	100.0	100.0	35.1
1.18	5.0	6.0	54.0	62.0	100.0	100.0	24.9
600µm	4.0	5.0	31.0	42.0	100.0	100.0	17.3
300µm	3.0	5.0	12.0	17.0	100.0	100.0	9.5
150µm	3.0	4.0	7.0	5.0	95.0	100.0	6.1
75µm	2.2	4.1	4.3	2.0	90.0	100.0	4.9

Sieve Size	Mixture Composition Specification	FORMULA	FORMULA RANGE Min	FORMULA RANGE Max
25.4		100	100	100
19.0	100	100	100	100
12.5	90-100	100	100	100
9.5	66-100	93	93	93
4.75	24-65	48	43	53
2.36	16-48	35	30	40
1.18	10-32	25	25	25
600µm		17	13	21
300µm	4-15	10	10	10
150µm	3-10	6	6	6
75µm	2-6	4.9	3.4	6.4

	#1	#2	#3	#4	#5	#6	Blended SpGr
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

Dust AC Ratio
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

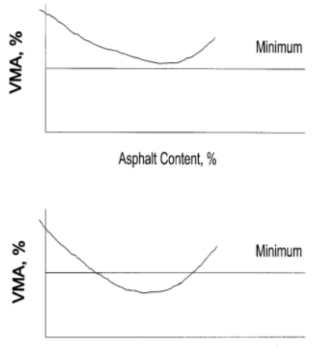
Variables

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})**

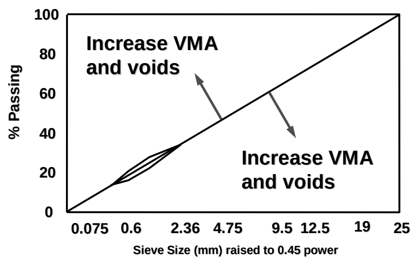
Analyze and Explain results of Class Mix Design

- Particle shape
- Surface texture
- Aggregate gradation
- CA vs. FA
- Dust
- Potential items to watch for during production.

Design 001 vs. 002



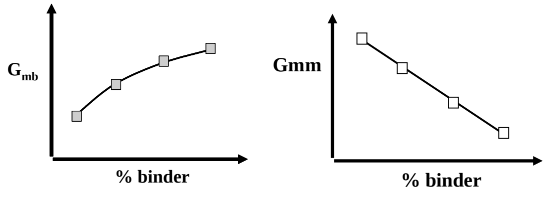
VMA Adjustments



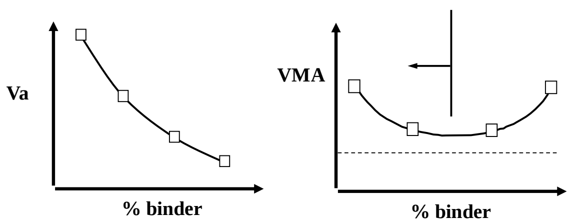
VMA Adjustments

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		FORMULA	FORMULA RANGE	
Min	Max		Min	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

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	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:

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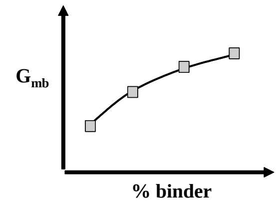
I. VOLUMETRIC RELATIONSHIPS

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.

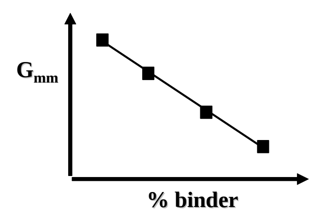
3. Should look at two lab specimens and their test values to determine if there is a flyer in that set of data. If so, need to discard bad sample and possibly redo test point.

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

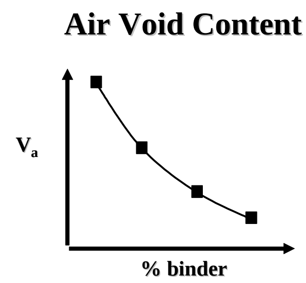


C. Voids (P_a)

1. Calculated value based on G_{mb} and G_{mm}.

2. Calculated and reported to one decimal place (tenth).

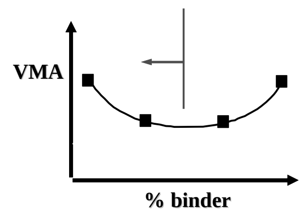
3. Air voids decrease with increasing asphalt binder content.



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.

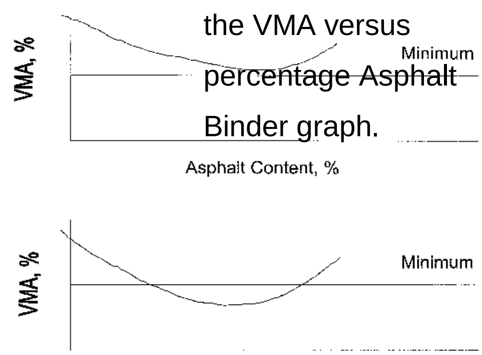
Based on this philosophy, the volume of the effective Asphalt Binder should remain constant and meet a minimum value. This ensures there is enough asphalt coating the outside surfaces of the aggregate particles. In simple terms, this is the function of VMA - to create enough film thickness on the aggregate 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.

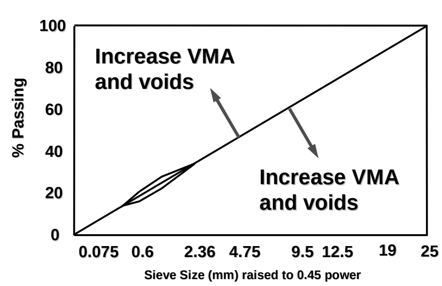
(b) Asphalt Binder film thickness assumes each aggregate particle is spread apart and coated. Normally the volume of Asphalt Binder is shared by adjacent aggregate particles.

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.



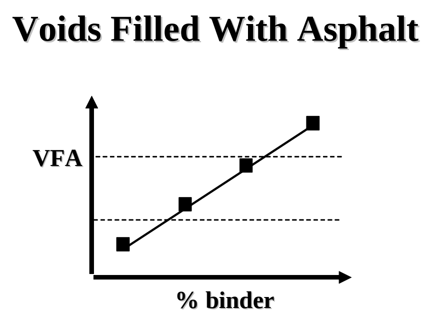
Voids in the Mineral Aggregate



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.

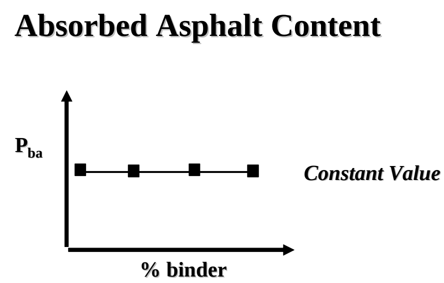
4. Requires the following ranges:
   - 70 – 80 @ N_{design} of 30
   - 65 – 78 @ N_{design} of 50
   - 65 – 75 @ N_{design} of 70, 90, or 105

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.

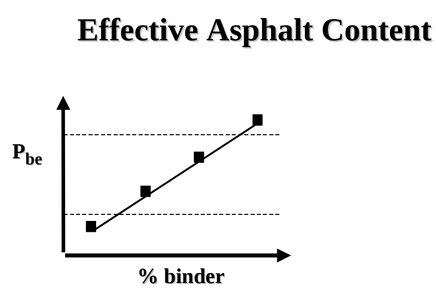
2. Calculated and reported to one decimal place (tenth).

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

Sieve Size	Specifications Min	Specifications Max	FORMULA	FORMULA RANGE Min	FORMULA RANGE Max
25.4 (1)	--	--	100	100	100
19.0 (3/4)		100	100	100	100
12.5 (1/2)	90	100	100	94	106
9.5 (3/8)		90	99	--	--
4.75 (#4)	24	65	57	52	62
2.36 (#8)	16	40	40	35	45
1.18 (#16)	10	32	24	24	24
600μm (#30)	--	--	13	--	--
300μm (#50)	4	15	8	4	12
150μm (#100)	3	10	6	6	6
75μm (#200)	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: →
Lab Preparing the design?(PP,PL,IL,etc.)

		PAGE 10-10
		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 Min	Specifications Max	FORMULA	FORMULA RANGE Min	FORMULA RANGE 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	ABSORPTION 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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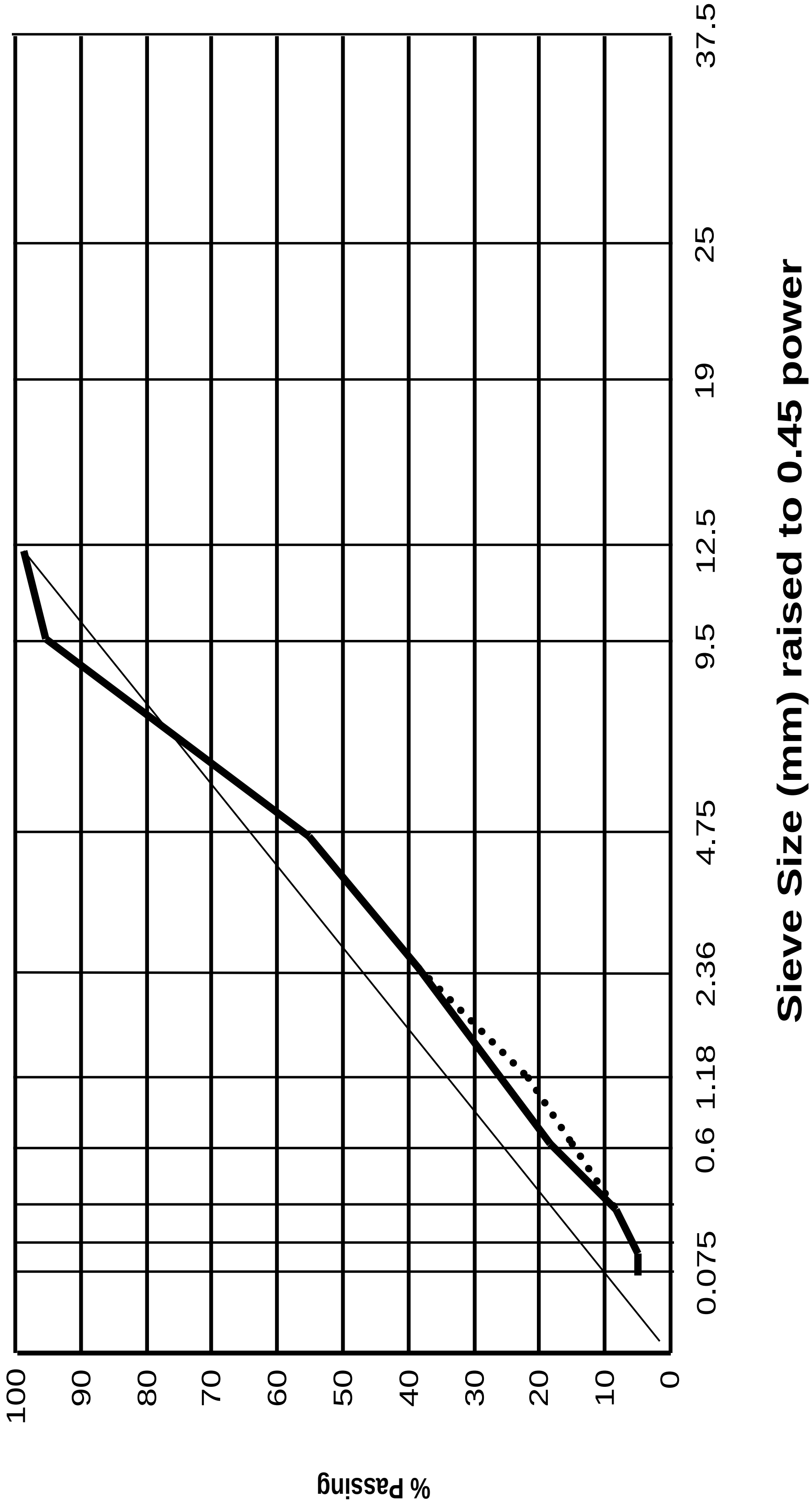

Gradation Graph Design A & B

This Page Is Reserved

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

	#1	#2	#3	#4	#5	#6
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	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

This Page Is Reserved

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 Min	Specifications Max	FORMULA	FORMULA RANGE Min	FORMULA RANGE 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	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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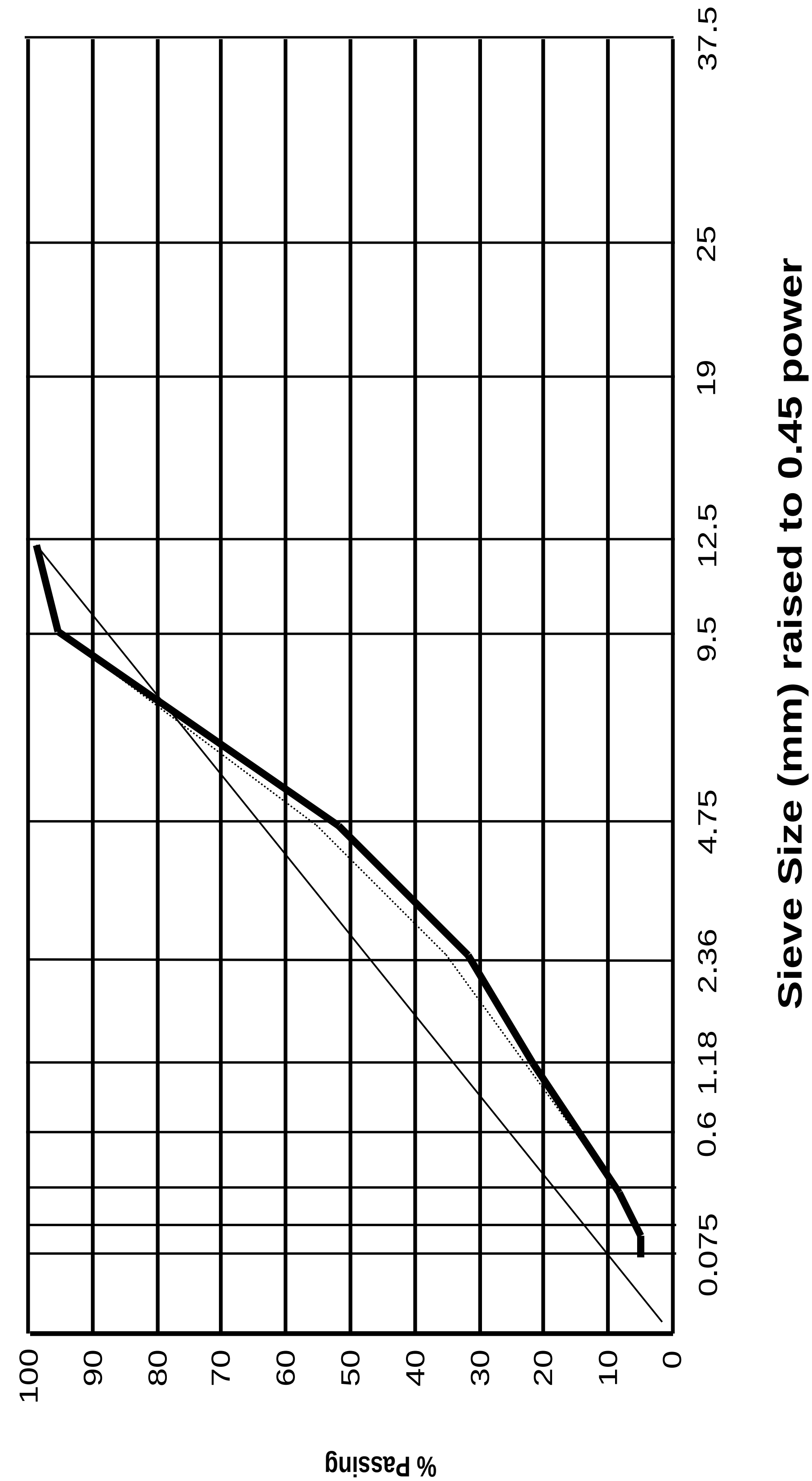

Gradation Graph Design C & D

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DATE:

SEQ NO:

Bituminous Mixture Design
Design Number: →
Lab Preparing the design?(PP,PL,IL,etc.)

	PAGE 12-17	
	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	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	90	100	100	100	100
19.0 (3/4)	89.1	100.0	100.0	100.0	100.0	100.0	94.9	--	90	95	95	95
12.5 (1/2)	41.5	100.0	100.0	100.0	100.0	100.0	72.4	45	75	72	66	78
9.5 (3/8)	18.5	98.6	100.0	100.0	100.0	100.0	61.3	--	--	61	--	--
4.75 (#4)	4.5	30.0	100.0	100.0	100.0	100.0	38.9	24	42	39	34	44
2.36 (#8)	3.8	7.6	100.0	99.7	100.0	100.0	33.4	16	31	33	28	38
1.18 (#16)	3.5	5.2	100.0	72.9	100.0	100.0	25.1	10	22	25	25	25
600µm (#30)	3.3	4.1	100.0	49.9	100.0	100.0	18.3	--	--	18	--	--
300µm (#50)	3.3	3.7	100.0	10.7	100.0	100.0	7.1	4	12	7	3	11
150µm (#100)	3.3	3.5	100.0	0.9	97.0	100.0	4.3	3	9	4	4	4
75µm (#200)	3.3	3.2	100.0	0.3	94.0	100.0	4.0	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 Min	Specifications Max	FORMULA	FORMULA RANGE Min	FORMULA RANGE 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

	#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	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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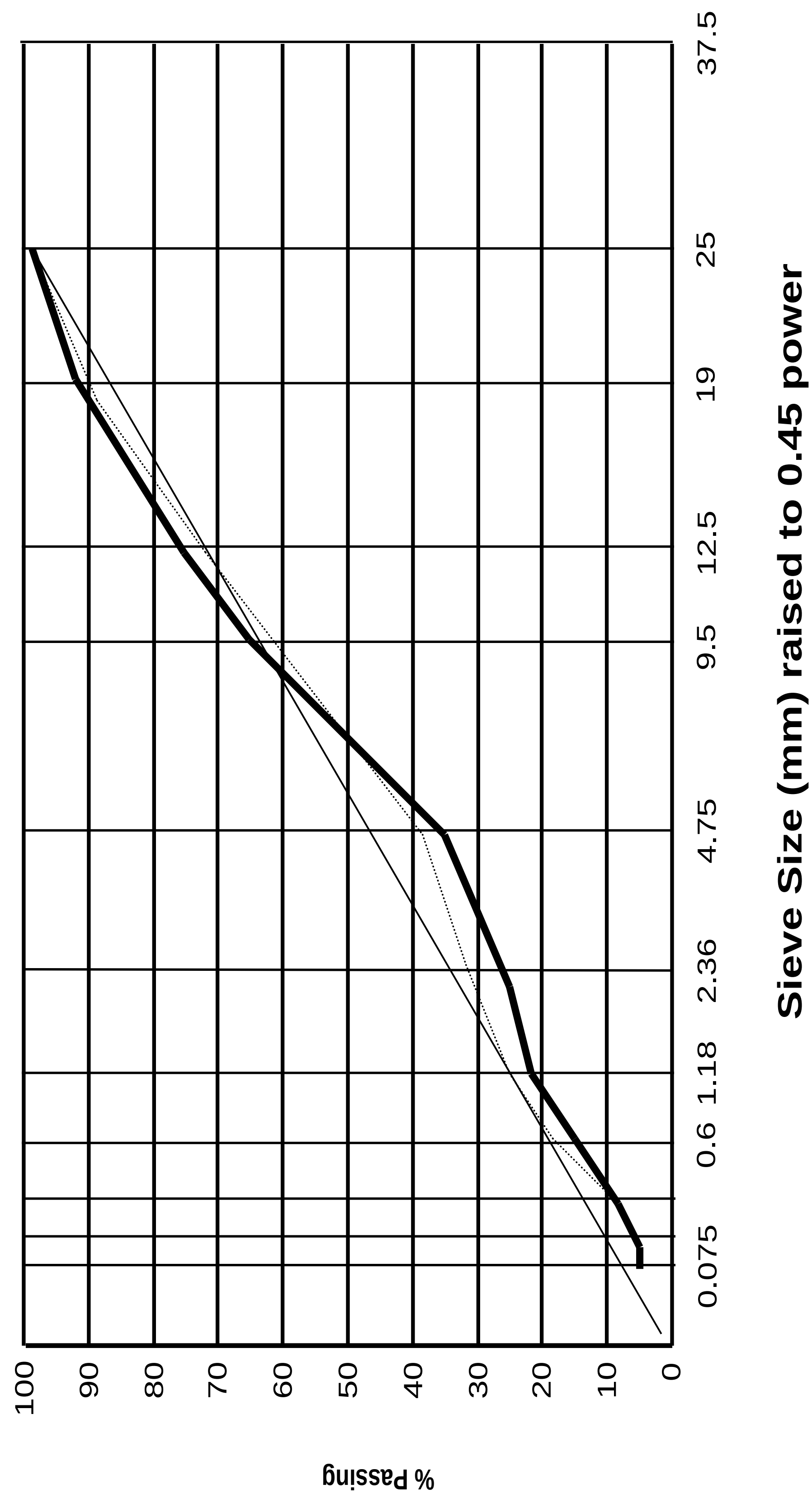

Gradation Graph Design E & F

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DATE:

SEQ NO:

Bituminous Mixture Design

Design Number: →			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	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	ABSORPTION 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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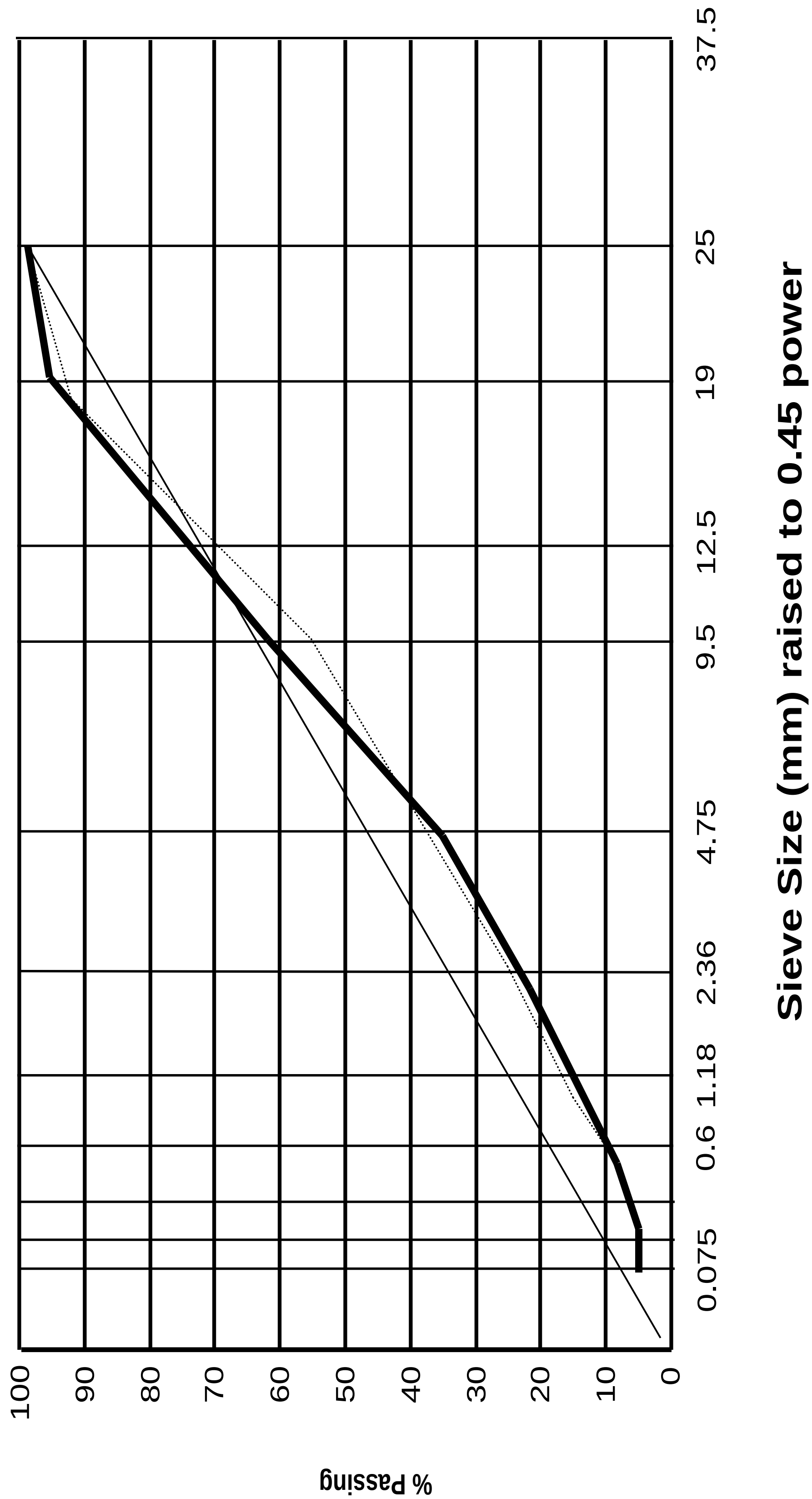

Gradation Graph Design G & H

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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	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	100
19.0 (3/4)	94.3	100.0	100.0	100.0	100.0	100.0	97.1	82	100	97	97	97
12.5 (1/2)	40.0	100.0	100.0	100.0	100.0	100.0	69.9	50	85	70	64	76
9.5 (3/8)	17.9	96.9	100.0	100.0	100.0	100.0	58.2	--	--	58	--	--
4.75 (#4)	4.9	30.8	97.7	96.8	100.0	100.0	37.2	24	40	37	32	42
2.36 (#8)	3.0	7.7	65.8	80.8	100.0	100.0	23.8	16	36	24	19	29
1.18 (#16)	2.7	4.9	36.9	64.8	100.0	100.0	16.0	10	25	16	16	16
600µm (#30)	2.6	4.1	20.1	48.4	100.0	100.0	11.2	--	--	11	--	--
300µm (#50)	2.5	3.7	11.6	18.5	100.0	100.0	7.1	4	12	7	3	11
150µm (#100)	2.4	3.5	7.9	3.1	99.0	100.0	5.1	3	9	5	5	5
75µm (#200)	2.0	3.0	4.8	1.5	88.0	100.0	3.9	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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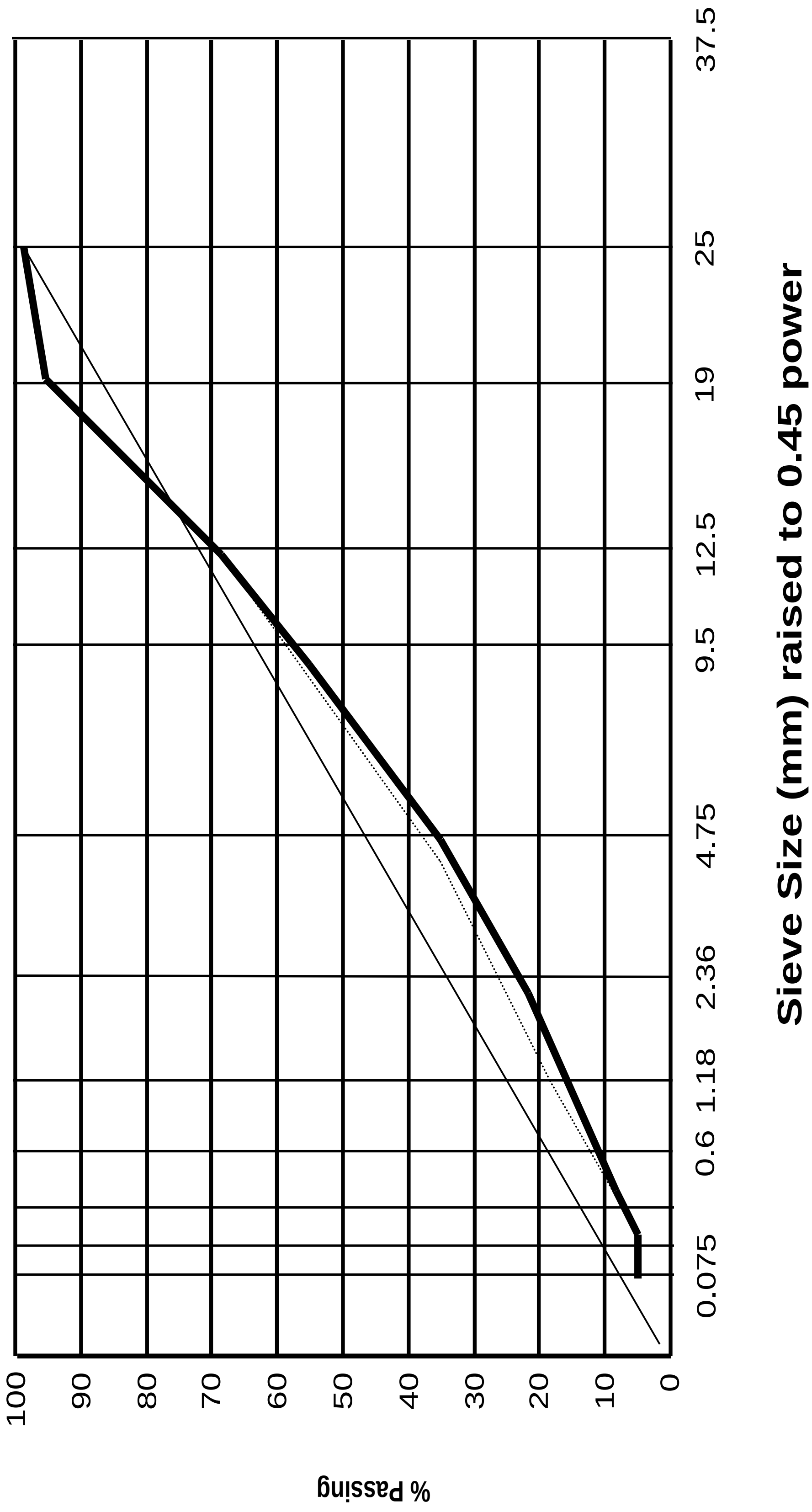

Gradation Graph Design I & J

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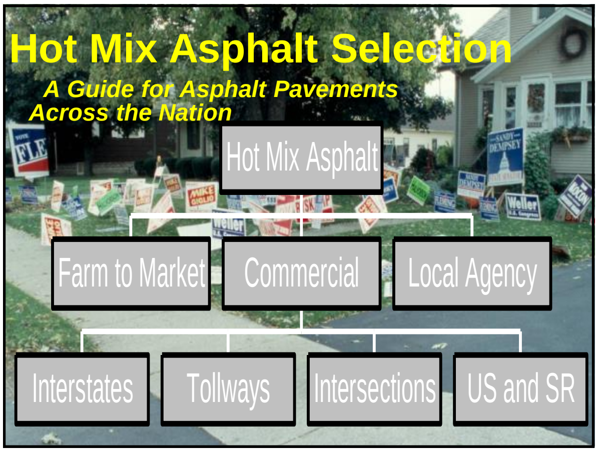
Specialty Mixes in HMA

Various high quality mixes for various applications.

Timothy R. Murphy, P.E.
President
Murphy Pavement Technology



Standard HMA Mixes

N_{des} Gyratory Levels

- N30, Low Volume, Local Municipalities — **PG 52-28**
- N50 — **PG 58-28**
- N70, Medium Volume, State Routes — **PG 64-28**
- N90, High Volume, Interstates — **PG 70-22**

PG 76-22

Polymers

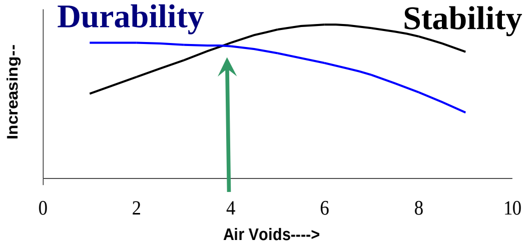
Full – Depth vs. Overlay

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

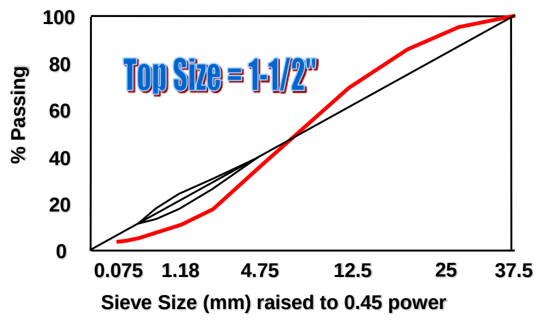
- Maximum aggregate size up to 1-1/2”
- *Old* 6 inch Marshall design (112-blow)

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

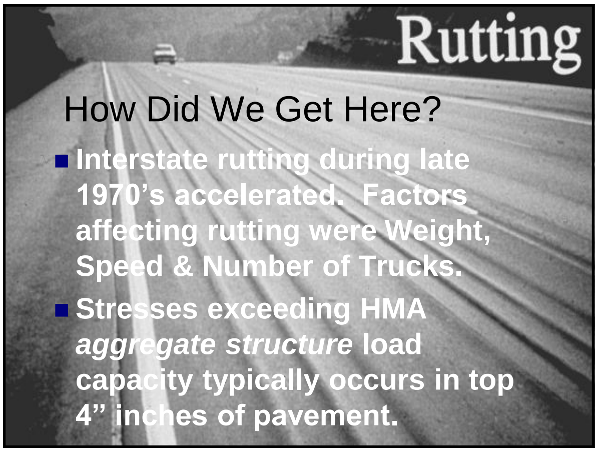
Stone Matrix Asphalt

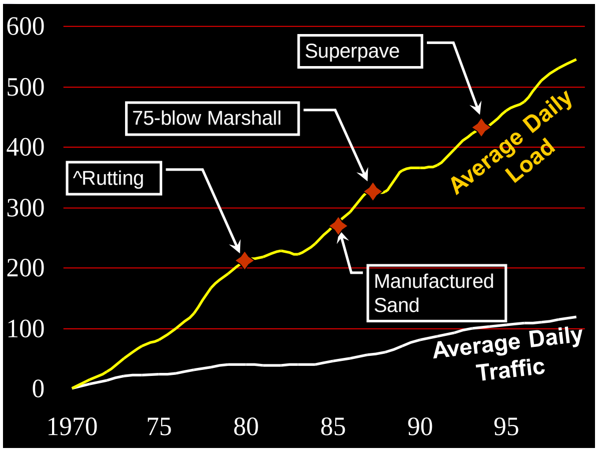
High Type Traffic Solution for high stress and large volumes.

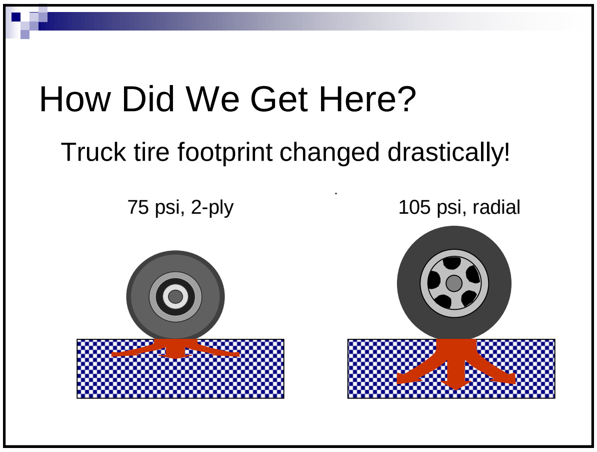
Timothy R. Murphy, P.E.
President

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
Superpave
75-blow Marshall
^Rutting
Manufactured Sand
Average Daily Load
Average Daily Traffic


How Did We Get Here?
Truck tire footprint changed drastically!
75 psi, 2-ply
105 psi, radial

Heavy, Concentrated Loading

Mix Properties

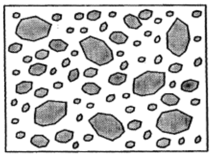
- Much coarser blend than HMA
- Uses highly modified AC, high dust content and fibers
- Stability from coarse aggregate structure
- Durability from mastic
- Very sensitive to changes in production and placement

Design Issues, General

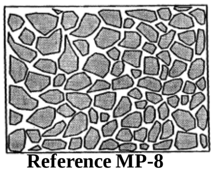
- ~ 76% of mix is CA,
- Balance is Manufactured Sand and MF,
- Target 2.36mm & 0.075mm in combined blend,
- Fiber introduction,
- High P200.

Design Issues, General

Dense-Graded Asphalt



Stone Matrix Asphalt



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.

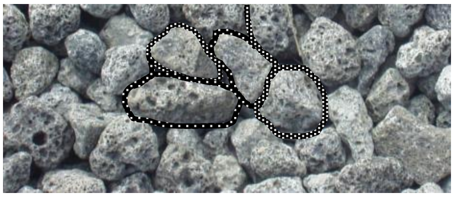
Design Issues, VCA Visual

Stone Matrix Asphalt

Design Issues, VCA Visual

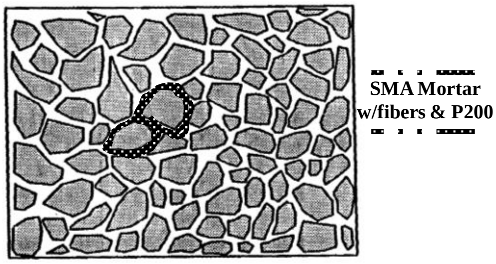
Stone Matrix Asphalt

SMA Mortar with fibers & P200



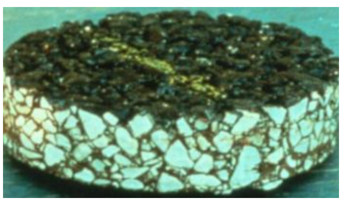
Stone Matrix Asphalt,

$VCA_{(DRC)} < VCA_{(MIX)}$



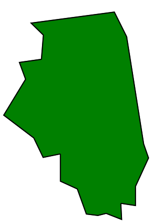
Stone Matrix Asphalt,

$VCA_{(DRC)} = VCA_{(MIX)}$



Mix Properties
Special Provision

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



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

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.

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

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.

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

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	

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

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%

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

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.

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

Mix Properties, Stripping

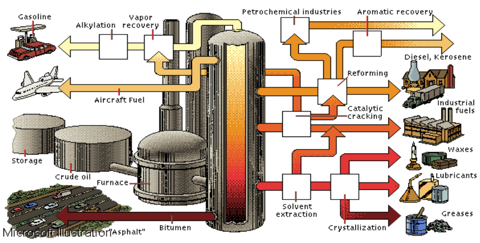
- The mixture shall contain an anti-strip agent consisting of 1.0% hydrated lime. If the minimum TSR of 0.75 is not achieved with hydrated lime alone the Department may require a liquid anti-strip to be used in addition to the hydrated lime.

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

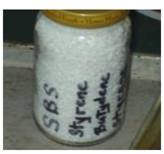
Quality Control Items

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)

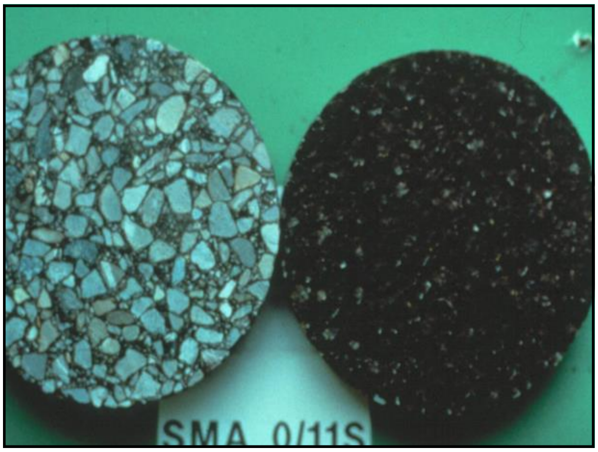
Crude Oil to End Product



Crude Oil to End Product



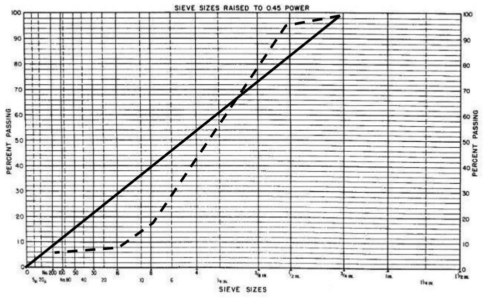
Polymers plus Asphalt Binder



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

Timothy R. Murphy, P.E.
President

Murphy Pavement Technology

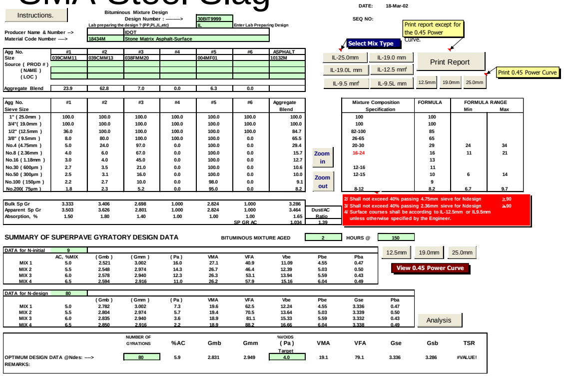
Dolomitic SMA Weight

- 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



Instructions.

Bituminous Mixture Design
Design Number : ---------> 30BIT9999
Lab preparing the design ? (PP,PL,IL,etc) IL Enter Lab Preparing Design
Producer Name & Number --> IDOT
Material Code Number ----> 18434M Stone Matrix Asphalt-Surface

DATE: 18-Mar-02
SEQ NO:

Select Mix Type | Print report except for the 0.45 Power Curve. | Print Report | Print 0.45 Power Curve
IL-25.0mm | IL-19.0 mm | IL-19.0L mm | IL-12.5 mm | IL-9.5 mm | IL-9.5L mm | 12.5mm | 19.0mm | 25.0mm

Agg No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	039CMM11	039CMM13	038FMM20		004MF01		10132M
Source (PROD #)							
(NAME)							
(LOC)							
Aggregate Blend	23.9	62.8	7.0	0.0	6.3	0.0	

Agg No. Sieve Size	#1	#2	#3	#4	#5	#6	Aggregate Blend	Mixture Composition Specification	FORMULA	FORMULA RANGE Min	FORMULA RANGE Max
1" (25.0mm)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100	100		
3/4"(19.0mm)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100	100		
1/2" (12.5mm)	36.0	100.0	100.0	100.0	100.0	100.0	84.7	82-100	85		
3/8" (9.5mm)	8.0	80.0	100.0	100.0	100.0	0.0	65.5	26-65	65		
No.4 (4.75mm)	5.0	24.0	97.0	0.0	100.0	0.0	29.4	20-30	29	24	34
No.8 (2.36mm)	4.0	6.0	67.0	0.0	100.0	0.0	15.7	16-24	16	11	21
No.16 (1.18mm)	3.0	4.0	45.0	0.0	100.0	0.0	12.7		13		
No.30 (600µm)	2.7	3.5	21.0	0.0	100.0	0.0	10.6	12-16	11		
No.50 (300µm)	2.5	3.1	16.0	0.0	100.0	0.0	10.0	12-15	10	6	14
No.100 (150µm)	2.2	2.7	10.0	0.0	98.0	0.0	9.1		9		
No.200(75µm)	1.8	2.3	5.2	0.0	95.0	0.0	8.2	8-12	8.2	6.7	9.7

Zoom in | Zoom out

	#1	#2	#3	#4	#5	#6	Blend	Dust/AC Ratio
Bulk Sp Gr	3.333	3.406	2.698	1.000	2.824	1.000	3.286	
Apparent Sp Gr	3.503	3.626	2.801	1.000	2.824	1.000	3.464	
Absorption, %	1.50	1.80	1.40	1.00	1.00	1.00	1.65	
						SP GR AC	1.034	1.39

2/ Shall not exceed 40% passing 4.75mm sieve for Ndesign ≥90
3/ Shall not exceed 40% passing 2.36mm sieve for Ndesign ≥90
4/ Surface courses shall be according to IL-12.5mm or IL9.5mm unless otherwise specified by the Engineer.

SUMMARY OF SUPERPAVE GYRATORY DESIGN DATA BITUMINOUS MIXTURE AGED 2 HOURS @ 150

12.5mm | 19.0mm | 25.0mm | View 0.45 Power Curve

DATA for N-initial 9

	AC, %MIX	(Gmb)	(Gmm)	(Pa)	VMA	VFA	Vbe	Pbe	Pba
MIX 1	5.0	2.521	3.002	16.0	27.1	40.9	11.09	4.55	0.47
MIX 2	5.5	2.548	2.974	14.3	26.7	46.4	12.39	5.03	0.50
MIX 3	6.0	2.578	2.940	12.3	26.3	53.1	13.94	5.59	0.43
MIX 4	6.5	2.594	2.916	11.0	26.2	57.9	15.16	6.04	0.49

DATA for N-design 80

		(Gmb)	(Gmm)	(Pa)	VMA	VFA	Vbe	Pbe	Gse	Pba
MIX 1	5.0	2.782	3.002	7.3	19.6	62.5	12.24	4.55	3.336	0.47
MIX 2	5.5	2.804	2.974	5.7	19.4	70.5	13.64	5.03	3.339	0.50
MIX 3	6.0	2.835	2.940	3.6	18.9	81.1	15.33	5.59	3.332	0.43
MIX 4	6.5	2.850	2.916	2.2	18.9	88.2	16.66	6.04	3.338	0.49

Analysis

	NUMBER OF GYRATIONS	%AC	Gmb	Gmm	%VOIDS (Pa) Target	VMA	VFA	Gse	Gsb	TSR
OPTIMUM DESIGN DATA @Ndes: ---->	80	5.9	2.831	2.949	4.0	19.1	79.1	3.336	3.286	#VALUE!
REMARKS:										

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)

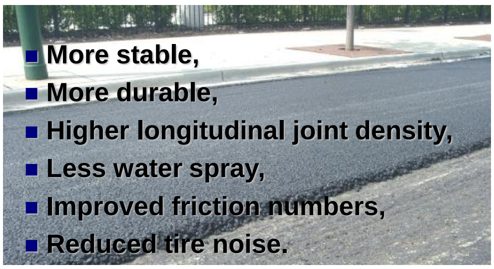
- Weight of roller is significant
- Static steel wheels heavier, but downfalls include:
  - narrower drums require more passes or more rollers for entire lane coverage
  - mat may cool due to increased time for passes
- Pneumatics not good because of pickup

Properly Ballast Rollers

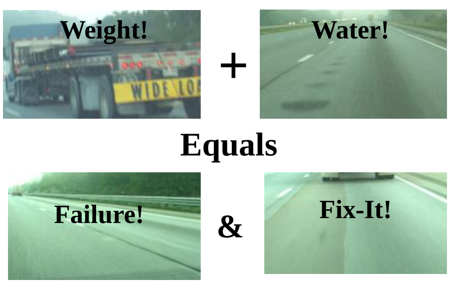
Mat Thickness

- 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

Timothy R. Murphy, P.E.
President

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 leveling binder.

Visuals are nice…

Why Use IL-4.75 mm?

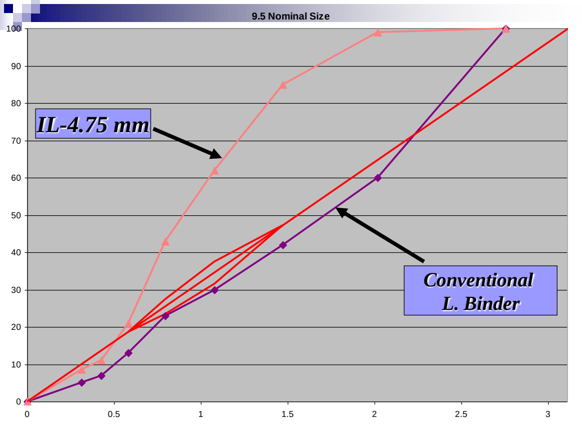
- Higher in-Place Density & Stability
- Resist reflective cracking
- Waterproof
- Improve ride

Mixture Composition

- Stone Sand / Slag Sand
- Natural Sand
- Mineral Filler
- Polymerized AC

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)
- Marshall Stability (>3,000 lb.)
- TSR (>80%)
- 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

Timothy R. Murphy, P.E.
President

Murphy Pavement Technology

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 – 80
2.36 mm (No. 8)	50 – 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
AC Content	5% to 7%

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:

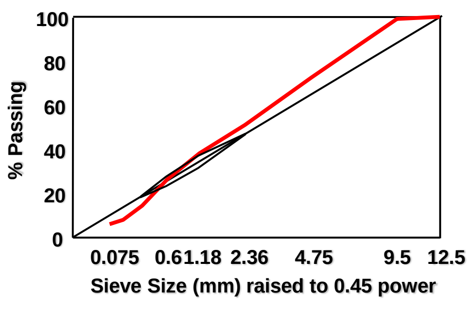
FMM-20	67%	Stone Sand
FMM-02	28%	Natural Sand
Mineral Filler	5%	Manufactured

- 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**

- Large Aggregate Mixture; IL-25.0 mm
- Stone Matrix Asphalt
- IL-4.75-mm
- Fine graded surface course, N50

Bituminous Mixture Design

Date: 7/22/02

Design Number:----->	SMA	roducer Name & Number>	912-09	Howell Asphalt @ Greenup, IL
Design Lab ?(PP,PL,IL ect.)	PP	Material Code Number--->	1843201	BIT CONC SURF CSE SMA N80 12.5

Agg No.	#1	#2	#3	#4	#5	#6	#7	ASPHALT	
Size		039CMM11	039CMM13	038FAM20	004MF01	003FA00		10132	AC PG 76-28
(PROD#)		52103-27	52103-27	50232-02	51832-02	52302-08		2260-01	
(NAME)		US Agg.	US Agg.	Vulcan	Material Ser	Miss. Lime		Asphalt Materials	
(LOC)		Gary Ind.	Gary Ind.	Casey	Nokomis	Ste. Genevi		Urbana	
Agg Blend %		12.0	73.5	9.0	4.5	1.0		100.0	

VCA	
DRC	MIX
37.2	35.4
OK	

Agg No. Sieve Size	#1	#2	#3	#4	#5	#6	#7	Blend	Mix Spec.	Formula By Mass	Formula By Vol.	Range Min	Range Max
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		100	100		
3/4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100	100	100		
1/2	100.0	33.9	100.0	100.0	100.0	100.0	100.0	92.1	90-99	92	93	86	98
3/8	100.0	7.4	85.3	100.0	100.0	100.0	100.0	78.1	50-85	78	79		
#4	100.0	3.4	21.1	100.0	100.0	100.0	100.0	30.4	20-40	30	33	25	35
#8	100.0	2.8	7.9	82.0	100.0	100.0	100.0	19.0	16-24	19	22	14	24
#16	100.0	2.5	5.4	42.0	100.0	100.0	100.0	13.5		14	15		
#30	100.0	2.3	4.7	21.0	100.0	100.0	100.0	11.1		11	13	7	15
#50	100.0	2.3	4.1	10.0	100.0	100.0	100.0	9.7		10	11		
#100	100.0	1.9	3.2	5.0	98.0	100.0	100.0	8.4		8	10		
#200	100.0	1.5	2.5	3.2	88.0	99.0	100.0	7.3	8.0-11.0	7.3	8.3	5.8	8.8

Rap AC ==========>>

	#1	#2	#3	#4	#5	#6	#7	Blend	
Bulk Sp Gr	1	3.449	3.357	2.61	2.8	2.343	1	3.241	Bulk Sp Gr
Apparent Sp G	1	1	1	1	1	1	1		Apparent Sp Gr
Absorption, %	1	1.4	1.7	1.5	1	1	1	1.6	Absorption, %
								1.030	AC Specific Gravity
								1.34	Dust/AC Ratio

BITUMINOUS MIXTURE AGED HOW LONG? 2 HOURS @ 315 F

SUMMARY OF SUPERPAVE GYRATORY TEST DATA

	N-initial			10	N-design			80	Adjusted Gse			
PB:	4.4	4.9	5.4	5.9	4.4	4.9	5.4	5.9	4.4	4.9	5.4	5.9
mb (corr):	2.548	2.555	2.574	2.580	2.797	2.807	2.825	2.827	2.797	2.807	2.825	2.827
Gmm:	3.004	2.979	2.944	2.915	3.004	2.979	2.944	2.915	3.005	2.975	2.946	2.917
Pa:	15.2	14.2	12.5	11.5	6.9	5.8	4.0	3.0	6.9	5.7	4.1	3.1
VMA:	24.8	25.0	24.9	25.1	17.5	17.6	17.5	17.9	17.5	17.6	17.5	17.9
FIELD VMA:	26.1	26.4	26.0	26.3	18.8	19.1	18.9	19.2	18.8	19.1	18.9	19.2
VFA:	38.9	43.2	49.5	54.2	60.7	67.3	76.9	83.1	60.5	67.9	76.6	82.8
Vbe:	9.7	10.8	12.3	13.6	10.6	11.9	13.5	14.9	10.6	12.0	13.4	14.8
Pbe:	3.9	4.4	4.9	5.4	3.9	4.4	4.9	5.4	3.9	4.4	4.9	5.4
Gse:	3.294	3.300	3.293	3.293	3.294	3.300	3.293	3.293	3.296	3.296	3.296	3.296
Pba:	0.5	0.6	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5

Slope: 8.5 Does Design Require Anti-Strip Additive (Yes/No)== No Material Code for Anti-Strip---

NUMBER OF REVS: 80

	% AC	Gmm	Gmb	% Voids Pa	VMA	Design Field VMA	VFA	Gse	Gsb	TSR W/Lime	TSR WO/Lime
OPT. DESIGN DATA:	5.4	2.944	2.825	4.0	17.5	18.9	76.9	3.293	3.241	0.89	0.85
Adjusted Design Data:	5.4	2.944	2.825	4.0	17.6	18.9	77.0	3.296	3.241	0.89	0.85
Minimum Requirements:				4.0	17.0					0.75	0.75
State Results:											

Sieve Size	Washed Point % Passing	Design	Diff
1	100.0	100.0	
3/4	100.0	100.0	
1/2	92.1	92.1	-0.1
3/8	77.9	78.1	0.1
#4	31.8	30.4	-1.3
#8	19.4	19.0	-0.4
#16	14.2	13.5	-0.7
#30	11.8	11.1	-0.7
#50	10.2	9.7	-0.5
#100	8.9	8.4	-0.4
#200	7.5	7.3	-0.2

Design	
CA Ratio	0.16
CA Ratio of FA	0.58
FA Ratio of FA	0.76

Washed	
CA Ratio	0.18
CA Ratio of FA	0.61
FA Ratio of FA	0.75

Remarks: Compacted @ 310 F - Aged 2 Hours

Cellulose Fiber from Hi-Tech Asp. Solutions .3% of total Mix

DATE: 18-Mar-02

SEQ NO:

Bituminous Mixture Design

Design Number : --------> 30BIT9999

Lab preparing the design ? (PP,PL,IL,etc) IL Enter Lab Preparing Design

Producer Name & Number --> IDOT

Material Code Number ----> 18434M Stone Matrix Asphalt-Surface

Agg No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	039CMM11	039CMM13	038FMM20		004MF01		10132M
Source (PROD #)							
(NAME)							
(LOC)							
Aggregate Blend	23.9	62.8	7.0	0.0	6.3	0.0	

Agg No. / Sieve Size	#1	#2	#3	#4	#5	#6	Aggregate Blend
1" (25.0mm)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
3/4"(19.0mm)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/2" (12.5mm)	36.0	100.0	100.0	100.0	100.0	100.0	84.7
3/8" (9.5mm)	8.0	80.0	100.0	100.0	100.0	0.0	65.5
No.4 (4.75mm)	5.0	24.0	97.0	0.0	100.0	0.0	29.4
No.8 (2.36mm)	4.0	6.0	67.0	0.0	100.0	0.0	15.7
No.16 (1.18mm)	3.0	4.0	45.0	0.0	100.0	0.0	12.7
No.30 (600µm)	2.7	3.5	21.0	0.0	100.0	0.0	10.6
No.50 (300µm)	2.5	3.1	16.0	0.0	100.0	0.0	10.0
No.100 (150µm)	2.2	2.7	10.0	0.0	98.0	0.0	9.1
No.200(75µm)	1.8	2.3	5.2	0.0	95.0	0.0	8.2

Mixture Composition Specification	FORMULA	FORMULA RANGE Min	Max
100	100		
100	100		
82-100	85		
26-65	65		
20-30	29	24	34
16-24	16	11	21
	13		
12-16	11		
12-15	10	6	14
	9		
8-12	8.2	6.7	9.7

	#1	#2	#3	#4	#5	#6	Blend
Bulk Sp Gr	3.333	3.406	2.698	1.000	2.824	1.000	3.286
Apparent Sp Gr	3.503	3.626	2.801	1.000	2.824	1.000	3.464
Absorption, %	1.50	1.80	1.40	1.00	1.00	1.00	1.65
						SP GR AC	1.034

Dust/AC Ratio: 1.39

SUMMARY OF SUPERPAVE GYRATORY DESIGN DATA

BITUMINOUS MIXTURE AGED 2 HOURS @ 150

DATA for N-initial: 9	AC, %MIX	(Gmb)	(Gmm)	(Pa)	VMA	VFA	Vbe	Pbe	Pba
MIX 1	5.0	2.521	3.002	16.0	27.1	40.9	11.09	4.55	0.47
MIX 2	5.5	2.548	2.974	14.3	26.7	46.4	12.39	5.03	0.50
MIX 3	6.0	2.578	2.940	12.3	26.3	53.1	13.94	5.59	0.43
MIX 4	6.5	2.594	2.916	11.0	26.2	57.9	15.16	6.04	0.49

DATA for N-design: 80		(Gmb)	(Gmm)	(Pa)	VMA	VFA	Vbe	Pbe	Gse	Pba
MIX 1	5.0	2.782	3.002	7.3	19.6	62.5	12.24	4.55	3.336	0.47
MIX 2	5.5	2.804	2.974	5.7	19.4	70.5	13.64	5.03	3.339	0.50
MIX 3	6.0	2.835	2.940	3.6	18.9	81.1	15.33	5.59	3.332	0.43
MIX 4	6.5	2.850	2.916	2.2	18.9	88.2	16.66	6.04	3.338	0.49

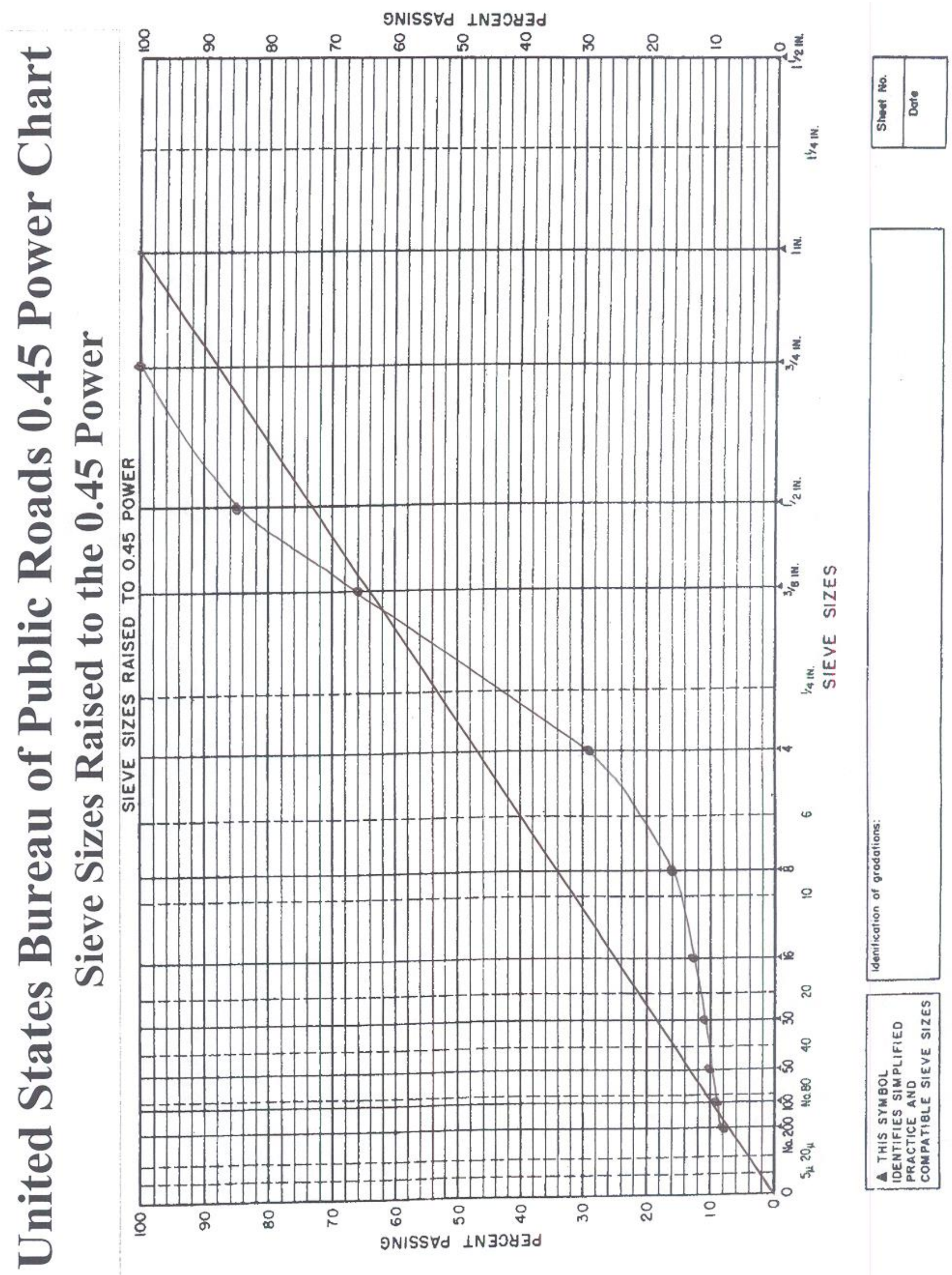
	NUMBER OF GYRATIONS	%AC	Gmb	Gmm	%VOIDS (Pa) Target	VMA	VFA	Gse	Gsb	TSR
OPTIMUM DESIGN DATA @Ndes: --->	80	5.9	2.831	2.949	4.0	19.1	79.1	3.336	3.286	#VALUE!

REMARKS:

Tested by : ____________________

Reviewed by : ____________________

Final Approval : ____________________


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:
Sheet No.
Date

Bituminous Mixture Design

DATE: 26-Mar-02

SEQ NO:

Design Number : ---------> 30BIT9998

Lab preparing the design ? (PP,PL,IL,etc) IL Enter Lab Preparing Design

Producer Name & Number --> IDOT

Material Code Number ----> 18435M Stone Matrix-Binder

Agg No.	#1	#2	#3	#4	#5	#6	ASPHALT
Size	032CMM00		038FMM20		004MF01		10132M
Source (PROD #)							
(NAME)							
(LOC)							
Aggregate Blend	80.9	0.0	12.5	0.0	6.6	0.0	

Agg No. / Sieve Size	#1	#2	#3	#4	#5	#6	Aggregate Blend
1" (25.0mm)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
3/4"(19.0mm)	100.0	0.0	100.0	0.0	100.0	0.0	100.0
1/2" (12.5mm)	78.0	0.0	100.0	0.0	100.0	0.0	82.2
3/8" (9.5mm)	36.0	0.0	100.0	0.0	100.0	0.0	48.2
No.4 (4.75mm)	4.5	0.0	100.0	0.0	100.0	0.0	22.7
No.8 (2.36mm)	3.0	0.0	97.0	0.0	100.0	0.0	21.2
No.16 (1.18mm)	3.0	0.0	62.5	0.0	100.0	0.0	16.8
No.30 (600µm)	3.0	0.0	32.6	0.0	100.0	0.0	13.1
No.50 (300µm)	3.0	0.0	14.2	0.0	100.0	0.0	10.8
No.100 (150µm)	3.0	0.0	5.2	0.0	98.0	0.0	9.5
No.200(75µm)	2.3	0.0	2.9	0.0	92.0	0.0	8.3

Mixture Composition Specification	FORMULA	FORMULA RANGE Min	Max
	100		
100	100		
82-100	82		
65max	48		
20-30	23	18	28
16-24	21	16	26
	17		
12-16	13		
12-15	11	7	15
	10		
8-12	8.3	6.8	9.8

	#1	#2	#3	#4	#5	#6	Blend
Bulk Sp Gr	2.657	1.000	2.723	1.000	2.824	1.000	2.676
Apparent Sp Gr	2.761	1.000	2.752	1.000	2.824	1.000	2.764
Absorption, %	1.41	1.00	1.10	1.00	1.00	1.00	1.34
						SP GR AC	1.034

Dust/AC Ratio: 1.46

SUMMARY OF SUPERPAVE GYRATORY DESIGN DATA

BITUMINOUS MIXTURE AGED 2 HOURS @ 150 CELSIUS

DATA for N-initial 9

	AC, %MIX	(Gmb)	(Gmm)	(Pa)	VMA	VFA	Vbe	Pbe	Pba
MIX 1	5.0	2.036	2.526	19.4	27.7	30.0	8.32	4.22	0.82
MIX 2	5.5	2.057	2.505	17.9	27.3	34.6	9.45	4.75	0.79
MIX 3	6.0	2.065	2.485	16.9	27.4	38.4	10.54	5.27	0.77
MIX 4	6.5	2.074	2.467	16.0	27.5	42.1	11.59	5.78	0.77

DATA for N-design 80

	AC, %MIX	(Gmb)	(Gmm)	(Pa)	VMA	VFA	Vbe	Pbe	Gse	Pba
MIX 1	5.0	2.377	2.526	5.9	15.6	62.3	9.71	4.22	2.733	0.82
MIX 2	5.5	2.391	2.505	4.6	15.5	70.7	10.98	4.75	2.732	0.79
MIX 3	6.0	2.403	2.485	3.3	15.6	78.8	12.26	5.27	2.730	0.77
MIX 4	6.5	2.411	2.467	2.3	15.7	85.5	13.47	5.78	2.730	0.77

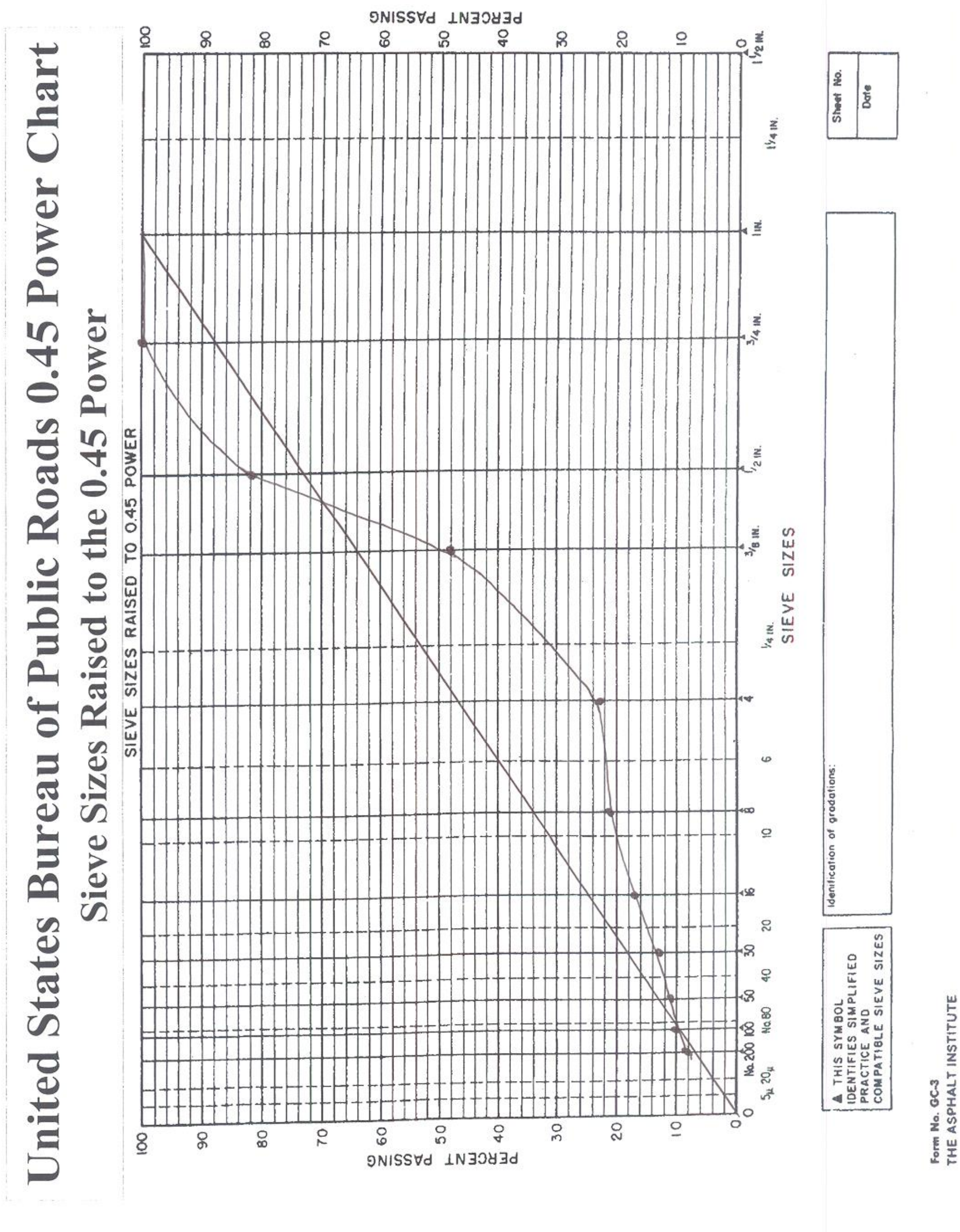
	NUMBER OF GYRATIONS	%AC	Gmb	Gmm	%VOIDS (Pa) Target	VMA	VFA	Gse	Gsb	TSR
OPTIMUM DESIGN DATA @Ndes: --->	80	5.7	2.398	2.498	4.0	15.5	74.2	2.731	2.676	#DIV/0!

REMARKS:

Tested by : ____________________

Reviewed by : ____________________

Final Approval : ____________________


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:
Sheet No.
Date
▲ THIS SYMBOL IDENTIFIES SIMPLIFIED PRACTICE AND COMPATIBLE SIEVE SIZES
Form No. GC-3
THE ASPHALT INSTITUTE

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	$T = [\{(X - F) / 100\} \times M]$

$T = [\{(94.4 - 0.3) / 100\} \times 10000\} = 9410.0$

Calculate the adjusted weight of the individual aggregates.

Eq. 2	$W = T \times (P / 100)$

$W_{aggr1} = 9410 \times (61.0 / 100) = 5740.1$

$W_{aggr2} = 9410 \times (20.0 / 100) = 1882.0$

$W_{aggr3} = 9410 \times (16.0 / 100) = 1505.6$

$W_{aggr4} = 9410 \times (3.0 / 100) = 282.3$

Calculate the weight of fibers

$W_f = M \times (F / 100)$

$W_f = 10000 \times (0.3 / 100) = 30.0$

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

$W_{ac} = M \times (AC / 100)$

$W_{ac} = 10000 \times (5.6 / 100) = 560$

Check the total weight of mix

$T_m = T_{af} + W_{ac}$

$T_m = 9440.0 + 560.0 = 10000$ **Checks, equals "M"**

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Effective Date: April 1, 2012
Revised Date: February 1, 2014

1 **SCOPE**

1.1. This test procedure covers the determination of bulk density ("unit weight") of aggregate in a compacted or loose condition, and calculated voids between particles in fine, coarse, or mixed aggregates based on the same determination. This test method is applicable to aggregates not exceeding 125mm (5 in.) in nominal maximum size.

Note 1 – Unit weight is the traditional terminology used to describe the property determined by this test method, which is weight per unit volume (more correctly, mass per unit volume or density).

1.2. The values stated in either inch-pound units or acceptable metric units are to be regarded separately as standard, as appropriate for a specification with which this test method is used. An exception is with regard to sieve sizes and nominal size of aggregate, in which the metric values are the standard as stated in ASTM E 11. Within the text, inch-pound units are shown in brackets. The values stated in each system in ASTM E 11. Within the text, inch-pound units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other, without combining values in any way.

1.3. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2 **REFERENCED DOCUMENTS**

2.1 Illinois Test Procedures (ITP):

- ITP 2, Sampling of Aggregates
- ITP 84, Specific Gravity and Absorption of Fine Aggregate
- ITP 85, Specific Gravity and Absorption of Coarse Aggregate
- ITP 248, Reducing Samples of Aggregate to Testing Size

Illinois Specifications:

- Illinois Specification 201 Aggregate Gradation Sample Size Table

AASHTO Standards:

- M 231, Weighing Devices Used in the Testing of Materials
- T 121M/T 121 (Illinois Modified), Density (Unit Weight), Yield and Air Content (Gravimetric) of Concrete

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2.2. *ASTM Standards:*

- C 29/C 29M, Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate
- C 125, Standard Terminology Relating to Concrete and Concrete Aggregates
- C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- D 123, Standard Terminology Relating to Textiles
- E 11, Woven Wire Test Sieve Cloth and Test Sieves
- E 29 (Illinois Modified), Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

3. TERMINOLOGY

3.1. *Bulk density*, n – of aggregate, the mass of a unit volume of bulk aggregate material, in which the volume includes the volume of the individual particles and the volume of the voids between the particles. Expressed in lb/ft^3 ($kg/m^{3)}$.

3.1.1 *Discussion* – units of mass are the pound (lb), the kilogram (kg), or units derived from these. Mass may also be visualized as equivalent to inertia, or the resistance offered by a body to change of motion (acceleration). Masses are compared by weighing the bodies, which amounts to comparing the forces of gravitation acting on them. ASTM D 123.

3.2 *Unit weight*, n - weight (mass) per unit volume. (Deprecated term - used preferred term bulk density.)

3.2.1. *Discussion* – the term weight means the force of gravity acting on the mass.

3.3 *Weight*, n – the force exerted on a body by gravity. (See also mass.)

3.3.1 *Discussion* – weight is equal to the mass of the body multiplied by the acceleration due to gravity. Weight may be expressed in absolute units (poundals, newtons) or in gravitational units (lbf, kgf), for example: on the surface of the earth, a body with a mass of 1lb has a weight of 1 lbf (approximately 32.2 poundals or 4.45N), or a body with a mass of 1kg has a weight of 1kgf (approximately 9.81N). . Since weight is equal to mass times the acceleration due to gravity the weight of a body will vary with the location where the weight is determined, while the mass of the body remains constant. On the surface of the earth, the force of gravity imparts to a body that is free to fall an acceleration of approximately 32.2 ft/s^2 ($9.81m/s^{2)}$. ASTM D 123.

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3.4 *Voids*, n – in unit volume of aggregate, the space between particles in an aggregate mass not occupied by solid mineral matter.

3.4.1 *Discussion* – voids within particles, either permeable of impermeable, are not included in voids as determined by 13.2, herein. .

4. SIGNIFICANCE AND USE

4.1. This test method is often used to determine bulk density values that are necessary for use for many methods of selecting proportions for concrete mixtures.

4.2. The bulk density also may be used for determining mass/volume relationships for conversions in purchase agreements. However, the relationship between degree of compaction of aggregates in a hauling unit or stockpile and that achieved in this method is unknown. Further, aggregates in hauling units and stockpiles usually contain absorbed and surface moisture (the latter affecting bulking), while this method determines the bulk density on a dry basis.

4.3. A procedure is included for computing the percentage of voids between the aggregate particles based on the bulk density determined by this method.

5. APPARATUS

5.1. *Balance* – The balance shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of AASHTO M 231.

5.2. *Tamping Rod* – A round, straight steel rod, 5/8 " (16mm) in diameter and a minimum of 23 inches (584mm) long, having one end rounded to a hemispherical tip of the same diameter as the rod.

5.3. *Measure* – A cylindrical metal measure, preferably provided with handles. It shall be watertight, with the top and bottom true and even, and sufficiently rigid to retain its form under rough usage. The measure should have a height approximately equal to the diameter, but in no case shall the height be less than 80 percent nor more than 150 percent of the diameter. The capacity of the measure shall conform to the limits in Table 1 for the aggregate size to be tested. The thickness of metal in the measure shall be as described in Table 2. The top rim shall be smooth and plane within 0.01 in. (0.25mm) and shall be parallel to the bottom within 0.5° (Note 2). The interior wall of the measure shall be a smooth and continuous surface.

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Table 1 – Capacity of Measures

Nominal Maximum Size of Aggregate		Capacity of Measure[a]	
inmm	mm in	Ft^3 L (m^3)	L (m^3) ft^3
½	12.5	1/10	2.8 (0.0028)
1	25.0	1/3	9.3 (0.0093)
1 1/2	37.5	1/2	14 (0.014)
3	75	1	28 (0.028)
4	100	2 1/2	70 (0.070)
5	125	3 1/2	100 (0.100)

The indicated size of measure shall be used to test aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95 percent of the nominal volume listed.

Note 2 – The top rim is satisfactorily plane if a 0.01 in (0.25mm) feeler gauge cannot be inserted between the rim and a piece of 6mm (1/4 in.) or thicker plate glass laid over the measure. The top and bottom are satisfactorily parallel if the slope between pieces of plate glass in contact with the top and bottom does not exceed 0.87 percent in any direction.

5.3.1. If the measure also is to be used for testing for bulk density of freshly mixed concrete according to AASHTO T 121M/T 121 (Illinois Modified), the measures shall be made of steel or other suitable metal not readily subject to attack by cement. Reactive materials, such as aluminum alloys are permitted, where as a consequence of an initial reaction, a surface film is formed which protects the metal against further corrosion.

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5.3.2. Measures larger than nominal 1 ft^3 (28L) capacity shall be made of steel for rigidity, or the minimum thicknesses of metal listed in Table 2 should be suitably increased.

5.4. *Shovel or Scoop* – A shovel or scoop of convenient size for filling the measure with aggregate.

5.5. *Calibration Equipment*

5.5.1. *Plate Glass* – A piece of plate glass, preferably at least ¼ in (6mm) thick and at least 1in (25mm) larger than the diameter of the measure to be calibrated.

Table 2 – Requirements for Measures

	Thickness of Metal, Min		
Capacity of Measure	Bottom	Upper 1 ½ in. or 38 mm of Wall[a]	Remainder of Wall
Less than 0.4 ft^3	0.20 in	0.10 in	0.10 in
0.4 ft^3 to 1.5 ft^3 incl	0.20 in	0.20 in	0.12 in
Over 1.5 to 2.8 ft^3, incl	0.40 in	0.25 in	0.15 in
Over 2.8 to 4.0 ft^3, incl	0.50 in	0.30 in	0.20 in
Less than 11 L	5.0 mm	2.5 mm	0.10 mm
11 to 42 L, incl	5.0 mm	5.0 mm	3.0 mm
Over 42 to 80 L, incl	10.0 mm	6.4 mm	3.8 mm
Over 80 to 133 L, incl	13.0 mm	7.6 mm	5.0 mm

The added thickness in the upper portion of the wall may be obtained by placing a reinforcing band around the top of the measure.

5.5.2. *Grease* – A supply of water insoluble grease.

Note 3 – Petrolatum, vacuum grease, water pump grease, or chassis grease are examples of suitable material used to form a seal between the glass plate and measure.

5.5.3. *Thermometer* – A thermometer having a range of at least 50 to 90˚F (10 to 32°C) and that is readable to at least 1˚F (0.5°C).

5.5.4 *Balance* – A balance as described in Section 5.1.

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5.6 Source of Heat – An oven of sufficient size, specifically built for drying, capable of maintaining a uniform temperature of 230±9°F (110±5°C) 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. SAMPLING

6.1 Field samples of aggregate shall be taken according to ITP 2. Field sample size shall conform to the minimum requirements in the Illinois Specification 201. Reduction of field samples shall be according to ITP 248.

7. SAMPLE

7.1 The size of sample shall be approximately 125 to 200 percent of the quantity required to fill the measure and shall be handled in a manner to avoid segregation. 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 230±9°F (110±5°C). 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.

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.

When more than on 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.

Note 4 – When testing Recycled Asphalt Pavement (RAP) samples shall be air dried to a constant mass.

8. CALIBRATION OF MEASURE

8.1 Measures shall be recalibrated at least once a year or whenever there is reason to question the accuracy of the calibration.

8.2 Place a thin layer of grease on the rim of the measure to prevent leakage of water from the measure.

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8.3 Determine the mass of the plate glass and measure to the nearest 0.1 lb (0.05kg).

8.4 Fill the measure with water that is at room temperature and cover with the plate glass in such a way as to eliminate bubbles and excess water. Remove any water that may have overflowed onto the measure or plate glass.

8.5 Determine the mass of the water, plate glass and measure to the nearest 0.1 lb (0.05kg).

8.6 Measure the temperature of the water to the nearest 1˚F (0.5°C) and determine its density from Table 3, interpolating if necessary.

Table 3 – Density of Water

Temperature			
˚F	˚C	Lb/ft³	Lg/m³
60	15.6	62.366	999.01
65	18.3	62.336	998.54
70	21.1	62.301	997.97
(73.4)	(23.0)	(62.274)	(997.54)
75	23.9	62.261	997.32
80	26.7	62.216	996.59
85	29.4	62.166	995.83

8.7. Calculate the volume, *V*, of the measure. Alternatively, calculate the factor, *F*, for the measure.

$$V = \frac{B-C}{D} \quad (1)$$

$$F = \frac{D}{B-C} \quad (2)$$

where:

V	=	Volume of the measure, ft^3 (m^3)
B	=	Mass of the water, plate glass and measure, lb (kg)
C	=	Mass of the plate glass and measure, lb (kg)
D	=	Density of the water for the measured lb/ft^3 (kg/m^3), and
F	=	Factor for the measure, $1/ft^3$ ($1/m^3$)

Note 5 – For the calculation of bulk density, the volume of the measure in acceptable metric units should be expressed in cubic meters, or the factor as l/m^3. However, for convenience the size of the measure may be expressed in liters (equal to $m^3/1000$).

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9. SELECTION OF PROCEDURE

9.1 The compact bulk density shall be determined by the rodding procedure for aggregates having a nominal maximum size of 1 1/2 in (37.5mm) or less, or by jigging procedure for aggregates have a nominal maximum size greater than 1 1/2im (37.5mm) and not exceeding 5in (125mm).

10. RODDING PROCEDURE

10.1 Fill the measure one-third full and level the surface with the fingers. Rod the layer of aggregate with 25 strokes of the tamping rod evenly distributed over the surface. Fill the measure two-thirds full and again level and rod as above. Finally, fill the measure to overflowing and rod again in the manner previously mentioned. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure. The tamping rod may be used as a straightedge.

10.2 In rodding the first layer, do not allow the rod to strike the bottom of the measure forcibly. In rodding the second and third layers, use vigorous effort, but not more force than to cause the tamping rod to penetrate to the previous layer of aggregate.

Note 6 – In rodding the larger sizes of coarse aggregate, it may not be possible to penetrate the layer being consolidated, especially with angular aggregates. The intent of the procedure will be accomplished if vigorous effort is used.

10.3 Determine the mass of the measure plus contents, and the mass of the measure alone and record the values to the nearest 0.1lb (0.05kg).

11. JIGGING PROCEDURE

11.1 Fill the measure in three approximately equal layers as described in Section 10.1, compacting each layer by placing the measure on a firm base, such as a cement-concrete floor, raising the opposite sides alternately about 2in (50mm), and allowing the measure to drop in such a manner as to hit with a sharp, slapping blow. The aggregate particles, by this procedure, will arrange themselves in a densely compacted condition. Compact each layer by dropping the measure 50 times in the manner described, 25 times on each side. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

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11.2 Determine the mass of the measure plus contents, and the mass of the measure alone, and record the values to the nearest 0.1lb (0.05kg).

12. CALCULATION OF RESULTS

12.1 Unit Weight – Calculate the unit weight for the rodding or jigging procedure as follows:

$$M = \frac{G-T}{V} \quad (3)$$

or,

$$M = G - T \, X \, F \quad (4)$$

where:

M	=	bulk density of aggregate, lb/ft^3 (kg/m^3);
G	=	mass of aggregate plus the measure, lb (kg);
T	=	mass of the measure, lb (kg);
V	=	volume of measure, ft^3 (m^3); and
F	=	factor for measure, ft^3 (m^{-3}).

12.1.1. The bulk density determined by this method is for aggregate in an oven-dry condition. If the bulk density in terms of saturated surface-dry (SSD) condition is desired, use the exact procedure in this method, and then calculate the SSD bulk density by the following formula:

$$M_{SSD} = M\left[1 + \left(\frac{A}{100}\right)\right] \quad (5)$$

where:

M_{SSD}	=	bulk density in SSD condition, lb/ft^3 (kg/m^3); and
A	=	absorption, percent, determined in accordance with ITP 84 or ITP 85.

12.2. *Void Content* – Calculate the void content in the aggregate using the unit weight determined by either the rodding or jigging procedures as follows:

$$\text{Voids \%} = \frac{100\,[(S \times W)-M]}{S \times W} \quad (6)$$

where:

M	=	bulk density of aggregate, lb/ft^3 (kg/m^3);

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S	=	bulk specific gravity (dry basis) as determined in accordance with ITP 84 or ITP 85; and
W	=	density of water, 62.3 lb/ft^3 (998 kg/m^3).

12.3 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

13. REPORT

13.1. Report the results for unit weight to the nearest 1 lb/ft^3 (1 kg/m^3). All rounding shall be according to ASTM E 29 (Illinois Modified).

13.1.1. Bulk density by rodding,

13.1.2. Bulk density by jigging,

13.2. Report the results for void content to the nearest one percent as follows:

13.2.1. Voids in aggregate compacted by rodding, percent,

13.2.2. Voids in aggregate compacted by jigging, percent

13.3 Indicate the procedure used.

14. PRECISION AND BIAS

14.1. The following estimates of precision for this method are based on results from the AASHTO Materials Reference laboratory (AMRL) Proficiency Sample Program, with testing conducted by this method and ASTM C 29. There are no significant differences between the two methods. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

14.2 *Coarse Aggregate (bulk density):*

14.2.1. Single-Operator Precision – The single-operator standard deviation has been found to be (0.88 lb/ft^3 (14 kg/m^3) (1s). Therefore, results of two properly conducted tests by

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the same operator on similar material should not differ by more than 2.50 lb/^{ft3} (40 kg/m^3) (d2s).

14.2.2. *Multilaboratory Precision* – The multilaboratory standard deviation has been found to be 1.87 lb/ft^3 (30 kb/m3) (1s). Therefore, results of two properly conducted tests from two different laboratories on similar material should not differ by more than 5.3 lb/ft^3 (85 kg/m^3) (d2s).

14.3. *Fine Aggregate (bulk density):*

14.3.1. *Single-Operator Precision* – The single-operator standard deviation has been found to be (0.88 lb/ft^3 (14 kg/m^3) (1s). Therefore, results of two properly conducted tests from the same operator on similar material should not differ by more than 40 kg/m^3 (2.5lb/ft^3) (d2s

14.3.2. *Multialaboratory Precision* – The multilaboratory standard deviation has been found to be 2.76 lb/ft^3 (44 kg/m^3) (1s). Therefore, results of two properly conducted tests from two different laboratories on similar material should not differ by more than 7.8 lb/ft^3 (125 kg/m^3) (d2s).

14.4 No precision data on void content are available. However as the void content in aggregate is calculated from bulk density and bulk specific gravity, the precision of the voids content reflects the precision of these measured parameters given in Sections 15.2 and 15.3 of this method and in ITP 84 and ITP 85.

14.5 *Bias* – The procedure in this test method for measuring bulk density and void content has no bias because the values for bulk density and void content can be defined only in terms of a test method.

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HOT-MIX ASPHALT MIXTURE IL-9.5FG

Effective: July 1, 2005
Revised: July 15, 2013

Description. This work shall consist of constructing fine graded hot-mix asphalt (HMA) surface course-or leveling binder with an IL-9.5FG mixture. Work shall be according to Sections 406, 407 and 1030 of the Standard Specifications, except as modified herein.

Equipment. Add the following to Article 406.03

(i) Non-Vertical Impact Roller……………………………………………1101.01

Materials. Revise Article 1003.03(c) of the Standard Specifications to read:

"(c) Gradation. The fine aggregate gradation for all HMA shall be FA 1, FA 2, FA 20, FA 21, or FA 22. For mixture IL-9.5FG, the fine aggregate fraction shall consist of at least 67 percent manufactured sand meeting FA 20, FA 21 or FA 22 gradation. The manufactured sand shall be stone sand, slag sand, steel slag sand, or combinations thereof."

Mixture Design. Add the following to the table in Article 1030.04(a)(1):

"High ESAL, MIXTURE COMPOSITION (% PASSING) 1/		
Sieve Size	IL-9.5FG	
	min	max
1 1/2 in (37.5 mm)		
1 in. (25 mm)		
3/4 in. (19 mm)		
1/2 in. (12.5 mm)		100
3/8 in. (9.5 mm)	90	100
#4 (4.75 mm)	65	80
#8 (2.36 mm)	50	65
#16 (1.18 mm)	25	40
#30 (600 µm)	15	30
#50 (300 µm)	8	15
#100 (150 µm)	6	10
#200 (75 µm)	4	6.5
Ratio Dust/Asphalt Binder		1.0

Revise the table in Article 1030.04(b)(1) of the Standard Specifications to read:

“VOLUMETRIC REQUIREMENTS High ESAL					
	Voids in the Mineral Aggregate (VMA), % minimum				Voids Filled with Asphalt Binder (VFA), %
N_{design}	IL-25.0	IL-19.0	IL-12.5	IL-9.5	
50	12.0	13.0	14.0	15 [1/]	65 - 78
70					65 - 75 [2/]
90					
105					

1/ The VMA for IL-9.5FG shall be a minimum of 15.0 percent.
2/ The VFA range for IL-9.5FG shall be 65 - 78 percent.”

Quality Control/Quality Assurance (QC/QA). Revise the second table in Article 1030.05(d)(4) to read:

DENSITY CONTROL LIMITS			
Mixture Composition		Parameter	Individual Test
IL-4.75		Ndesign = 50	93.0 – 97.4% [1/]
IL-9.5FG	Lifts < 1.25 in. (32 mm)	N_{design} 50 - 105	90.0 – 95.0% [1/]
	Lifts ≥ 1.25 in. (32 mm)	N_{design} 50 - 105	92.0 – 96.0%
IL-9.5, IL-12.5		N_{design} ≥ 90	92.0 – 96.0 %
IL-9.5, IL-9.5L, IL-12.5		N_{design} < 90	92.5 – 97.4 %
IL-19.0, IL-25.0		N_{design} ≥ 90	93.0 – 96.0 %
IL-19.0, IL-19.0L, IL-25.0		N_{design} < 90	93.0 – 97.4 %
All Other		N_{design} = 30	93.0 [2/] - 97.4 %

1/ Density shall be determined by cores or by correlated, approved thin lift nuclear gauge
2/ 92.0 % when placed as first lift on an unimproved subgrade.

CONSTRUCTION REQUIREMENTS

Leveling Binder. Revise the table and second paragraph of Article 406.05(c) of the Standard Specifications to read:

“Leveling Binder	
Nominal, Compacted, Leveling Binder Thickness, in. (mm)	Mixture Composition
≤ 1 1/4 (32)	IL 4.75, IL-9.5, IL-9.5 FG, or IL-9.5L
> 1 1/4 to 2 (32 to 50)	IL-9.5, IL-9.5FG, IL-9.5L, or IL-12.5

The density requirements of Article 406.07 (c) shall apply for leveling binder, machine method, when the nominal, compacted thickness is: 3/4 in. (19 mm) or greater for IL-9.5FG and IL 4.75 mixtures, 1 1/4 in. (32 mm) or greater for IL-9.5 and IL-9.5L mixtures, and 1 1/2 in. (38 mm) or greater for IL-12.5 mixtures."

Compaction. Revise Table 1 in Article 406.07(a) of the Standard Specifications to read:

"TABLE 1 - MINIMUM ROLLER REQUIREMENTS FOR HMA[4/]

	Breakdown Roller (one of the following)	Intermediate Roller	Final Roller (one or more of the following)	Density Requirement
Level Binder: (When the density requirements of Article 406.05(c) do not apply.)	P [3/]	- -	V_S, P [3/], T_B, T_F, 3W	To the satisfaction of the Engineer.
Level Binder: (When placed at ≤ 1 ¼ (32 mm) and density requirements of Article 406.05 (c) apply.)	V_N,T_B, 3W	P [3/]	V_S, T_B, T_F	As specified in Articles: 1030.05(d)(3), (d)(4), and (d)(7).
Level Binder[1/] >1 ¼ in. (32 mm) Binder and Surface [1/]	V_D, P [3/], T_B, 3W	P [3/]	V_S, T_B, T_F	As specified in Articles: 1030.05(d)(3), (d)(4), and (d)(7).
Bridge Decks [2/]	T_B	- -	T_F	As specified in Articles: 582.05 and 582.06.

1/ If the average delivery at the job site is 85 ton/hr (75 metric ton/hr) or less, any roller combination may be used provided it includes a steel wheeled roller and the required density and smoothness is obtained.

2/ One T_B may be used for both breakdown and final rolling on bridge decks 300 ft (90 m) or less in length, except when the air temperature is less than 60 ºF (15 ºC).

3/ A vibratory roller (V_D) may be used in lieu of the pneumatic-tired roller on mixtures containing polymer modified asphalt binder.

4/ For mixture IL-4.75 a minimum of two T_B and one T_F roller shall be provided. Both the T_B and T_F rollers shall be a minimum of 280 lb/in. (49 N/mm). P and V rollers will not be permitted.

Add the following to EQUIPMENT DEFINITION

V_N - Non-Vertical Impact roller operated in a mode that will provide non-vertical impacts and operate at a speed to produce not less than 10 impacts/ft (30 impacts/m).

Rollers. Add the following to Article 1101.01 of the Standard Specifications:

h) The non-vertical impact roller shall be self-propelled and provide a smooth operation when starting, stopping or reversing directions. Non-vertical impact drum(s) amplitude and frequency shall be approximately the same in each direction and meet the following minimum requirements: drum diameter 48 in. (1200 mm), length of drum 66 in. (1650 mm), unit static force on drum(s) 125 lb/in. (22 N/m), adjustable eccentrics, and reversible eccentrics on non-driven drum(s). The total applied force and the direction it is applied for various combinations of VPM and eccentric positions shall be shown on decals on the roller or on a chart maintained with the roller. The roller shall be equipped with water tanks and sprinkling devices, or other approved methods, which shall be used to wet the drums to prevent material pickup.

Basis of Payment. Add the following two paragraphs after the third paragraph of Article 406.14 of the Standard Specifications:

"Mixture IL-9.5FG will be paid for at the contract unit price per ton (metric ton) for LEVELING BINDER (HAND METHOD), IL-9.5FG, of the Ndesign specified; LEVELING BINDER (MACHINE METHOD), IL-9.5FG, of the Ndesign specified; or HOT-MIX ASPHALT SURFACE COURSE, IL-9.5FG, of the Ndesign specified.

Mixture IL-9.5FG in which polymer modified asphalt binders are required will be paid for at the contract unit price per ton (metric ton) for POLYMERIZED LEVELING BINDER (HAND METHOD), IL-9.5FG, of the Ndesign specified; POLYMERIZED LEVELING BINDER (MACHINE METHOD), IL-9.5FG, of the Ndesign specified; or POLYMERIZED HOT-MIX ASPHALT SURFACE COURSE, IL-9.5FG, of the Ndesign specified."

HMA IL-9 5 FG

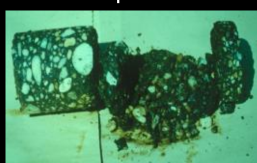
Stripping of Hot Mix Asphalt

- 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

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

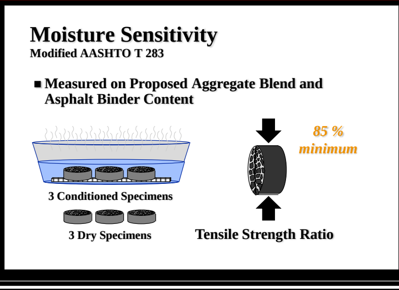
Stripping Contributes to Pavement Distresses including:

- Rutting,
- Raveling, and
- Cracking.

Tests to Evaluate Stripping

- AASHTO T-283
- Visual Stripping Evaluation

Testing Protocol



Specimen Preparation

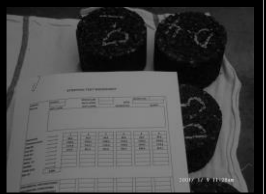
- Illinois uses 6-inch (150mm) specimens, compacted using the Gyratory compactor.

Specimen Preparation

Compact pilot specimens (at optimum AC) to a void level of 7% +/- 0.5%. 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% +/- 0.5% 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.

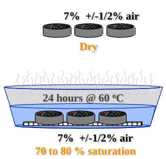
Specimen Preparation

- 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

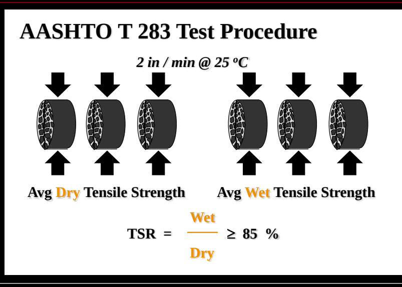
- **Unconditioned "Dry" Set**
  - **2 hrs @ 25°C before testing**
- **Conditioned "Wet" Set**
  - **24 hrs @ 60°C**
  - **2 hrs @ 25°C before testing**



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



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 may be obtained from the Department and is typically updated throughout the year.

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

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 / (100 – Lime %) / 100 = ____________ g * (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***

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

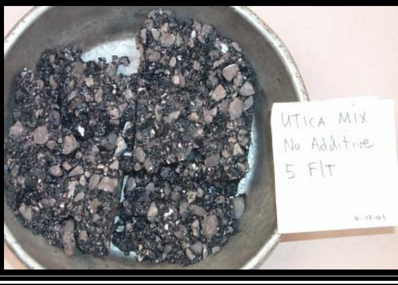
- Assign a strip rating to the fine aggregate of the split face based on the following descriptions:
  - 1 - less than 10% of the entire area of all the fine aggregate particles viewed is stripped
  - 2 - between 10% and 25% of the entire area of all the fine aggregate particles viewed is stripped
  - 3 - more than 25% of the entire area of all the fine aggregate particles viewed is stripped

Visual Identification of Stripping Procedure

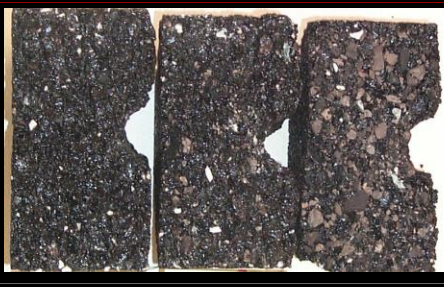
- Report the individual strip ratings for coarse and fine aggregate, the composite strip rating, and the description on the strip rating form.
- Include any comments or special notes about the observations from that sample.

Visual Strip Rating: Coarse & Fines = 1.0

Visual Strip Rating:
Coarse = 3.0

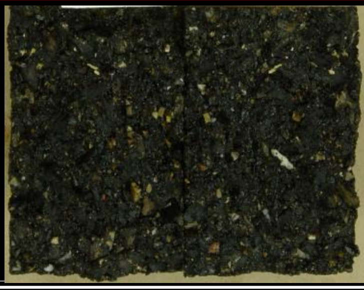


Visual Strip Rating:
Coarse = 1.0, 2.0, & 3.0



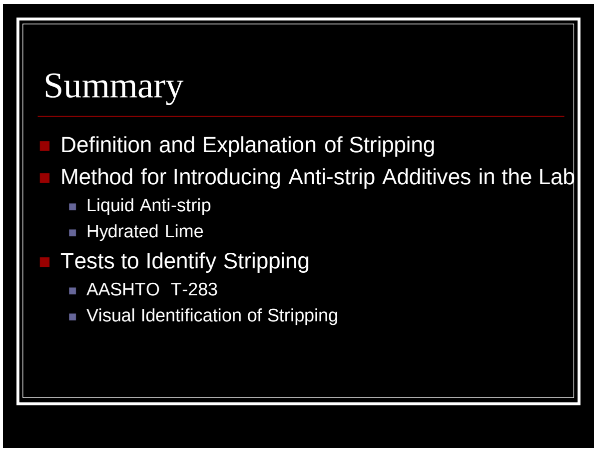
Visual Strip Rating:
Fines = 3.0

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

A. General

B. Aggregate/Asphalt Compatibility

C. Tensile Strength Ratio (TSR)

D. Additives

1. Anti-Strip
   (a) Procedure for Introducing into Mixture
   (b) Calculating Quantity
2. Hydrated Lime
   (a) Procedure for Introducing into Mixture
   (b) Calculating Quantity

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 0.75 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, Marshall bricks 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 assuming it is on IDOT's current approved list.

See IDOT's Web Site

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!

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STRIPPING OF BITUMINOUS MIXTURES VISUAL IDENTIFICATION AND CLASSIFICATION

November 2003

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 phenomenon in numerical terms. This procedure is applicable to both laboratory compacted specimens and pavement cores[1].

INSTRUCTIONS

1. This procedure should only be applied to freshly split specimen faces, such as those obtained from split tensile testing. The observation of cored, sawed, or chiseled faces should be avoided, as the true condition of the stripping will be obscured.

2. The rating should be completed within ten (10) minutes of splitting for maximum clarity. When the specimens dry out, they may look considerably different. The aggregate surfaces should be examined carefully to determine if the asphalt was stripped from the aggregate as a result of being "washed" by water before the specimen was split or if the asphalt was "ripped apart" near the asphalt/aggregate interface during the split tensile test. Also, aggregate surfaces with small, relatively isolated, globules of asphalt are quite likely not stripped.

3. Special attention should 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

[1] Pavement cores taken from the field should be sealed in plastic bags immediately after coring in order to retain their in-situ moisture. Pavement cores should be split and visually rated as soon as possible after coring to avoid any "healing" of the asphalt to the aggregate surfaces.

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 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 should 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 (3) 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.

STRIP RATING FORM

PROJECT ______________________________ DATE ____________

GENERAL COMMENTS ______________________________

SPECIMEN #	TYPE OF CONDITIONING	COARSE RATING	FINE RATING	COMMENTS

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Procedure for Introducing Additives to Hot Mix Asphalt Mixtures and Testing in the Lab Appendix B17

Effective Date: March 7, 2005
Revised: January 1, 2013

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

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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-modified AASHTO T-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-modified AASHTO T-248.

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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.

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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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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	MARB LEHD	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	46.0	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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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

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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)

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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 ± 0.5% 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 ± 0.5% 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 ± 0.5%.

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."

Illinois Department of Transportation

Procedure for Introducing Additives to Hot Mix Asphalt Mixtures and Testing in the Lab Appendix B17 (continued)

Effective Date: March 7, 2005
Revised Date: January 1, 2013

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.

Illinois Department of Transportation

Procedure for Introducing Additives to Hot Mix Asphalt Mixtures and Testing in the Lab
Appendix B17
(continued)

Effective Date: March 7, 2005
Revised Date: January 1, 2013

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

Mass of AC in Container = ______________ g
(100 – Additive %) / 100 (Total Liquid)

___________Total Liquid, g – Mass of AC, g = ___________ g
(Mass of Additive
to introduce)

Figure 13.2

CALCULATION TO BLEND LIME

<u>Mass of Aggregate Batch</u> = ______________ 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 Bituminous Mix Design Verification Procedure

Timothy R. Murphy, P.E.
President
Murphy Pavement Technology

Mix Design Verification

Contractor Mix Design

- Sign off by Mix Specialist
  Lab Work by min Level One
- Mix Formula: Gradation
  Optimum AB

Mix Design Verification

Contractor Mix Design

Component Materials
- Material Name
- Material Code Number
- Source Name
- Source Number/Location

{ Aggregates, AB, Anti-strip }

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

SuperPave 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

SuperPave 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

Ready to Blend Components

Agency Verification

Review Design Data

Mix & Test Components at Optimum AB Content

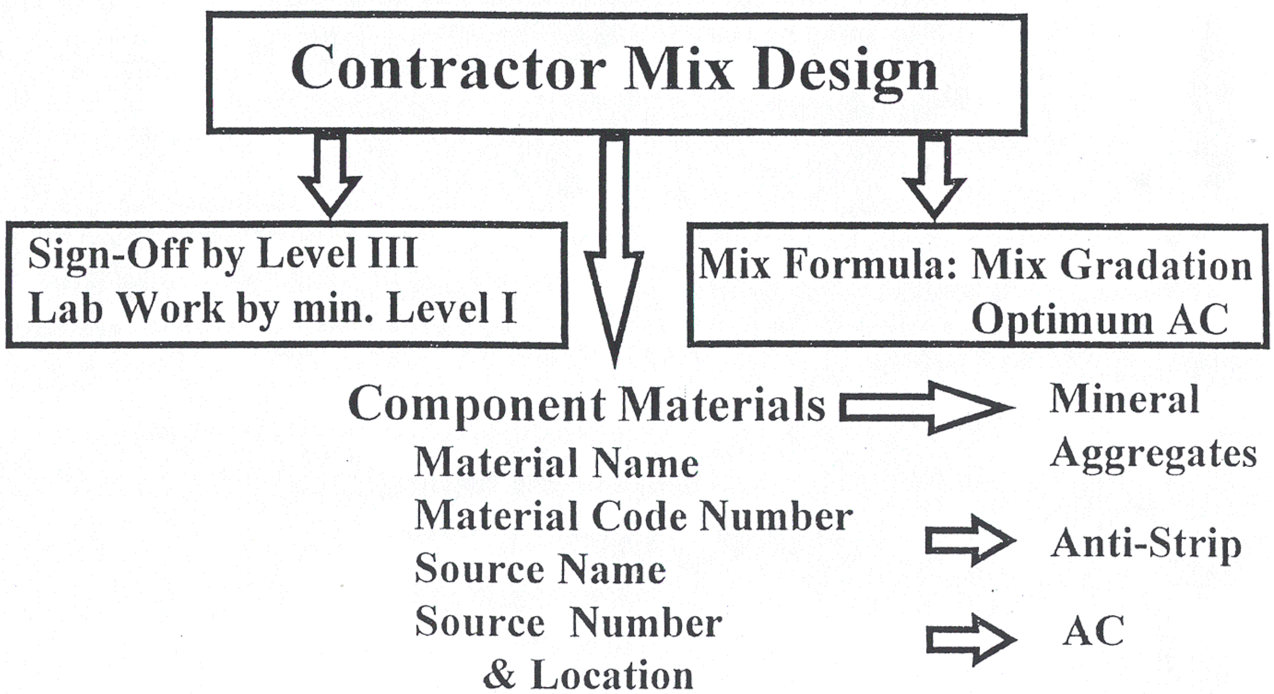
Comparison of Test Results

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

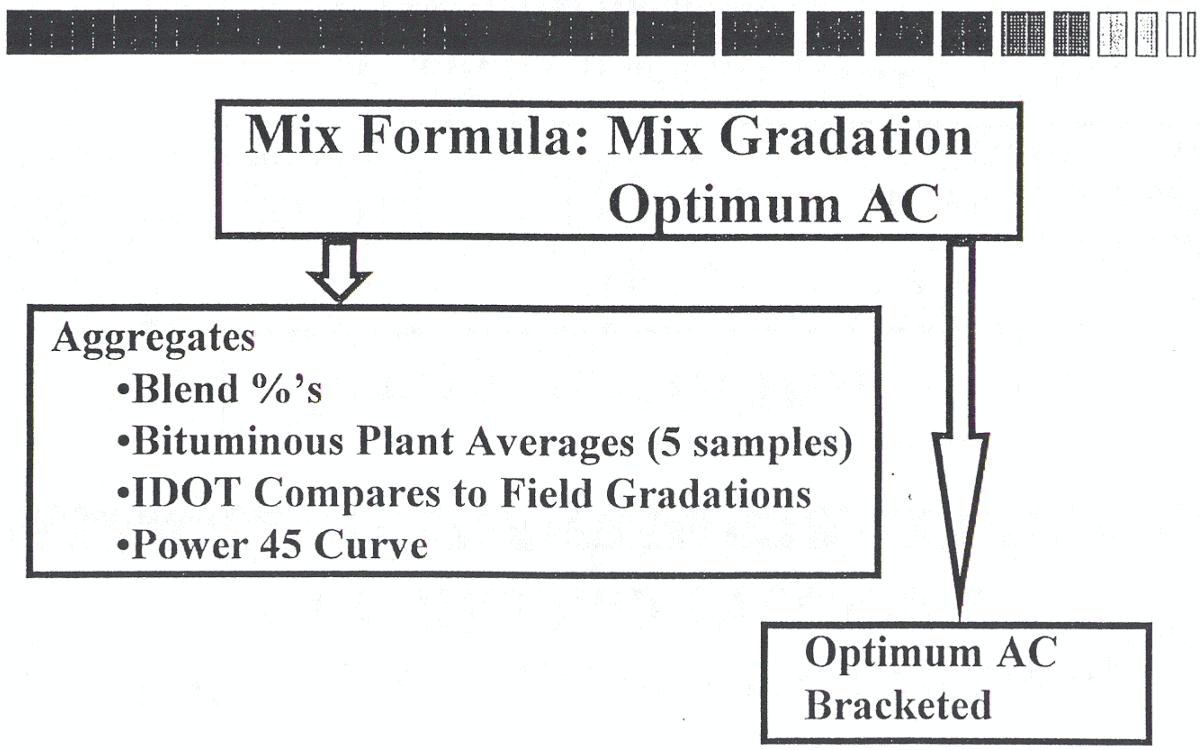
Mix Design Verification

- 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

IDOT Bituminous Mixture Design Verification Procedure



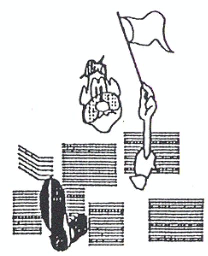
IDOT Bituminous Mixture Design Verification Procedure



IDOT Bituminous Mixture Design Verification Procedure

Test Data

- Cover Page (BdesignW or CAMA
- HMA Data Sheet
- Gmm ("D") Lab Worksheets
- Batching Worksheets
- Batching Sources Sheet
- Recalculations/Retested Points/Address Flyers
- TSR Worksheets
- Mix Design Graphs

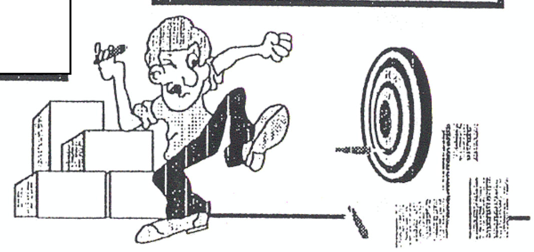


IDOT Bituminous Mixture Design Verification Procedure

Mix Design Graphs

- Gradation (45 curve)
- Asphalt Binder vs. d/D
- Asphalt Binder vs. Voids
- Asphalt Binder vs. VMA
- Asphalt Binder vs. VFA

Optimum Design Data Bracketed

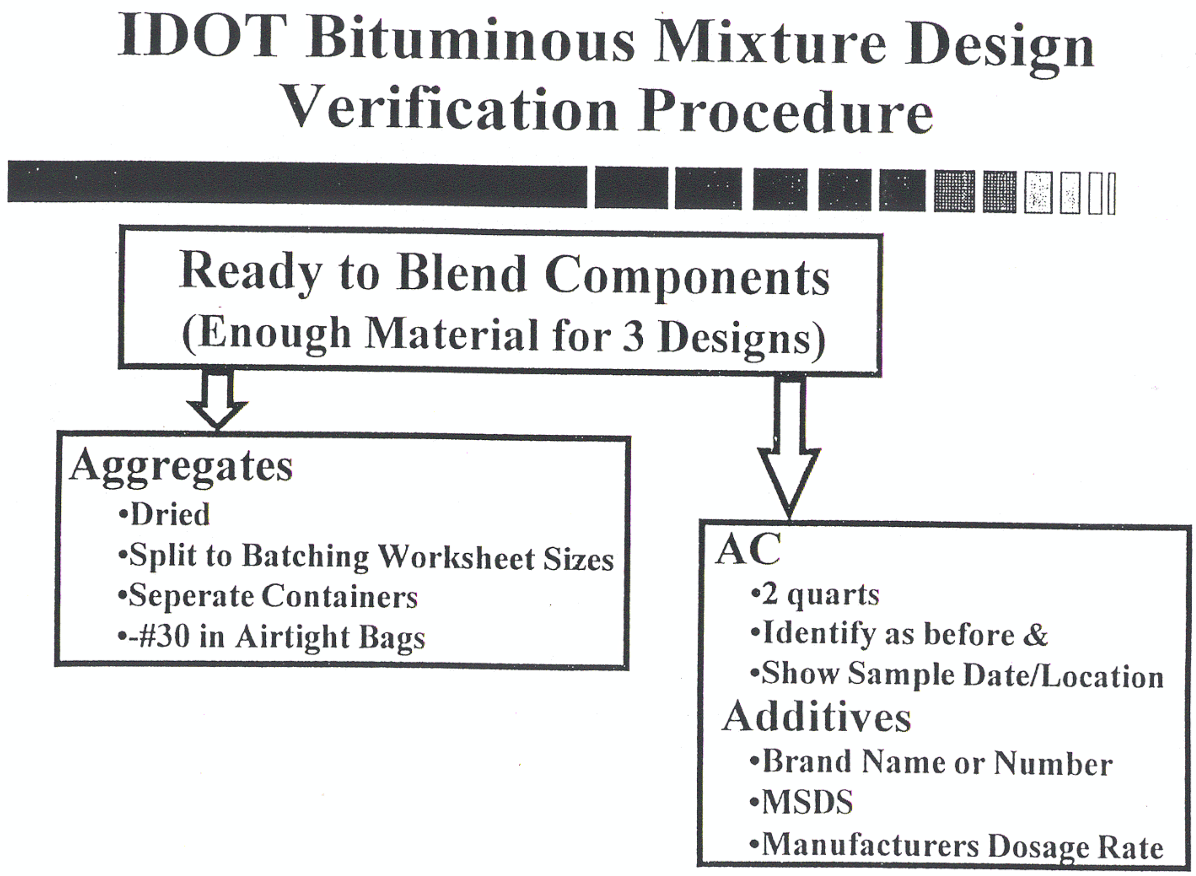


IDOT Bituminous Mixture Design Verification Procedure

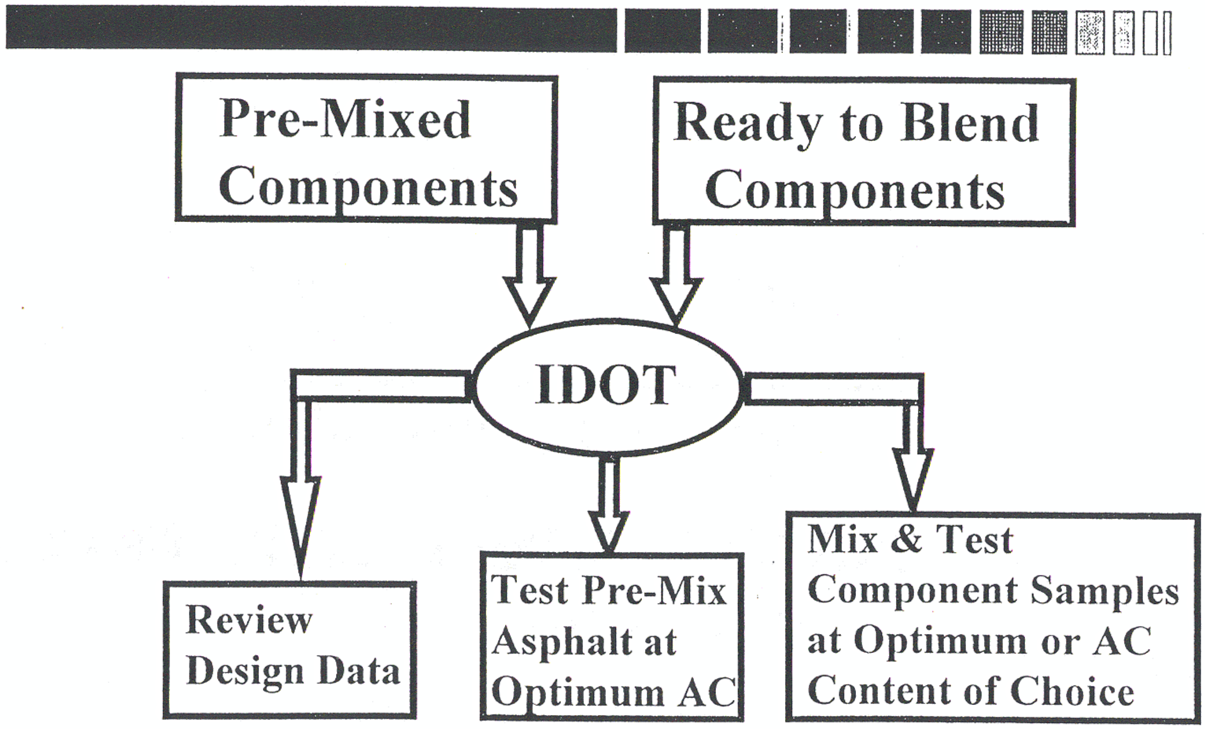
Samples to IDOT

1.) **Pre-Mixed Asphalt Mixture**
- 2 @ 10,000 g (Dry Agg. Wt.)
- Optimum Point Only
- Anti-Strip Already Added

2.) **Ready to Blend Components**
- Aggregates
- AC
- Additives


IDOT Bituminous Mixture Design
Verification Procedure
Ready to Blend Components
(Enough Material for 3 Designs)
Aggregates
•Dried
•Split to Batching Worksheet Sizes
•Seperate Containers
•-#30 in Airtight Bags
AC
•2 quarts
•Identify as before &
•Show Sample Date/Location
Additives
•Brand Name or Number
•MSDS
•Manufacturers Dosage Rate

IDOT Bituminous Mixture Design Verification Procedure



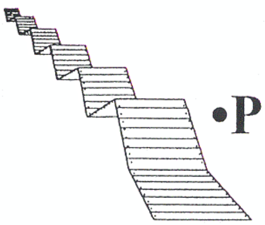
IDOT Bituminous Mixture Design Verification Procedure

- Comparison of Test Results

Gse		+/- 0.014
Gmb		+/- 0.020
Gmm		+/- 0.014
Extractions		
12mm	(1/2")	+/- 3.0
4.75mm	(#4)	+/- 2.0
2.36mm	(#8)	+/- 1.5
0.6mm	(#30)	+/- 1.0
0.075mm	(#200)	+/- 0.5
Pb (AC Content)		+/- 0.15

IDOT Bituminous Mixture Design Verification Procedure

- 30-Day TurnAround
- Contractor Certification of Materials
  1.) Meet Department Requirements
      Quality
      Material from Sources Indicated
  2.) Represent Materials for Actual Production



- Previously Submitted Designs
  1.) Resubmit Paperwork
  2.) Resubmit Samples if IDOT Requests
- Mix Must Be Reproducable at Plant

This Page Is Reserved

MIX DESIGN WORKSHEET

DESIGN NO. HMA SURFACE, MIX D, N70 DISTRICT ____TY____DATE ________

CONTRACTOR: __Example Company Inc. Somewhere, IL

POINT #: 1

Pb	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

Pb	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

Pb	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

Pb	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

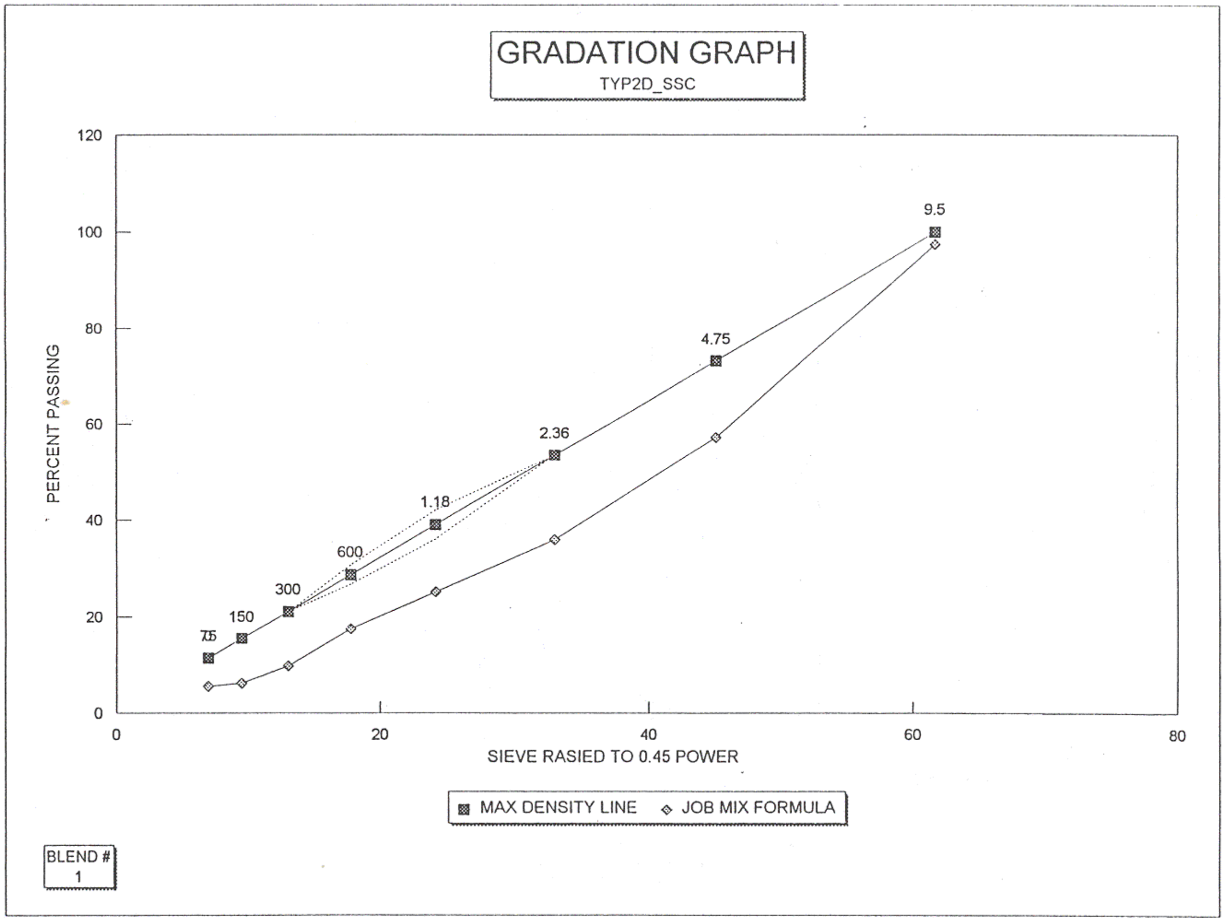
Design No. HMA Surf. “D”, N70 Dist TY Date ______________

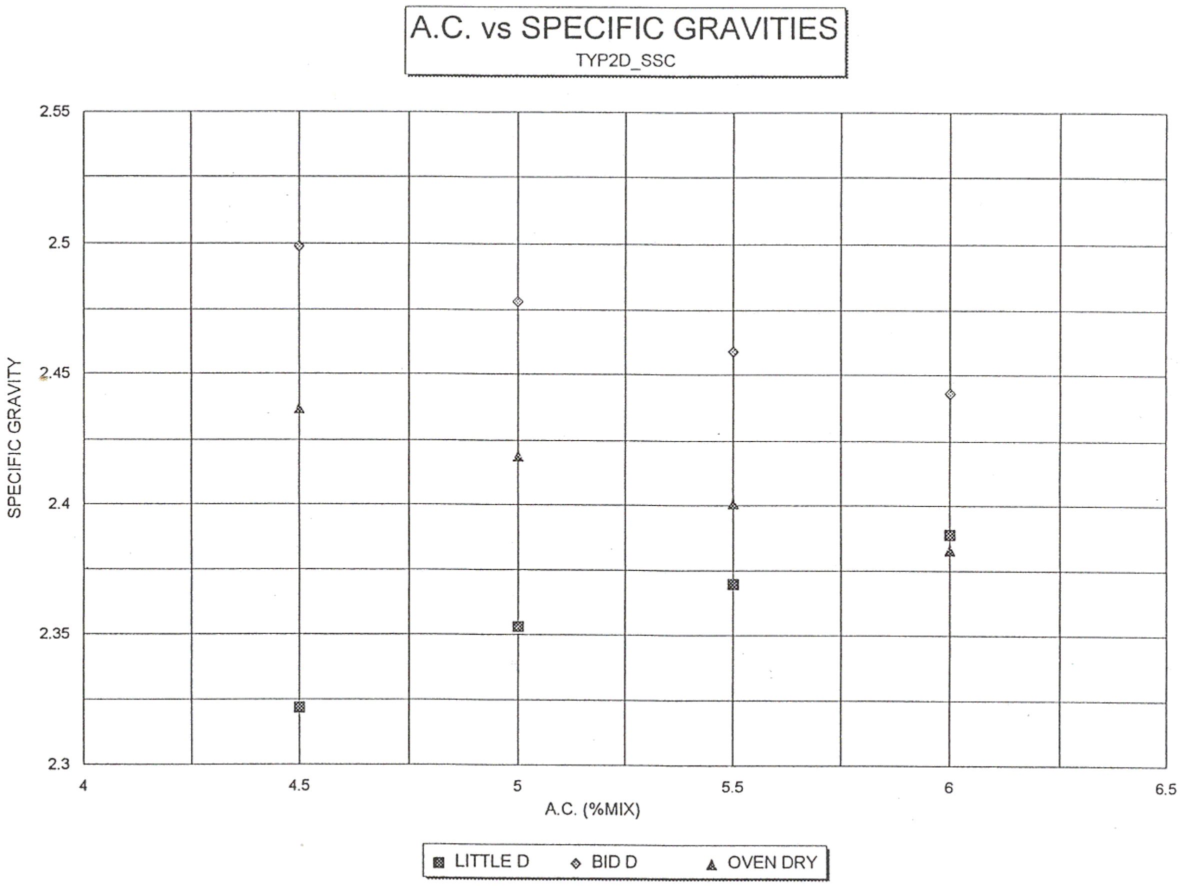
Contractor Example Company Inc., Somewhere, IL Sheet 1 of 1

Mix Type HMA Surface, Mix D, N70

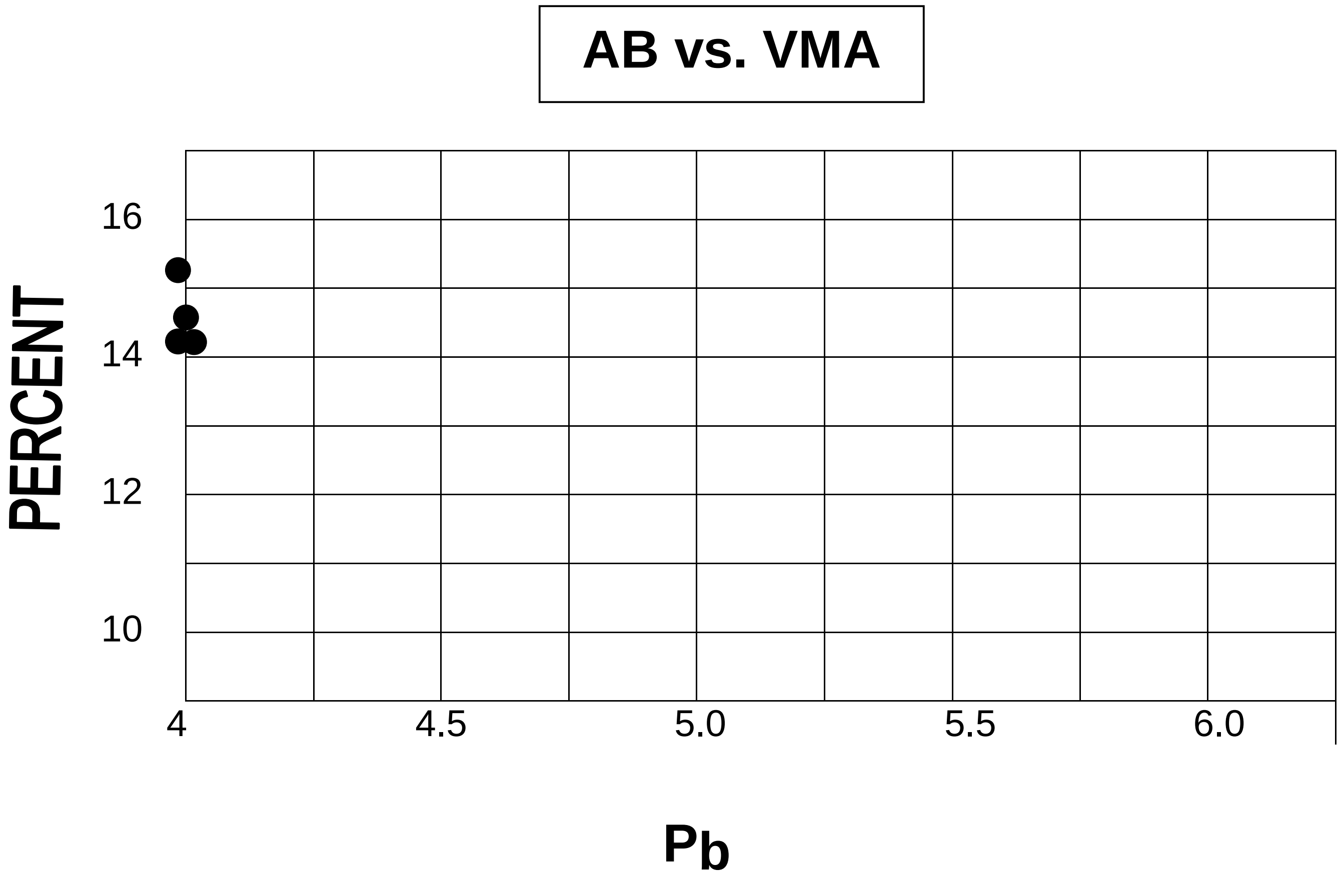
AGG. #1->	032CMM16	What %->	63.2	AGG. #4->	037FAM02	What %->	22.3
MATERIAL	PERCENT	WEIGHTS	ACCUMULATIVE WEIGHTS	MATERIAL	PERCENT	WEIGHTS	ACCUMULATIVE WEIGHTS
+ 9.5	4	253	253	+2.36	11	245	7,765
9.5 – 4.75	63	3,982	4,234	-2.36 - +600	43	959	8,724
4.75 – 2.36	25	1,580	5,814	-600	46	1,026	9,750
-2.36 - +600	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	

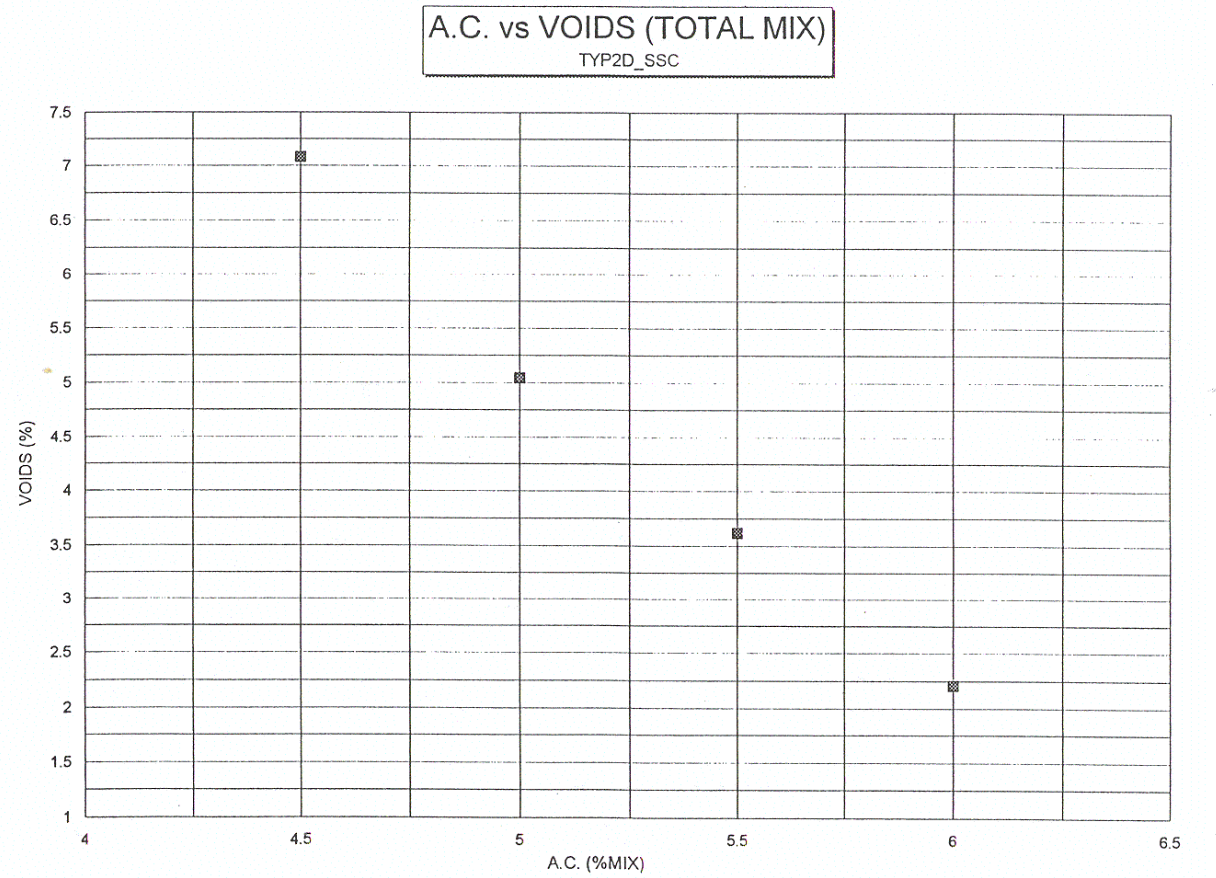
NOTES:


GRADATION GRAPH
TYP2D_SSC
PERCENT PASSING
SIEVE RASIED TO 0.45 POWER
MAX DENSITY LINE
JOB MIX FORMULA
BLEND #
1
75
150
300
600
1.18
2.36
4.75
9.5
0
20
40
60
80
100
120

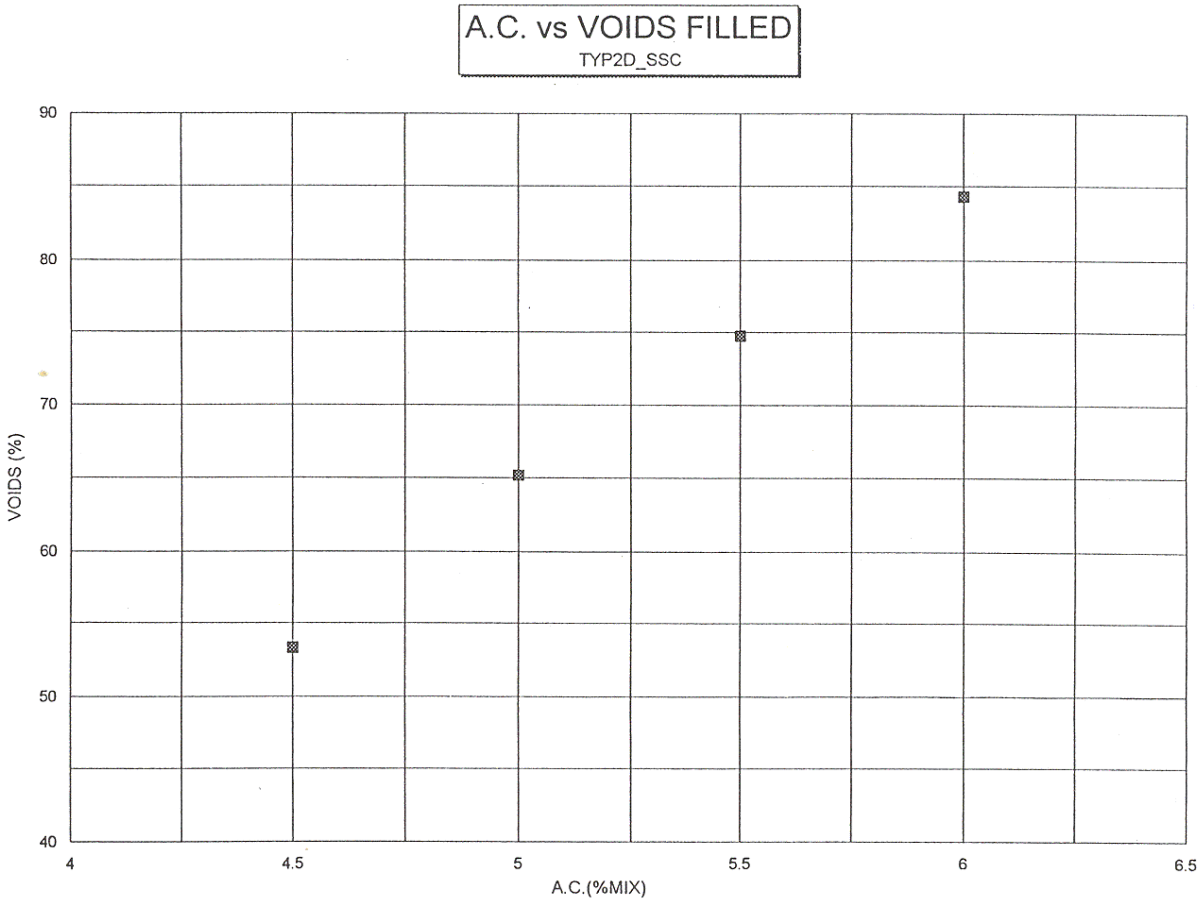


A.C. vs SPECIFIC GRAVITIES
TYP2D_SSC
SPECIFIC GRAVITY
2.55
2.5
2.45
2.4
2.35
2.3
4
4.5
5
5.5
6
6.5
A.C. (%MIX)
LITTLE D
BID D
OVEN DRY


AB vs. VMA
PERCENT
16
14
12
10
4
4.5
5.0
5.5
6.0
Pb


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
A.C. (%MIX)

Pb


A.C. vs VOIDS FILLED
TYP2D_SSC
90
80
70
60
50
40
VOIDS (%)
4
4.5
5
5.5
6
6.5
A.C.(%MIX)

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: ________ UPDATE: ____ DELETE: _____

BIT MIX#: HMA Surf. "D", N70 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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Illinois Department of Transportation

Hot-Mix Asphalt Mixture Design Verification Procedure
Appendix B9

Effective Date: January 1, 2002
Revised: January 1, 2013

1.0 GENERAL

Contractors shall provide all hot-mix asphalt (HMA) mix designs for use on Department contracts. All mix designs must provide mixture meeting Department mix criteria. The Department will provide current aggregate bulk specific gravity. The Engineer reserves the right to be present for the sampling of all aggregates for mix designs. Once verified, a mix design will be approved for use for a three year period. After three years, the mix design shall be redesigned if necessary, and re-verified.

2.0 PURPOSE

Establish a verification procedure to evaluate Contractor mix designs for use on Department contracts. This procedure also allows for comparison of the test accuracy and precision between laboratories.

3.0 REQUIRED DESIGN DATA/MATERIAL SAMPLES

3.1 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 Technicians or higher. The mix design shall be submitted with the following design data:

A. The material name, material code number, source name, source Producer/Supplier Number, and source location shall be provided for all materials used in the mix design.

B. The Contractor shall provide 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 5 (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 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.

Illinois Department of Transportation

Hot-Mix Asphalt Mixture Design Verification Procedure
Appendix B9
(continued)
Effective Date: January 1, 2002
Revised: January 1, 2013

C. The Contractor shall provide a summary of design test data and optimum design data utilizing a design package with the same output format as CARE-AC.

(1) Design sheet. The design shall contain a minimum of four design points, two of which shall bracket the optimum design asphalt binder (AB) content by at least ± 0.5%. Under remarks include: short-term aging time, dust correction factor, compaction temperature, and mixing temperature.

(2) Design summary data sheet (in CARE-AC format).

(3) Actual graph paper from the stability machine and actual G_{mm} lab worksheets (original copy unless otherwise specified).

(4) Batching worksheet.

(5) Dust correction worksheet (include an example packet, such as the one from the Level III manual).

(6) Batching sources sheet.

(7) Mix design graphs (full page).

(a) Gradation (45 power curve).

(b) Asphalt Binder Content vs. G_{mb}/G_{mm}.

(c) Asphalt Binder Content vs. VMA.

(d) Asphalt Binder Content vs. Air Voids.

(e) Asphalt Binder Content vs. Voids Filled with Asphalt (VFA).

(8) Recalculations and/or retested points (e.g., recalculated G_{mm}'s using average G_{se}).

(9) TSR worksheet.

The forms used shall be the Department's computer spreadsheet from CARE-AC, or other forms having the same format as CARE-AC.

Illinois Department of Transportation

Hot-Mix Asphalt Mixture Design Verification Procedure
Appendix B9
(continued)
Effective Date: January 1, 2002
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3.2 The Contractor shall provide samples of blended aggregate, asphalt binder, and additives which represent the materials in the mix design. The representative samples shall be identified and submitted as follows:

A. Aggregate (including mineral filler/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 (2) 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 4 qts (4,000 mL). Identified with source name, source location, source Producer/Supplier Number, material code, sample location, and sample date.

C. Additive(s) -- The same additive(s) as used in the Contractor's design, identified by the additive source name, source location, brand name or number, material code, sample location, sample date, additive MSDS, the manufacturer's recommended dosage rate, and the rate used in the design if different than the manufacturer's recommended dosage rate. NOTE: Prior to submitting the additive(s), the Contractor shall contact the District Materials Engineer for the required sample size.

3.3 All design data and material samples shall be submitted to the Department a minimum of 30 calendar days prior to production.

3.4 The Contractor shall certify in writing that all materials submitted for mix design verification meet Department requirements and represent the materials to be used during mix production.

3.5 Previously verified mix designs shall be resubmitted for verifications as per Section 4.1 herein.

4.0 DEPARTMENT VERIFICATION

4.1 At the option of the Department, mix designs may be verified using either Method A or Method B listed below:

Illinois Department of Transportation

Hot-Mix Asphalt Mixture Design Verification Procedure
Appendix B9
(continued)
Effective Date: January 1, 2002
Revised: January 1, 2013

Method A. 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 testing of the asphalt mixture. Verification testing will include volumetric, TSR and Hamburg Wheel on a mixture made from the individual materials submitted by the Contractor. The mixture at the optimum design asphalt binder content shall meet the mix design criteria for the following: VMA, VFA, G_{mb}, G_{mm}, Pa (voids), Tensile Strengths, TSR values, and Hamburg Wheel.

Method B. 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 IL Modified AASHTO T 283 and IL Modified AASHTO T 324. IL Modified AASHTO T 324 will not be required for "All Other" HMA mixes.

4.2 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):

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

Illinois Department of Transportation

Hot-Mix Asphalt Mixture Design Verification Procedure
Appendix B9
(continued)
Effective Date: January 1, 2002
Revised: January 1, 2013

All aggregate field gradations submitted by the Contractor will be compared to previous mix plant and/or Aggregate Gradation Control System gradations for validity.

4.3 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 verification fails, the 30-calendar-day time for the Department to notify the Contractor starts over. Acceptable designs may be used in Department contracts, provided the design is reproducible in the mix plant.

This Page Is Reserved.

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

Designing & Building HMA Successfully to *Your* Agency Specification

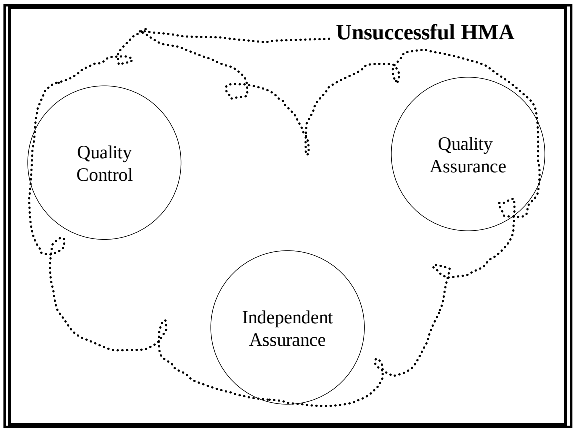
Timothy R. Murphy, P.E.
President
Murphy Pavement Technology

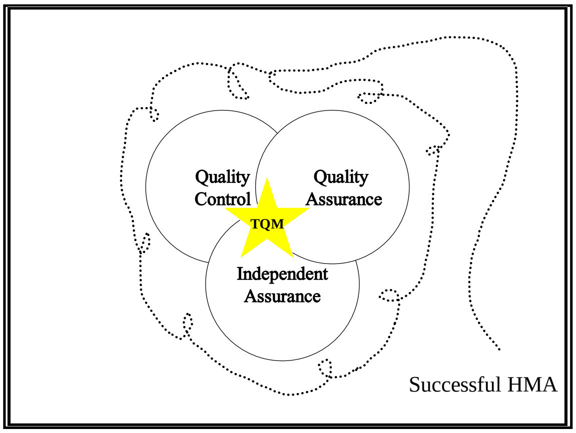
Preparing for Hot Mix Asphalt

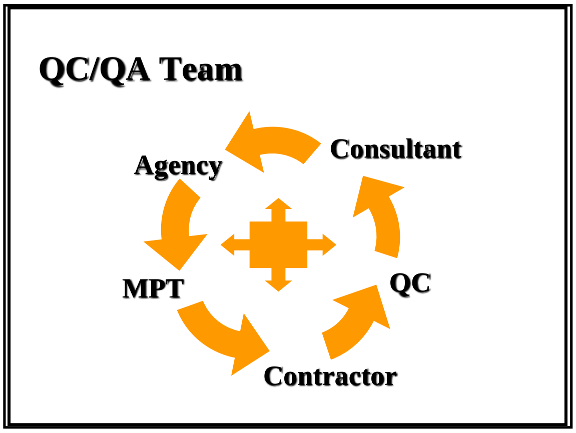
From the bucket to the road and all the twists and turns you take to get there!

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

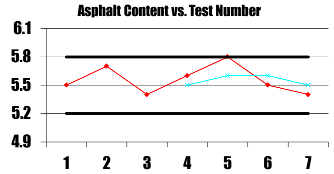
- Certify asphalt plants via permissive use regimen,
- Segregation mitigation.

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%

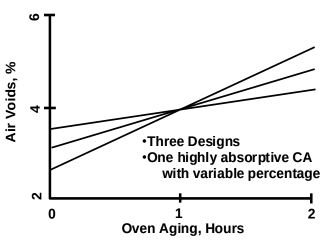
**Deviation from JMF*

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

Effect of Absorption II



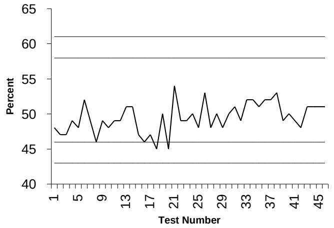
Field Verification of Laboratory Mix Designs

Quality Control Efforts

- Aggregate gradation
- Asphalt content
- Volumetric analysis
- In-place density

Laboratory Mix Designs vs. Plant-Produced Mixture

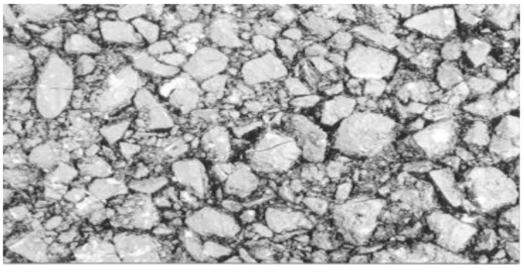
Control Charts - # 4 Sieve



Where are these samples taken from and what do they mean?

Aggregate Gradation

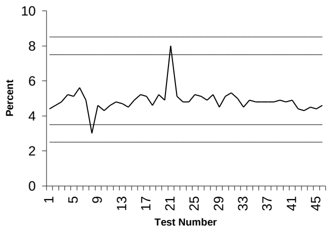
- •Cross-Contamination of Stock Piles
- •Cross-Contamination Between Cold Feed Bins



Aggregate Gradation

Breakage of Coarse Aggregate Particles During Production

Control Charts - P200

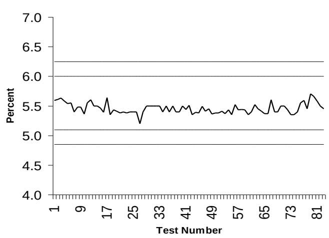


Aggregate Gradation

Dust Coating on Particle Surface

Dry Versus Washed Gradations

Control Charts - AC



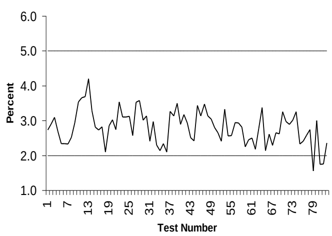
Asphalt Content

Nuclear AB Gauge

Asphalt Content & Gradation

- **Ignition Oven**
- **Centrifuge, or**
- **Reflux AB**

Control Charts - Air Voids



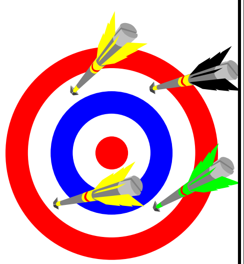
Designing & Building HMA Successfully

Test Strips
or HMA Beta

Test Strips

Always be ready for surprises...

- **Increased testing,**



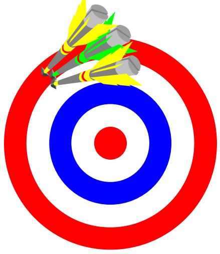
Recommended Testing and Observations

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

$$G_{mm} = \frac{100}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

$$V_a = \left(\frac{G_{mm} - G_{mb}}{G_{mm}} \right) x\ 100$$

$$VMA = 100 - \frac{G_{mb} \ x \ P_s}{G_{sb}}$$

$$VFA = \left(\frac{VMA - V_a}{VMA} \right) x\ 100$$

$$P_{be} = P_b - \frac{P_{ba} \ x \ P_s}{100}$$

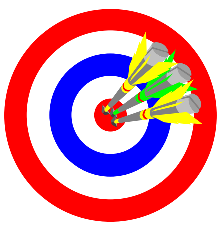
$$P_{ba} = 100 \ x \left(\frac{G_{se} - G_{sb}}{G_{se} \ x \ G_{sb}} \right) x \ G_b$$

$$Eff.\ Vol. = VMA - V_a$$

Test Strips

Always be ready for surprises...

- **Increased testing,**
- **Increased analysis,**
- **Increased comparisons.**

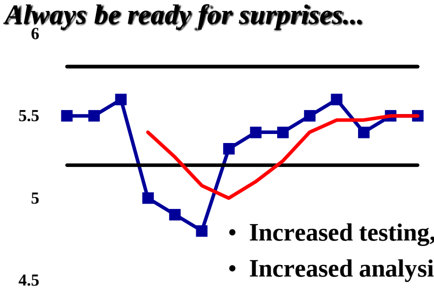


Comparisons and Tolerances

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

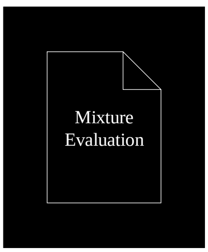
Factors Affecting Compaction

- **Material Properties**
- **Thickness**
- **Mix Temperature**
- **Weather Conditions**
- **Compaction Forces**

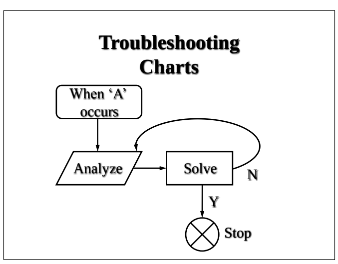
Test Strips and Equipment

Smoothness

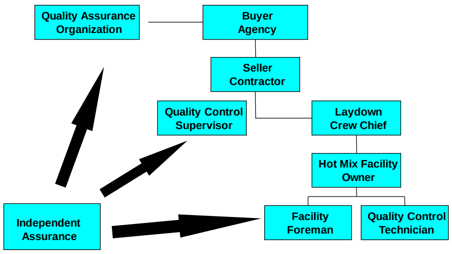
Examples



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.

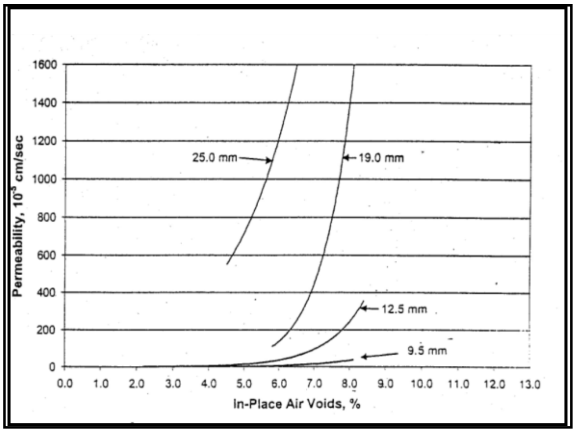
Permeability, Background

- 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

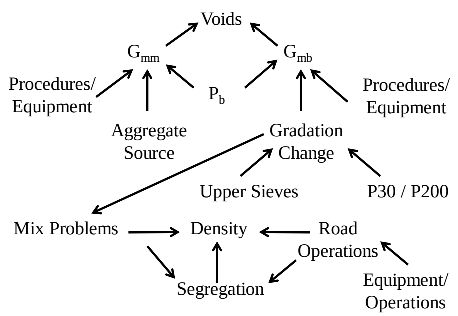
- 19 mm Mixes - Target 93% to 94%
- 12.5 mm Mixes - Target 92% to 93%

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/α Inversely Proportional - Each variable reacts in the opposite direction. One increases and the other decreases.

Proportionality Rules of HMA

- Voids 1/α Density
- Voids α G_{mm}
- Voids 1/α G_{mb}
- Voids 1/α Binder Content

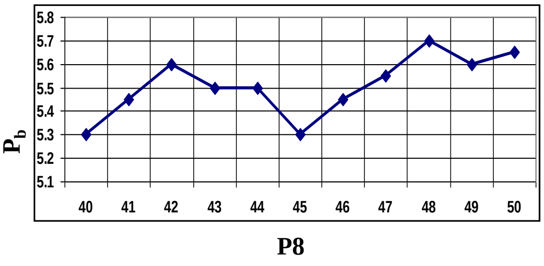
Proportionality Rules of HMA

- Voids 1/α P200
- Voids α VMA
- Voids α Coarseness of mix
- Voids 1/α Temperature
- Voids α Manufactured to Natural Sand Blend

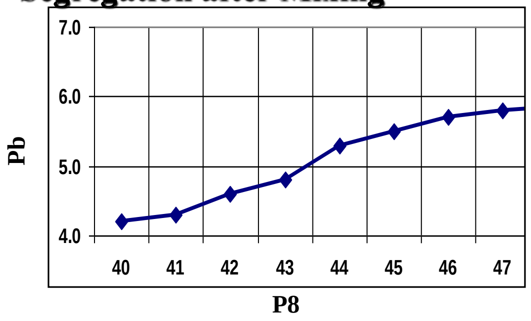
Additional Rules

- 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

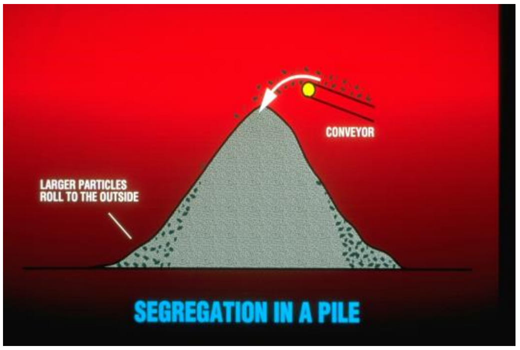
- **Voids falling,**
- **G_{mm} level,**
- **G_{mb} rising,**
- **P200 level,**
- **P8 rising,**
- **Density rising.**

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?



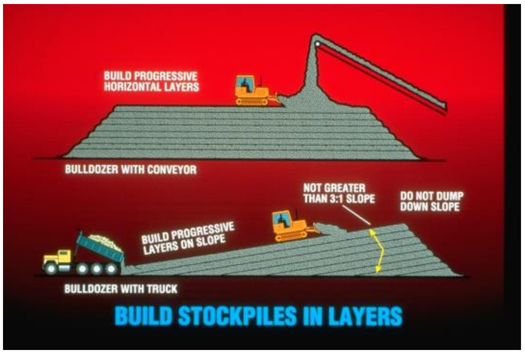
Problem 2

- **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

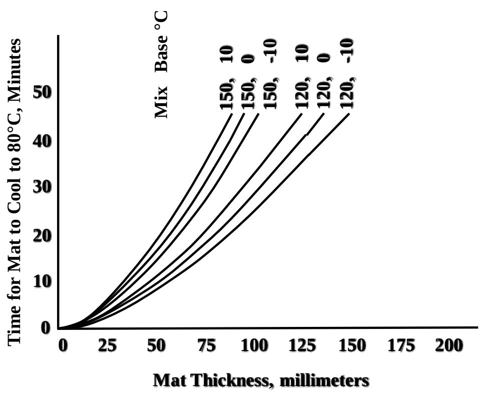
- **Voids level,**
- **G_{mm} level,**
- **G_{mb} level,**
- **P200 level,**
- **P8 level,**
- **Density dropping.** **Density α Temperature**

Question: What is happening to VMA?

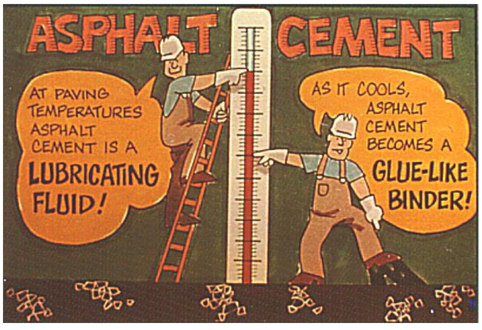
Time Available for Compaction

(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?

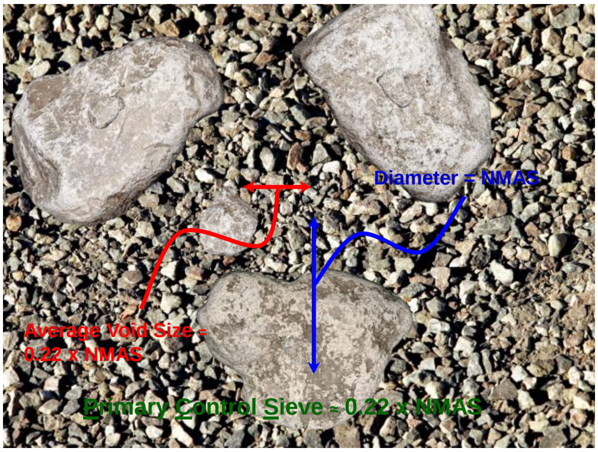
- **Gradation**
  - continuously-graded, gap-graded, etc.
- **Type & Amount of Compactive Effort**
  - static pressure, impact or shearing
- **Shape**
  - flat & elongated, cubical, round
- **Surface Texture** (micro-texture)
  - smooth, rough
- **Strength**
  - Weak vs. Strong, Influence of particle **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 Control Sieve

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**

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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

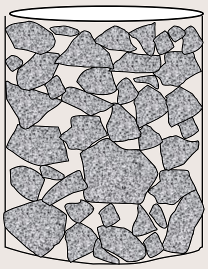
Fine-graded

Coarse-graded

SMA

7

Loose Unit Weight - 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

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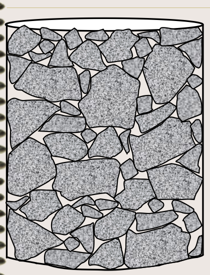
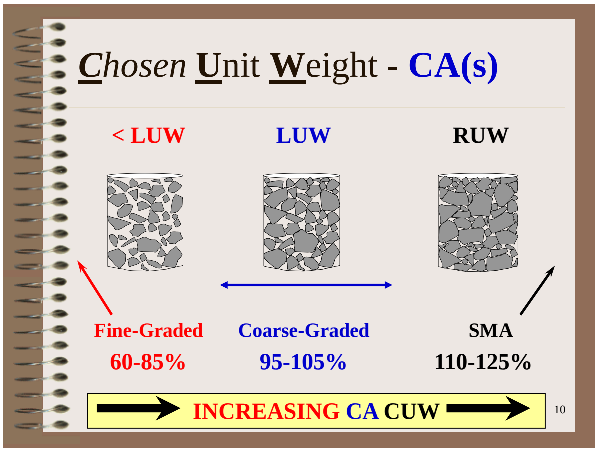
Rodded Unit Weight - CA

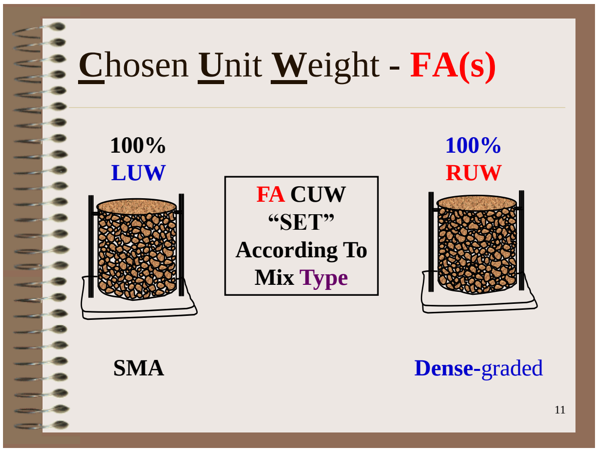


- **With** compactive effort applied
- **Increased** particle-to-particle contact
- **Three** equal lifts using **shoveling** procedure
- Rod **25** times per lift
- Strike off ~ level
  - Careful **not** to compact
- Determine **RUW**
  - Kg/m^3 or lbs./ft^3
- Determine **volume** of **voids**

AASHTO T19

9





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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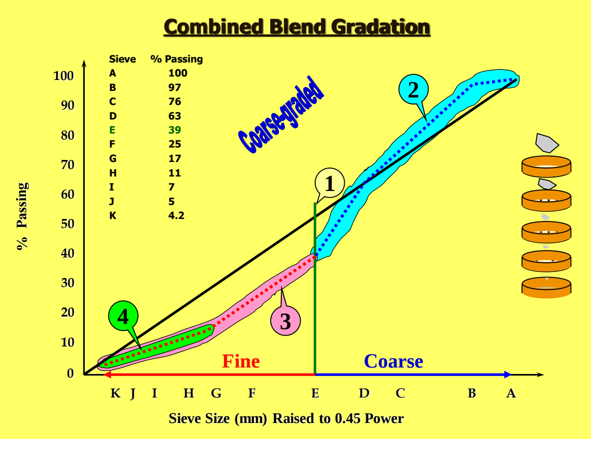

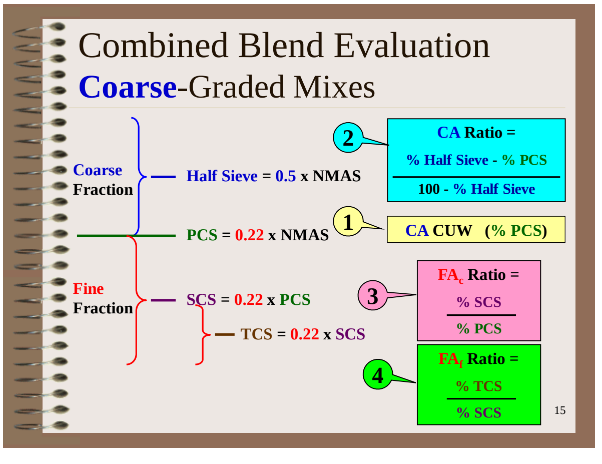

Combined Blend Evaluation
Coarse-Graded Mixes

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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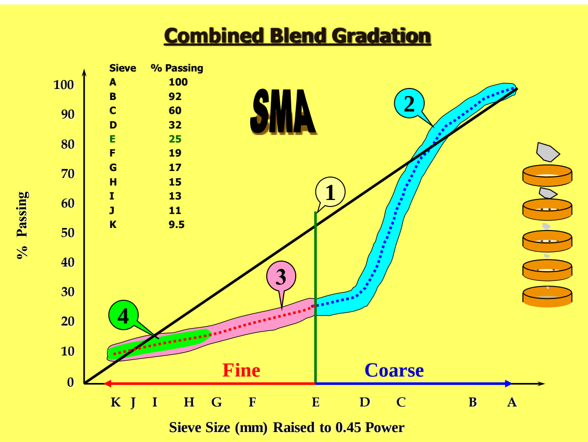

Combined Blend Evaluation
SMA Mixes

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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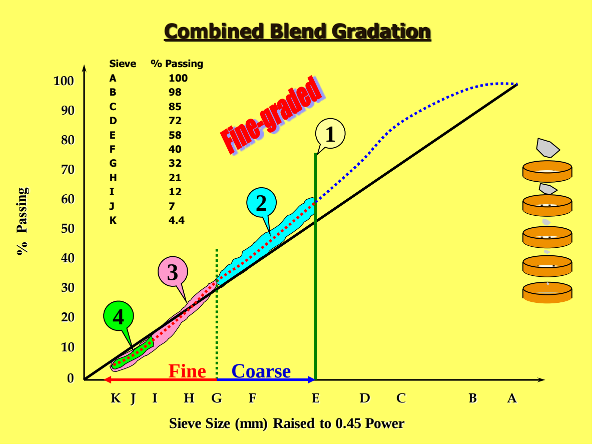

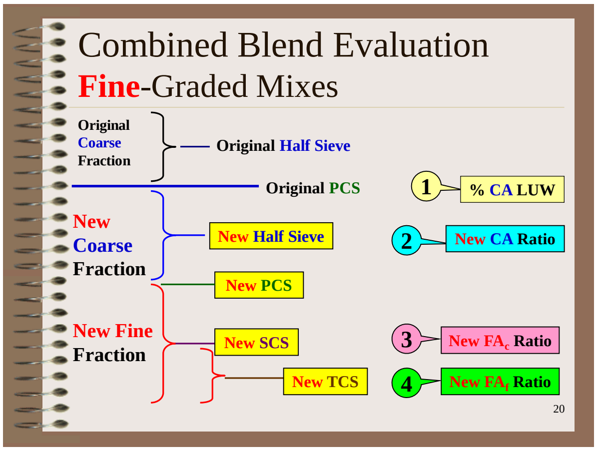

Combined Blend Evaluation
Fine-Graded Mixes

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
- **Increases** VMA or Voids
  1.0/4.0 = + 0.25%
- **CA** ratio
  0.725 – 0.693 = + 0.032
- **Increases** VMA or Voids
  0.032/0.2 = + 0.16%
- **FA_c** ratio
  0.444 – 0.492 = - 0.048
- **Increases** VMA or Voids
  0.048/0.05 = + 0.96%
- **FA_f** ratio
  0.412 – 0.394 = + 0.018
- **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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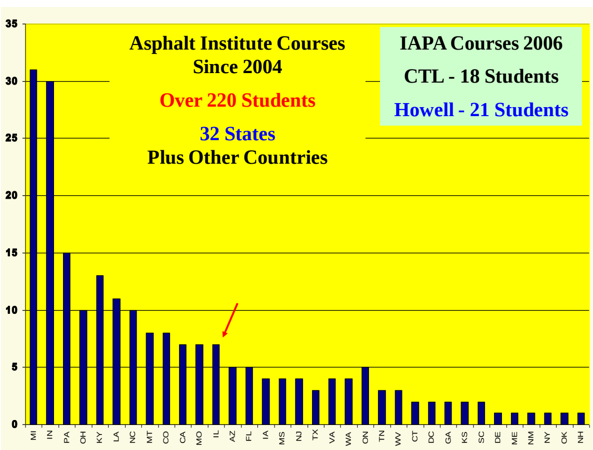


Questions or Comments?
Thank You!
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