7 Blending Aggregates

All of the particles needed in the aggregate to meet specifications and "do the job" are rarely found in a single material. Different sizes and materials must be blended in the proper quantities to produce the desired gradation and meet gradation specifications for a particular asphalt mix. It is extremely important that this blending process be completed correctly. This requires proper sampling of the materials to be blended and accurate determination of the gradation or sieve size distribution of the materials. In addition, we must determine the properties of each aggregate component and/or the total blend of the mix.

The end result of a successful mix design is a recommended mixture of aggregate and asphalt binder type. This mixture is often referred to as the job mix formula (JMF) or recipe. The ability to blend aggregates to produce the right job mix formula is critical to success.

Learning Objectives:

Upon completion of this chapter, you should be able to:

- ☑ Describe the components of the job mix formula
- ☑ Describe the process for conducting mix design
- ☑ Combine aggregates to achieve the target blend, using the "Trial and Error" method and appropriate blending worksheets
- ☑ Demonstrate the procedure for hot bin sampling
- ☑ Calculate batch weight

Mix Design

	DEFINITIONS. The following terms will be used throughout this section:
Aggregate blending	The process of proportionately mixing several aggregate gradations to obtain one desired aggregate gradation.
Gradation	The particle size distribution of an aggregate, which helps determine the properties of pavement materials.
Job mix formula (JMF)	The optimized mixture of aggregate and asphalt binder type; the required AC and Gradation targets that the contractor must produce for the project.
Trial and Error method	The method used to determine an optimum combination of aggregates.
Combined gradation	A mathematically-determined theoretical combination of aggregates based on their relative percent volume in the mixture.
.45 Power Chart	A graphical technique that plots the percent passing vs. sieve size. This chart is very useful in comparing aggregate gradations and specification limits.

Hot mix asphalt is a complex material upon which many different, and sometimes conflicting, performance demands are placed. It must resist deformation and cracking, be durable over time, resist water damage, provide a surface with good traction, and yet be inexpensive, readily made and easily placed. In order to meet these demands, the mix designer can manipulate three variables:

- **Aggregate**—Items such as type (source), gradation and size, toughness and abrasion resistance, durability and soundness, shape, texture and cleanliness all can be measured, judged and altered to some degree.
- **Asphalt binder**—Items such as type, durability, rheology and purity, as well as additional modifying agents can be measured, judged and altered to some degree.
- **The ratio of asphalt binder to aggregate**—Usually expressed in terms of percent asphalt binder by total weight of HMA or total weight of aggregate, this ratio has a profound effect on HMA pavement performance.

Hot mix asphalt design is the process of determining what aggregate to use, what asphalt binder to use, and the optimum combination of these ingredients. Hot mix asphalt design has evolved as a laboratory procedure that uses critical tests to make characterizations of each trial hot mix asphalt blend. These characterizations can give the mix designer a good understanding of how a particular mix will perform in the field during construction and under traffic loading.

VDOT utilizes the Superpave mix design system and Stone Matrix Asphalt mix designs for the majority of asphalt concrete produced for the State.

The Job Mix Formula

Gradation has a profound effect on material performance. But what is the best gradation? The target values of aggregate gradation and asphalt binder content for a job are specified based on the job mix formula (JMF). In its simplest form, the job mix formula is the recommended mixture of aggregate and asphalt binder type. It consists of two parts:

1. The **combined gradation** of the aggregates to be used in the production of the asphalt concrete mixture.
2. The **asphalt content** necessary to produce a satisfactory mix, meeting all the specification requirements.

In order to meet the demands placed by the desirable hot mix asphalt properties, mix design processes involve the three basic steps illustrated in Figure 7-1.

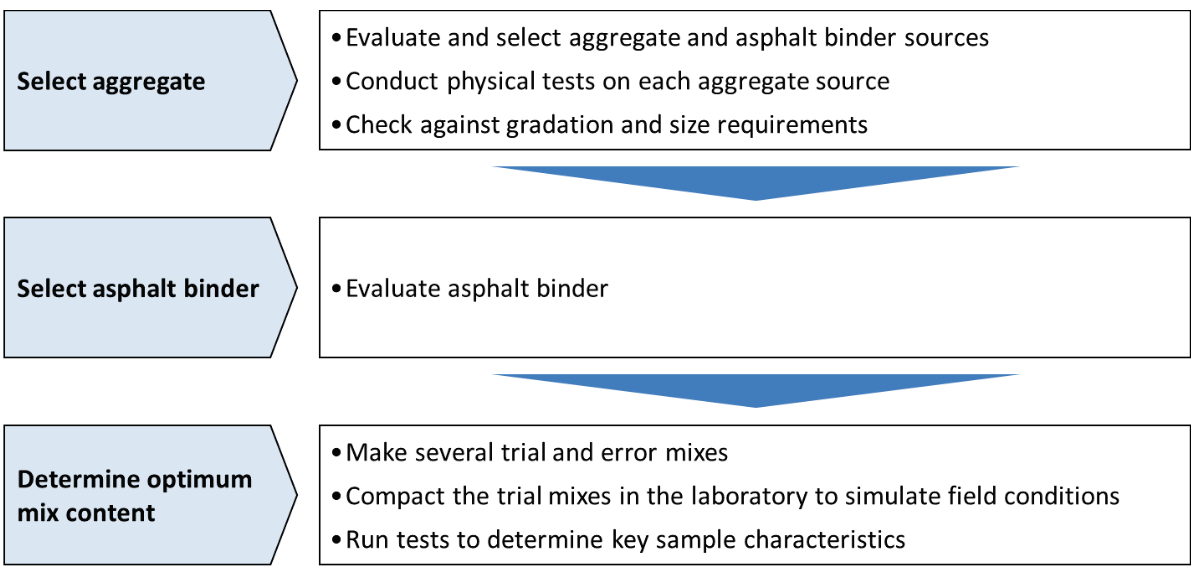

Figure 7-1: Mix Design Process

Refer to the VDOT *Road and Bridge Specifications*– Section 211 Asphalt Concrete, Section 211.03 Table II-13 (reproduced in this chapter as Figure 7-3 on page 7-6) for the design gradations for various types of mixes.

An example of a completed job mix formula is shown on the next page.

Form TL-127 (Rev. 11/05)

VIRGINIA DEPARTMENT OF TRANSPORTATION
MATERIALS DIVISION
STATEMENT OF ASPHALT CONCRETE OR CENTRAL-MIX AGGREGATE JOB-MIX FORMULA

Submit to the District Administrator, Virginia Department of Transportation. Approval must be received by the contractor from the Materials Division before work is begun. This job-mix design is approved for all projects of the Department for the type of mix and the calendar year shown below.

Contractor Design Mix No. ______ Design Lab No. R - 5

Date 11/8/2011 Job Mix ID No. ______ Calendar Yr. 2011 TSR Test No. ______

Type Mix / Size Aggregate Bit. Conc. Type SM-12.5D

Producer Name & Plant Location Stone Plant Co., White, VA Phone ______

Materials					Kind	Source
Approval Phase	A	B*	C			
Aggregate	85			%	#28	Rocky Rd. Corp., Unicoi, VA
Aggregate				%		
Rap				%		
Sand	15			%	Natural Sand	Gravel King, Loafers Glory, VA
Screening				%		
Lime				%		
Asphalt Cement					PG 70 - 22	Chevron or Citgo
Asphalt Prime/Tack						
Additives:						
0.50					Kling Beta 2700	Scan Rd, Waco, TX

Job-Mix Sieves	Total % Passing Lab JMF	Total % Passing Production JMF	Tolerance % + or -	Acceptance Range Average of 8 Test(s)		End of Year Average	Design/Spec. Range
Approval Phase	A	B*		A	B	C	
3/4"	100		0.0	100			100
1/2"	98		2.8	95.2 – 100			95 - 100
3/8"	87		2.8	84.2 – 89.8			90 Max
# 8	43		2.8	40.2 – 45.8			34 - 50
# 200	5.5		0.7	4.8 – 6.2			2 - 10
Asphalt (%)	5.5		0.17	5.33– 5.67			

Lay Down Temperatures	270-350 °F(°C)	Muffle Furnace Correction Factor:	0.50
		Field Correction Factor ($G_{se} – G_{sb}$):	0.024
Lab Compaction Temperatures	- °F (°C)	Pill Weight:	
		SMA Mixes	
		VCA_{DRC}:	
Producer Technician's Certification Number	123-45-6789	G_{CA}:	

MATERIALS DIVISION USE ONLY

Remarks							
Nominal Max. Size Aggregate		Application Rates:	Min.	lb/yd² (kg/m²)	Max.	lb/yd² (kg/m²)	
Mix Properties at the Job-Mix Asphalt Content:	Compacted Unit Weight	lb/ft³ (kg/m³)	VTM:	______	G_{mm}:	______	
Checked By: ______							

Approved tentatively subject to the production of material meeting all other applicable requirements of the specification.
* Note: Part B 'Production JMF' and corresponding Material percentages will be filled out by the DME upon receipt of the additional requirements of the HMA producer within the first three lots under Section 502.01(b)

Copies:	Approvals			
State Materials Engineer		Part A:		Date:
District Materials Engineer		Part B:		Date:
Project Inspector		Part C:		Date:
Sub-Contractor and/or Producer				

In the following sections we will cover the procedures for combining aggregates to achieve the target blend. This procedure can be applied:

- In the lab during design
- To set a drum plant's cold feed rate
- To proportion batch weights from the hot bins in a batch plant.

We will also introduce VDOT's allowable gradation bands for Superpave mixes and production tolerances and the acceptance range allowed during production. By attending to the gradation bands, production tolerances, and acceptance range, the Producer/Contractor can prevent producing material that does not conform to the JMF.

Combining Aggregates to Achieve the Target Blend

Mathematical procedures are available to determine an optimum combination of aggregates. However, the "Trial and Error" method, guided by a certain amount of reasoning, is the most practical procedure to determine a satisfactory combination. A key feature of this method is the use of continual measurements and adjustments to achieve success.

How to Conduct the "Trial and Error" Method

Use a Blending Worksheet (Figure 7-2) to capture gradations for each aggregate material and determine the percentage of each type of aggregate that will result in the target gradation needed for the final mix.

BLENDING WORKSHEET

Aggregate:									
% Used:									
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Target Value**	**Design Range**
1 1/2									
1									
3/4									
1/2									
3/8									
No. 4									
No. 8									
No. 30									
No. 50									
No. 100									
No. 200									

Figure 7-2: Blending Worksheet

STEP 1. Enter the individual aggregate gradations to be used, and the design range limits for the mix type being produced or evaluated in the lab, in the appropriate columns of the Blending Worksheet.

- You will use the Blending Worksheet to mathematically calculate the blending of aggregates.
- VDOT *Road and Bridge Specifications*– Section 211.03 (Table II-13, shown as Figure 7-3) defines the allowable design ranges (gradation bands) for VDOT Superpave mix types.

Table II-13. Asphalt Concrete Mixtures-Design Range Percentage by Weight Passing Square Mesh Sieves (In)

Mix Type	2	1 ½	1	3/4	1/2	3/8	No. 4	No. 8	No. 30	No. 50	No. 200
SM-9.0 A,D,E					100 *	90-100	90 max	47-67			2-10
SM-9.5 A,D,E					100 *	90-100	80 max	38-67			2-10
SM-12.5 A,D,E				100	95-100	90 max	--	34-50			2-10
IM-19.0 A,D,E			100	95-100	90 max	--	--	28-49			2-8
BM-25.0		100	95-100	90 max				19-38			1-7
C (Curb Mix)					100	92-100	70-75	50-60	28-36	15-20	7-9

Legend: *SM = Surface Mixture, IM = Intermediate Mixture, BM = Base Mixture*

**A production tolerance of 1% will be applied to this sieve, regardless of the number of tests in the lot.*

Figure 7-3: Table II-13 from VDOT *Road and Bridge Specifications*, Section 211.03

STEP 2. Enter the Target Values for the mix type being produced or evaluated in the **Target Value** column of the Blending Worksheet.

- The target value for the combined gradation must be within the design limits of the specifications

Note: The target value is provided by the Asphalt Mix Design Technician for lab evaluation and design, or from an approved JMF for production.

STEP 3. Estimate the proportions (i.e., the correct percentage of each aggregate needed) to get a combined gradation near the target value and enter these figures on the line marked **% Used**.

- If two aggregates are combined, the first estimate might be 50% of Aggregate 1 and 50% of Aggregate 2.

Note: Remember, the sum of the proportions must always equal 100.

STEP 4. Calculate the individual proportions on each sieve for each aggregate and enter in the column **% Blend**. Then determine the sum of the % Blend columns for each sieve and enter this total sum in the **Total Blend** column.

- The method of calculating the combined gradation will be shown in the sample problem that begins on page 7-9.

STEP 5. Compare the result with the target value, using the decision table below and the .45 Power Chart (shown as Figure 7-4 on the next page) to determine success and make adjustments.

Condition	**Action**
IF the calculated gradation is close to the target value…	…*THEN* no further adjustments need to be made.
IF the calculated gradation is not close to the target value…	… *THEN* an adjustment in the proportions must be made and the calculations repeated.
IF the second trial is still not close to the target value…	… *THEN* continue trials until the right proportions of each aggregate are found.
IF after several trials the aggregates will not combine within the design range…	… *THEN* consider using or adding different materials.

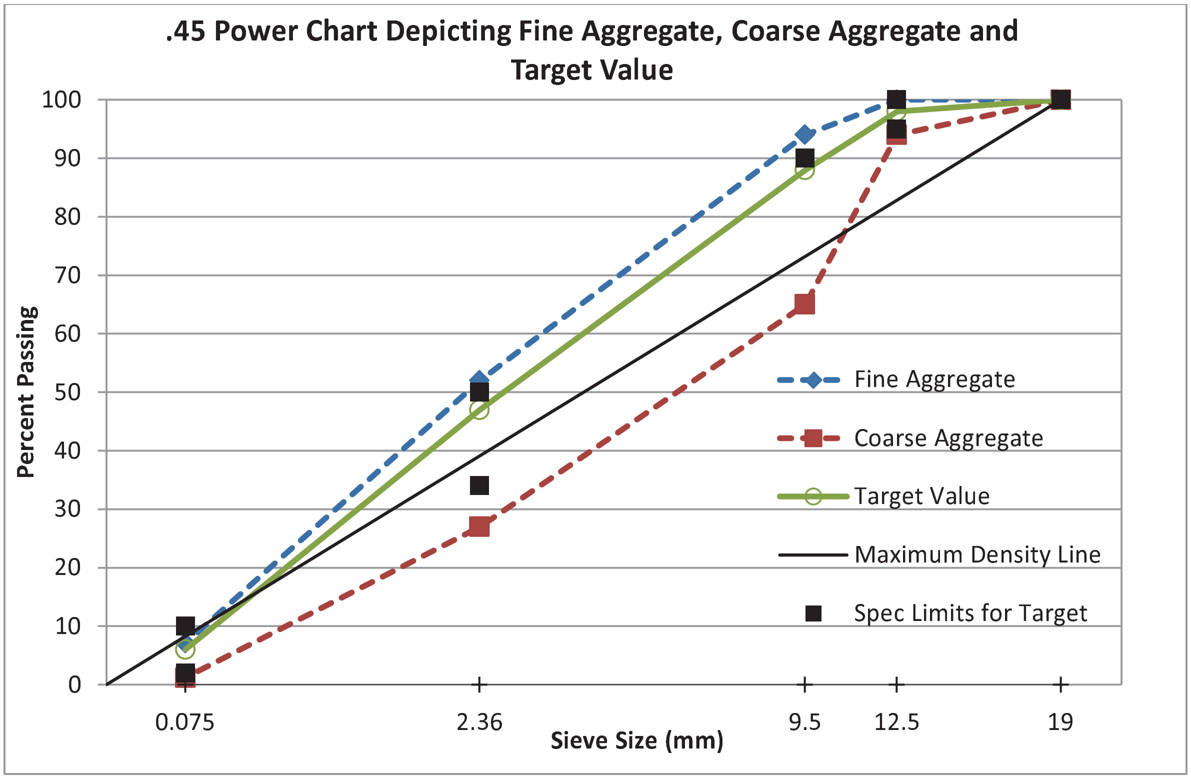

Figure 7-4: A .45 Power Chart

Key Points of the .45 Power Chart:

- Fine gradations will plot *above* the Maximum Density Line (MDL).
- Coarse gradations will plot *below* the MDL.
- When combining aggregates, *only targets that fall between two of the individual aggregate gradations are possible*. Using this chart will help eliminate the frustration of the fourth step in the decision table on the previous page.

General Math Conversion: To convert a percentage (%) to a decimal, divide by 100 or move the decimal place two places to the left. Example: 75% → 75/100 = .75

Sample Problems

The sample problems in this section are designed to illustrate the "Trial and Error" method of determining aggregate mix ratios. Each sample problem will display steps that map the steps outlined in the "Trial and Error" method section of this chapter (pages 7-5 through 7-7).

Sample Problem 1: Trial and Error Combination of Two Aggregates

Mix type: SM-12.5 A

STEP 1. Enter the aggregate gradations and design range into the appropriate columns of the Blending Worksheet.

Aggregate:	Fine Aggregate		Coarse Aggregate				
% Used:							
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Target Value**	**Design Range**
1 1/2							
1							
3/4	100		100				100
1/2	100		94				95 – 100
3/8	94		65				90 max
No. 4							
No. 8	52		27				34 – 50
No. 30							
No. 50							
No. 100							
No. 200	7.1		1.2				2 – 10

STEP 2. Obtain the target values and enter these values in the **Target Value** column of the Blending Worksheet, as shown on the worksheet that follows.

- The target value must be within design range.
- The target value is provided by Asphalt Mix Design Technician.

Aggregate:	Fine Aggregate		Coarse Aggregate				
% Used:							
Sieve (in)	% Pass	% Blend	% Pass	% Blend	Total Blend	Target Value	Design Range
1 ½							
1							
¾	100		100			100	100
½	100		94			98	95 – 100
3/8	94		65			88	90 max
No. 4							
No. 8	52		27			47	34 - 50
No. 30							
No. 50							
No. 100							
No. 200	7.1		1.2			6	2 - 10

STEP 3. Estimate the proportions and enter these figures on the line marked **% Used**.

- The first estimate might be 50% of the Fine Aggregate and 50% the Coarse Aggregate.
- *Note*: Remember, the sum of the proportions must always equal 100.
- Data resulting from this step is presented in the blending worksheet shown below and in Figure 7-5.

Aggregate:	Fine Aggregate		Coarse Aggregate				
% Used:	50		50				
Sieve (in)	% Pass	% Blend	% Pass	% Blend	Total Blend	Target Value	Design Range
1 ½							
1							
¾	100		100			100	100
½	100		94			98	95 – 100
3/8	94		65			88	90 max
No. 4							
No. 8	52		27			47	34 - 50
No. 30							
No. 50							
No. 100							
No. 200	7.1		1.2			6	2 - 10

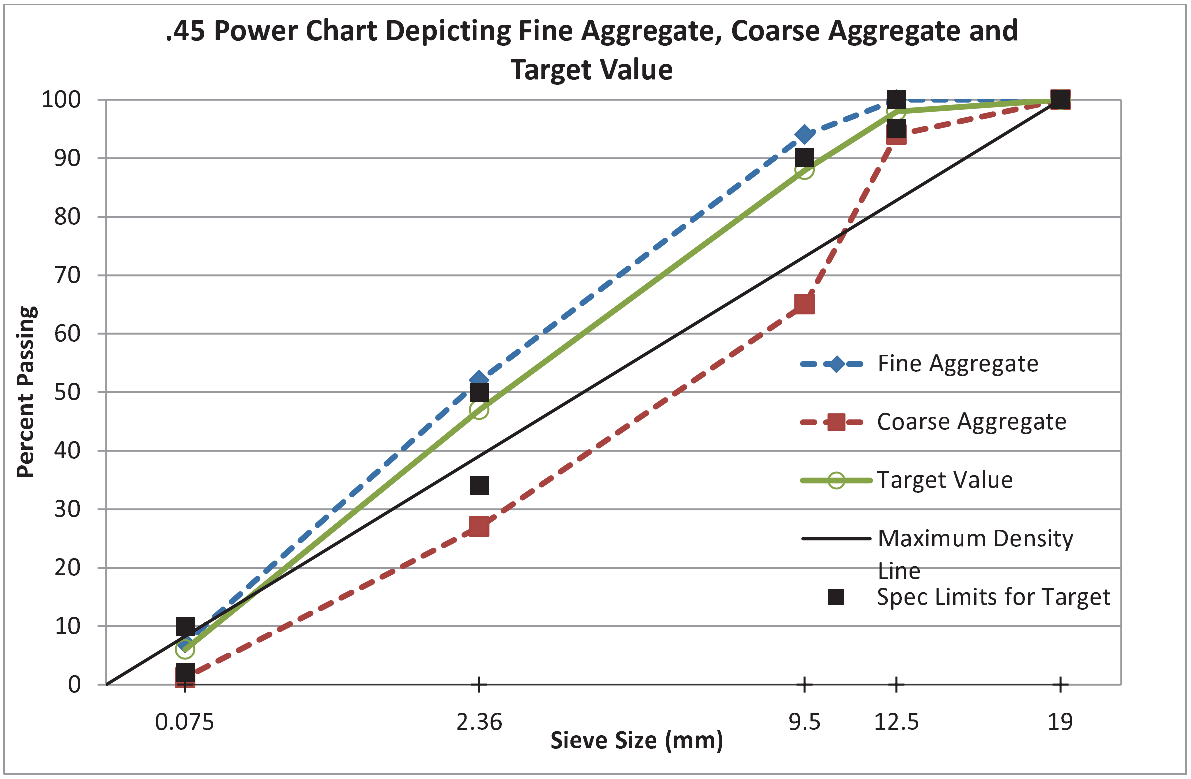

Figure 7-5: Data from Step 3 Plotted on the .45 Power Chart

STEP 4. Determine individual proportions (% Blend) and Total Blend:

4.1 Calculate the individual proportions on each sieve for each of the two aggregates and enter in the column **% Blend**.

% Blend = Percent Passing (a given sieve) x Percent Used (of that Aggregate)

- *Note*: Change Percent Used to a decimal.

4.2 Add the two columns for each sieve and enter in the column marked **Total Blend**.

Total Blend = % Blend for Aggregate 1 +… + % Blend for Aggregate n

Calculations:

% Blend:

Sieve	Fine Aggregate	Coarse Aggregate
3/4	100 x .50 = 50	100 x .50 = 50
1/2	100 x .50 = 50	94 x .50 = 47
3/8	94 x .50 = 47	65 x .50 = 32.5
No. 8	52 x .50 = 26	27 x .50 = 13.5
No. 200	7.1 x .50 = 3.6	1.2 x .50 = 0.6

Total Blend:

Sieve	Fine Aggregate	+	Coarse Aggregate	=	Total Blend
3/4	50	+	50	=	100
1/2	50	+	47	=	97
3/8	47	+	32.5	=	79.5 round to 80
No. 8	26	+	13.5	=	39.5 round to 40
No. 200	3.6	+	0.6	=	4.2

STEP 5. Compare this combined gradation and recalculate as needed.

5.1 Compare the **Total Blend** with the **Target Value**. The blending worksheet that follows and Figure 7-6 present the results.

Aggregate:	Fine Aggregate		Coarse Aggregate						
% Used:	50		50						
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Target Value**	**Design Range**
1 ½									
1									
¾	100	50	100	50			100	100	100
½	100	50	94	47			97	98	95 – 100
3/8	94	47	65	32.5			80	88	90 max
No. 4									
No. 8	52	26	27	13.5			40	47	34 - 50
No. 30									
No. 50									
No. 100									
No. 200	7.1	3.6	1.2	0.6			4.2	6	2 – 10

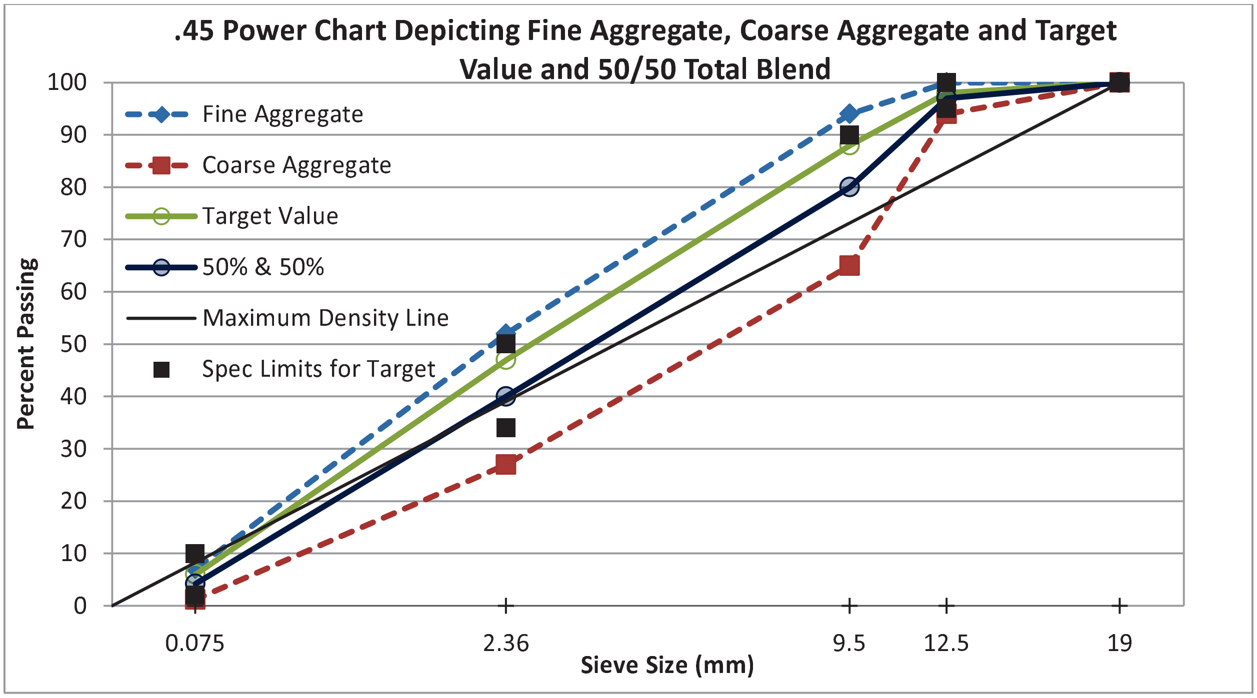

Figure 7-6: Data from Step 5.1 plotted on the .45 Power Chart

Observations: The 3/8" (9.5mm) and No. 8 (2.36mm) sieves are not close to target value, therefore an adjustment needs to be made. On the .45 Power Chart shown as Figure 7-6, note that the blend is too coarse. Increase the percentage of the fine aggregate used to fine the Total Blend.

5.2 It is helpful to use one sieve to make an adjustment before recalculating all sieves.

- This example illustrates use of the **3/8 sieve**:

Aggregate:		**Fine Aggregate**	**Coarse Aggregate**
% Used	Trial 1	50	50
	Trial 2	55	45
	Trial 3	60	40
	Trial 4	70	30
	Trial 5	75	25
	Trial 6	45	55
	Trial 7	40	60

Sieve (in)		% Pass	% Blend	% Pass	% Blend	Total Blend	Target Value	Design Range
3/8	Trial 1	94	47	65	32.5	80	88	90 max
	Trial 2	94	51.7	65	29.3	81	88	90 max
	Trial 3	94	56.4	65	26	82	88	90 max
	Trial 4	94	65.8	65	19.5	85	88	90 max
	Trial 5	94	70.5	65	16.3	87	88	90 max
	Trial 6	94	42.3	65	35.8	78	88	90 max
	Trial 7	94	37.6	65	39	77	88	90 max

Conclusion from this table: Choose Trial No. 5 and recalculate rest of sieves.

5.3 Recalculate Blend (using Trial 5). The results are illustrated in the blending worksheet below and in Figure 7-7.

Aggregate:	Fine Aggregate		Coarse Aggregate				
% Used:	75		25				
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Target Value**	**Design Range**
1 1/2							
1							
3/4	100	75	100	25	100	100	100
1/2	100	75	94	23.5	99	98	95 – 100
3/8	94	70.5	65	16.3	87	88	90 max
No. 4							
No. 8	52	39	27	6.8	46	47	34 - 50
No. 30							
No. 50							
No. 100							
No. 200	7.1	5.3	1.2	0.3	5.6	6	2 - 10

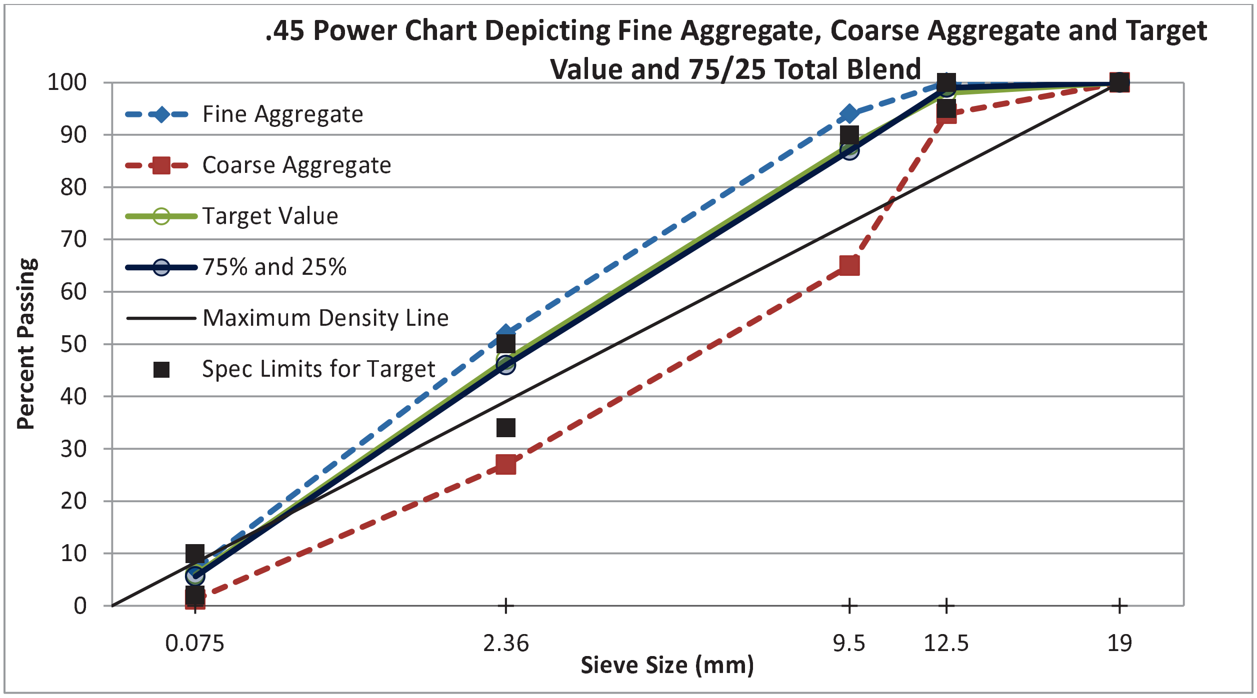

Figure 7-7: Data from Step 5.3 Plotted on the .45 Power Chart

As shown in Figure 7-7, adjustments have moved the Total Blend to the Target Value. At this point, stockpile variability and plant precession need to be considered and accounted for in the amount of fine tuning to the percent of each aggregate used.

Sample Problem 2: Trial and Error Combinations of More than Two Aggregates.

Mix Type: IM-19.0 A

The same basic principles and steps are followed when combining more than two aggregates.

STEP 1. Enter the aggregate gradations and design limits into the appropriate columns of the Blending Worksheet.

Aggregate:	Mineral Filler		Fine Aggregate		Coarse Aggregate				
% Used:									
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Target Value**	**Design Range**
1 1/2									
1	100		100		100				100
3/4	100		100		96				90 – 100
1/2	100		99		47				90 max
3/8									
No. 4									
No. 8	100		69		8				28 – 49
No. 30									
No. 50									
No. 100									
No. 200	28		0		0				2 – 8

STEP 2. Obtain the target values and enter these values in the **Target Value** column of the Blending Worksheet, as shown below.

- The target value must be within design range.
- The target value is provided by Asphalt Mix Design Technician.

Aggregate:	Mineral Filler		Fine Aggregate		Coarse Aggregate				
% Used:									
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Target Value**	**Design Range**
1 1/2									
1	100		100		100			100	100
3/4	100		100		96			98	90 – 100
1/2	100		99		47			79	90 max
3/8									
No. 4									
No. 8	100		69		8			47	28 – 49
No. 30									
No. 50									
No. 100									
No. 200	28		0		0			4.5	2 – 8

Figure 7-8 illustrates a .45 Power Chart for this sample problem.

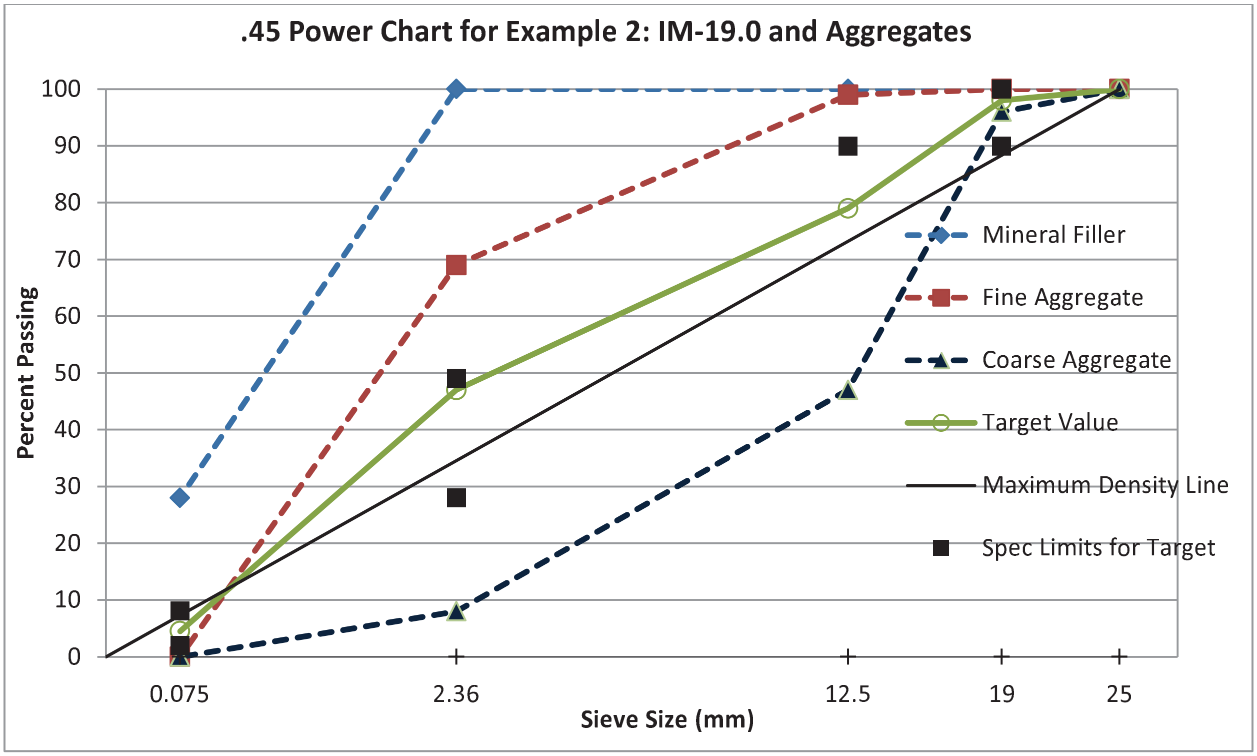

Figure 7-8: Data for Problem 2 Plotted on the .45 Power Chart

STEP 3. Estimate the proportions and enter these figures on the line marked **% Used**:

- The first estimate used for this trial blend is 40% of Mineral Filler, 30% of Fine Aggregate, and 30% of Coarse Aggregate.
- *Note*: Remember, the sum of the proportions must always equal 100.

Aggregate:	Mineral Filler		Fine Aggregate		Coarse Aggregate				
% Used:	40		30		30				
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Target Value**	**Design Range**
1 1/2									
1	100		100		100			100	100
3/4	100		100		96			98	90 – 100
1/2	100		99		47			79	90 max
3/8									
No. 4									
No. 8	100		69		8			47	28 - 49
No. 30									
No. 50									
No. 100									
No. 200	28		0		0			4.5	2 - 8

STEP 4. Determine % Blend and Total Blend.

4.1 Calculate the individual proportions on each sieve for each of the three aggregates and enter in the column **% Blend**.

4.2 Add the three columns for each sieve and enter in the column **Total Blend**.

- ***% Blend*** = % Pass x Percent Aggregate Proportion
- *Note*: Change Percent Aggregate Proportion to a decimal.
- ***Total Blend*** = % Blend Mineral Filler + % Blend Fine Aggregate + % Blend Coarse Aggregate.

Calculations:

% Blend:

Sieve	Mineral Filler	Fine Aggregate	Coarse Aggregate
1	100 x .40 = 40	100 x .30 = 30	100 x .30 = 30
3/4	100 x .40 = 40	100 x .30 = 30	96 x .30 = 28.8
1/2	100 x .40 = 40	99 x .30 = 29.7	47 x .30 = 14.1
No. 8	100 x .40 = 40	69 x .30 = 20.7	8 x .30 = 2.4
No. 200	28 x .40 = 11.2	0 x .30 = 0	0 x .30 = 0

Total Blend:

Sieve	Mineral Filler	+	Fine Aggregate	+	Coarse Aggregate	=	Total Blend
1	40	+	30	+	30	=	100.0
3/4	40	+	30	+	28.8	=	98.8 = 99
1/2	40	+	29.7	+	14.1	=	83.8 = 84
No. 8	40	+	20.7	+	2.4	=	63.1 = 63
No. 200	11.2	+	0	+	0	=	11.2

STEP 5. Compare this combined gradation and recalculate as needed.

5.1 Compare the **Total Blend** with the **Target Value**, as shown below. Figure 7-9 present the results.

Aggregate:	Mineral Filler		Fine Aggregate		Coarse Aggregate				
% Used:	40		30		30				
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Target Value**	**Design Range**
1 1/2									
1	100	40	100	30	100	30	100	100	100
3/4	100	40	100	30	96	28.8	99	98	90 – 100
1/2	100	40	99	29.7	47	14.1	84	79	90 max
3/8									
No. 4									
No. 8	100	40	69	20.7	8	2.4	63	47	28 – 49
No. 30									
No. 50									
No. 100									
No. 200	28	11.2	0	0	0		11.2	4.5	2 – 8

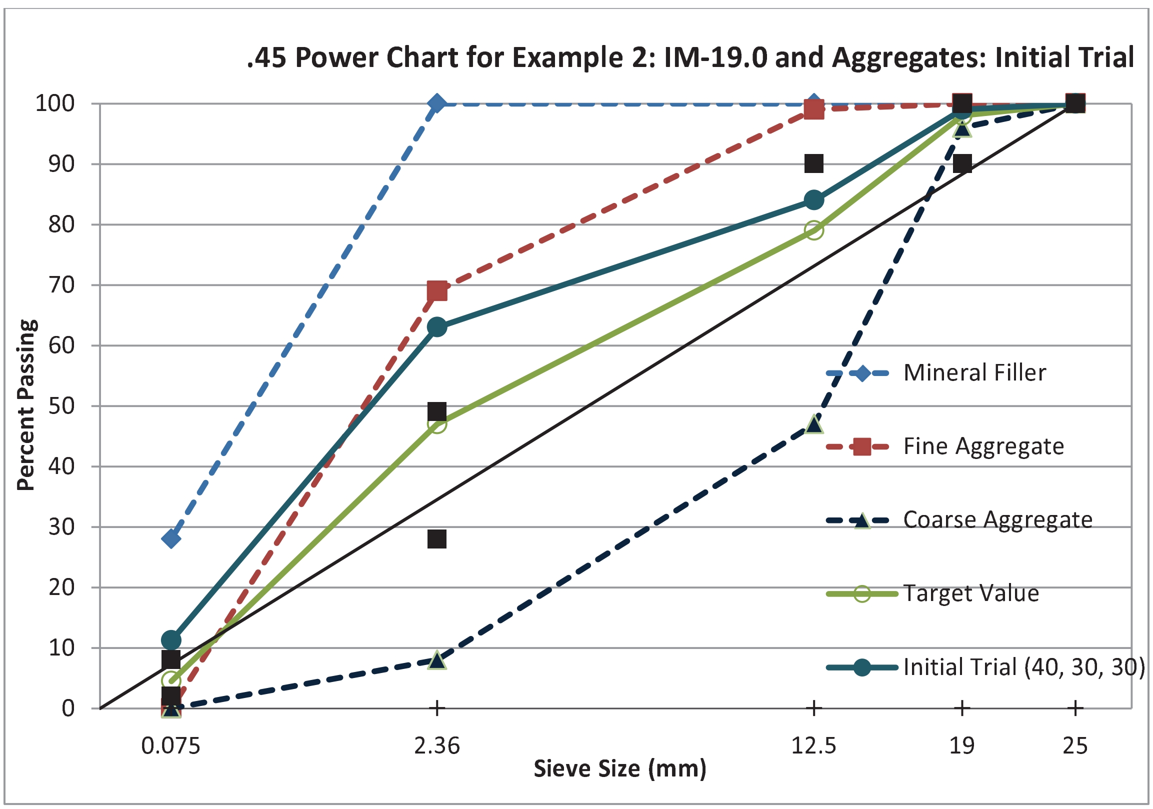

Figure 7-9: Data from Step 5.1 Potted on the .45 Power Chart

Observation: The Total Blend is too fine. Investigate reducing the amount of Mineral Filler and/or Fine Aggregate and increasing the percent coarse aggregate.

5.2 It is helpful to use one sieve to make an adjustment before recalculating all sieves.

- This example illustrates use of the **No. 8 sieve:**

Aggregate		Mineral Filler	Fine Aggregate	Coarse Aggregate
% Used	Trial 1	30	30	40
	Trial 2	30	35	35
	Trial 3	25	40	35
	Trial 4	20	35	45
	Trial 5	15	40	45

Sieve (in)		% Pass	% Blend	% Pass	% Blend	% Pass	% Blend	Total Blend	Target Value	Design Range
No. 8	Trial 1	100	30	69	20.7	8.0	3.2	54	47	28 - 49
	Trial 2	100	30	69	24.2	8.0	2.8	57	47	28 - 49
	Trial 3	100	25	69	27.6	8.0	2.8	55	47	28 - 49
	Trial 4	100	20	69	24.2	8.0	3.6	48	47	28 - 49
	Trial 5	100	15	69	27.6	8.0	3.6	46	47	28 - 49

Conclusion from this table: Choose Trial No. 4 and recalculate rest of sieves.

5.3 Recalculate Blend (using Trial 4). The results are shown in the worksheet below.

Aggregate:	Mineral Filler		Fine Aggregate		Coarse Aggregate				
% Used:	20		35		45				
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Target Value**	**Design Range**
1 1/2									
1	100	20	100	35	100	45	100	100	100
3/4	100	20	100	35	96	43.2	98	99	90 – 100
1/2	100	20	99	34.7	47	21.2	76	79	90 max
3/8									
No. 4									
No. 8	100	20	69	24.2	8	3.6	48	47	28 – 49
No. 30									
No. 50									
No. 100									
No. 200	28	5.6	0	0	0		5.6	4.5	2 – 8

This is one possible solution. The **Total Blend** can be adjusted to be closer to the **Target Value**.

5.4 Recalculate Blend (using Trial 5). The results are illustrated below and in Figure 7-10.

Aggregate:	Mineral Filler		Fine Aggregate		Coarse Aggregate				
% Used:	15		40		45				
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Target Value**	**Design Range**
1 1/2									
1	100	15	100	40	100	45	100	100	100
3/4	100	15	100	40	96	43.2	98	99	90 – 100
1/2	100	15	99	39.6	47	21.2	76	79	90 max
3/8									
No. 4									
No. 8	100	15	69	27.6	8	3.6	46	47	28 - 49
No. 30									
No. 50									
No. 100									
No. 200	28	4.2	0	0	0		4.2	4.5	2 - 8

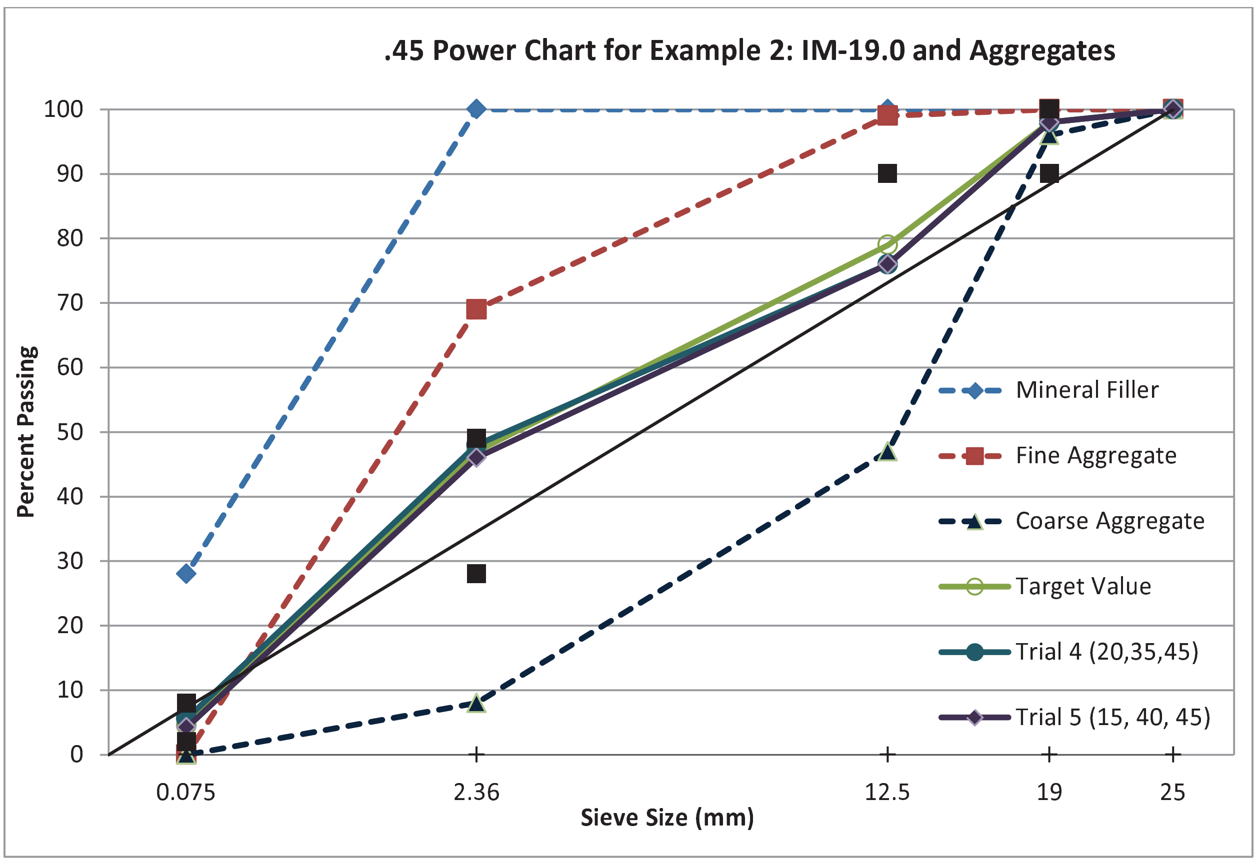

Figure 7-10: Data from Step 5-4 Plotted on .45 Power Chart

AWARENESS/IMPORTANT

Once the percent of each aggregate to be used has been determined and conforms to the requirements, a plant can then use these percentages to set the gates of the cold feed.

The precision of the plant controls and variability of the stockpiles need to be taken into account when fine tuning aggregate percentages.

Highlights a step in the procedure which is either unusual or very particular to this procedure.
May also indicate awareness (additional information) or a cautionary concern in the procedure.

Proportioning Aggregate at the Batch Plant

	DEFINITIONS. The following terms will be used throughout this section:
Sampling gates	Gates or windows in the sides of the hot bins that allow the Technician to sample aggregates at the plant.
Sampling device	A device used to obtain a representative sample of aggregates.

Aggregates must also be proportioned at the batch plant to ensure that the plant is producing the desired asphalt mix. To do so, it is necessary to pull a certain amount of aggregate from each hot bin, as well as the stockpiles. It is the hot bin gradation that will be used to determine aggregate proportions. The amount that is pulled from each bin is dependent upon:

- What the job mix formula calls for
- The gradation contained in each bin.

The technique used to pull the aggregate from each bin is called hot bin sampling.

Hot Bin Sampling

STEP 1. Start up.

Start running the plant, the cold feed, the dryer and the screens. This is required to ensure that the material in the bins is representative of the proportions established at the cold gates. Only after the plant has "settled down" should a sample of aggregate be taken from each bin.

STEP 2. Locate the sampling facilities and devices.

Most hot mix asphalt concrete plants are equipped with devices for sampling hot aggregate bins. These vary from sampling "gates" or "windows" in the sides of the hot bins, to devices for diverting the flow of aggregates from the bins into sample containers.

In the case of batch plants, the best place to obtain a representative sample is from the bin gates, as the material falls in the weigh hopper.

Use a sampling device such as the one shown in Figure 7-11 to capture material.

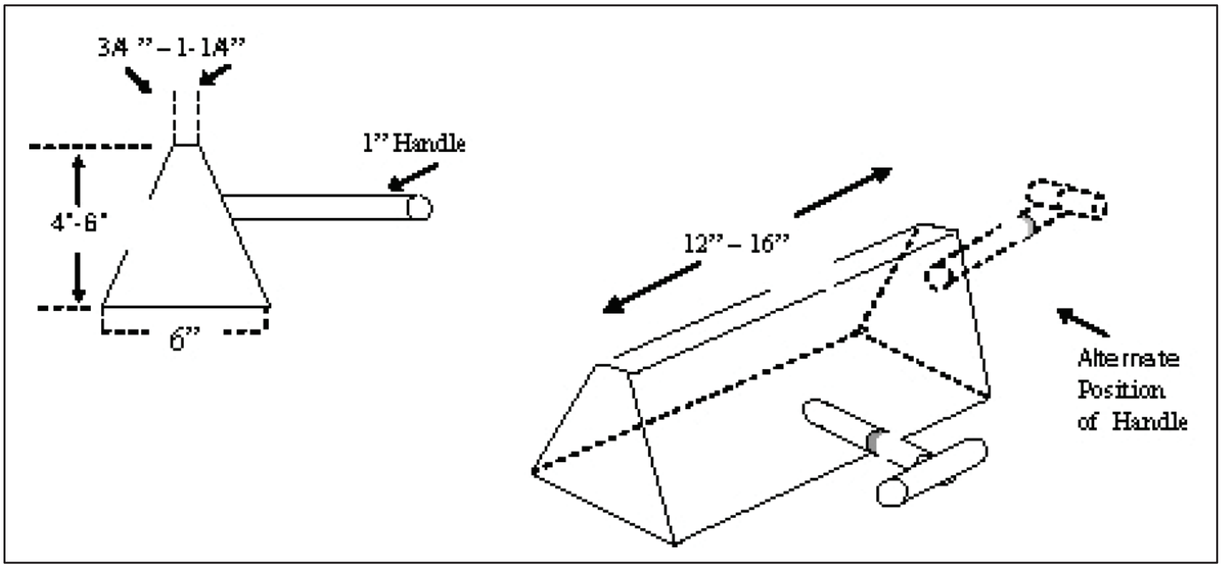

Figure 7-11: Sampling Device

.**STEP 3.** Withdraw material in representative samples.

3.1. Properly position and pass the sampling device through the stream of material, so that all the sizes are collected and a representative sample is obtained. Correct use of the sampling device is illustrated in Figure 7-12.

3.2. Withdraw the sampling device before it overflows and deposit the sample in a clean container.

3.3. Repeat the procedure for each bin to be analyzed.

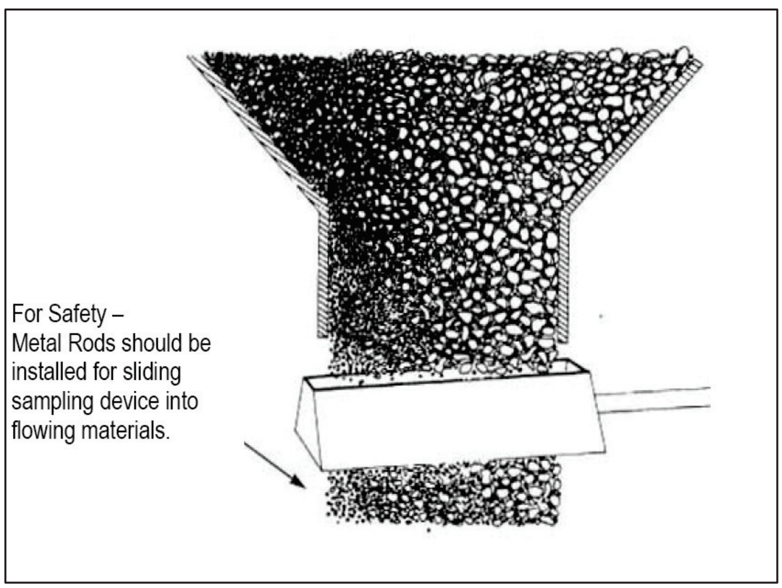

Figure 7-12: Correct Use of the Sampling Device

The following provides background that is important for sampling success:

- As materials flow over the plant screens, the finer particles fall to the near side of the bins, and the coarser particles to the far side, as illustrated in Figure 7-13.

  When material is drawn from the bins by opening a gate at the bottom, the stream consists predominately of fine material at one edge and coarse material at the other. This condition is critical in the number 1, or fine bin, since the asphalt demand is influenced by the material from this bin.

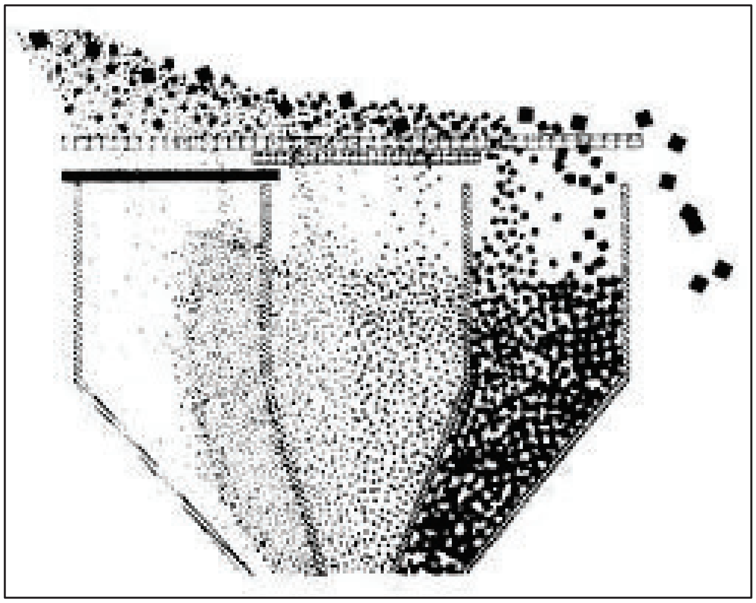

Figure 7-13: Hot Bin Sampling

- The relative position of the sampling device in the stream determines whether the sample will be composed of the fine portion, the coarse portion, or will be an accurate representation of the material in the bin. It is most important that the sampling device be properly positioned in the stream of material, so that all of the sizes are collected and a *representative* sample is obtained.

Hot Bin Sampling
Sampling improperly can ruin test results. Use proper techniques to pull samples from the hot bins: ▪ Always make sure the containers and sampling device are clean. ▪ When you hear the bin open, steadily push the sampling container down the rails and pull it back at the same speed once it reaches the end to ensure that you sample the entire stream. ▪ Do not leave the sampling container in one place to collect the sample because the stream of material coming from the bin may be segregated, with small rock on one side and large rock on the other.

Hot Bin Proportions by the "Trial and Error" Method

	DEFINITIONS. The following terms will be used throughout this section:
Acceptance range	The job mix formula with the tolerances applied.
Process tolerance	The amount of deviation allowed from the job mix formula.
Production tolerance	The allowable target-miss that is allowed during production before price adjustments are applied.

Before the bin weights can be calculated, the proportions (percentages) required from each bin must be determined. The "Trial and Error" method again is the easiest method to use to determine these proportions and combined gradations for the job mix formula.

Note: The steps for these calculations are the same as those covered in the previous section for cold feed and lab blending determinations. However, in this section we will be using the gradations of the batch plant's hot bins, rather than stockpile gradations. Additionally, we will cover production tolerances and acceptance ranges in this section. The production tolerance is the allowable target-miss that is allowed during production before price adjustments are applied.

The acceptance range is determined by taking the job mix formula and applying the process tolerances for eight tests. These tolerances are found in the VDOT *Road and Bridge Specifications*, Section 211.08 Table II–15. (See Figure 7-14.)

Sample Problem 1: Hot Bin Proportioning

STEP 1. Obtain required data from the following and enter it into the appropriate columns, as shown in the worksheet that follows:

- Job mix formula (TL-127)
- Hot bin gradations

Aggregate:	Bin 1		Bin 2		Bin 3		Bin 4				
% Used:											
Sieve (in)	% Pass	% Blend	% Pass	% Blend	% Pass	% Blend	% Pass	% Blend	Total Blend	Job Mix Formula	Accept Range
1 1/2	100		100		100		100			100	
1	100		100		100		93			97	
3/4	100		100		90		35			84	
1/2											
3/8											
No. 4											
No. 8	91		10		0		0			36	
No. 30											
No. 50											
No. 100											
No. 200	12		0		0		0			4	

STEP 2. Determine the acceptance range and enter it into the **Accept Range** column of the worksheet, as shown on the next page.

- Use Table II-15 Process Tolerance for Eight Tests (Plus and Minus Tolerance) found in Section 211.08 (shown on the next page as Figure 7-14).
- *Note*: The Process tolerance is the amount above and the amount below the job mix formula that can be tolerated for a specific mix. The upper acceptance range cannot be greater than 100.
- To calculate the upper and lower acceptance ranges, add or subtract, respectively, the process tolerance from the job mix formula.

Sieve	Job Mix Formula	Process Tolerance	Lower Acceptance Range	Upper Acceptance Range
1 ½	100	0	100 - 0 = 100	100 + 0 = 100
1	97	± 2.8	97 - 2.8 = 94.2	97 + 2.8 = 99.8
¾	84	± 2.8	84 - 2.8 = 81.2	84 + 2.8 = 86.8
No. 8	36	± 2.8	36 - 2.8 = 33.2	36 + 2.8 = 38.8
No. 200	4	± 0.7	4 - 0.7 = 3.3	4 + 0.7 = 4.7

Aggregate:	Bin 1		Bin 2		Bin 3		Bin 4				
% Used:											
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Job-Mix Formula**	**Accept Range**
1 1/2	100		100		100		100			100	100
1	100		100		100		93			97	94.2 - 99.8
3/4	100		100		90		35			84	81.2 - 86.8
1/2											
3/8											
No. 4											
No. 8	91		10		0		0			36	33.2 - 38.8
No. 30											
No. 50											
No. 100											
No. 200	12		0		0		0			4	3.3 - 4.7

Table II-15. Process Tolerance for Eight Tests (Plus and Minus Tolerance), Section 211.08
Process Tolerance on Each Laboratory Sieve and Asphalt Content - Percent Plus & Minus

No. Tests	Top Size	1.5 in	1 in	3/4 in	1/2 in	3/8 in	No. 4	No. 8	No. 30	No. 50	No. 200	AC*
1	0.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	6.0	5.0	2.0	0.60
2	0.0	5.7	5.7	5.7	5.7	5.7	5.7	5.7	4.3	3.6	1.4	.43
3	0.0	4.4	4.4	4.4	4.4	4.4	4.4	4.4	3.3	2.8	1.1	.33
4	0.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.0	2.5	1.0	.30
5	0.0	3.6	3.6	3.6	3.6	3.6	3.6	3.6	2.7	2.2	0.9	0.27
6	0.0	3.3	3.3	3.3	3.3	3.3	3.3	3.3	2.4	2.0	0.8	0.24
7	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.3	1.9	0.8	0.23
8	0.0	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.1	1.8	0.7	.21
12	0.0	2.3	2.3	2.3	2.3	2.3	2.3	2.3	1.7	1.4	0.6	0.17

**Asphalt content will be measured as extractable asphalt or mass after ignition*

Source: VDOT *Road and Bridge Specifications*, Section 211.08.

Figure 7-14: Table II-15, Process Tolerance for Eight Tests

STEP 3. Estimate the proportions and enter them into the appropriate columns of the worksheet, as shown below.

- The sum of the Bin Percentages (Total Blend) must always equal 100.

Aggregate:	Bin 1		Bin 2		Bin 3		Bin 4				
% Used:	25		25		25		25				
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Job Mix Formula**	**Accept Range**
1 1/2	100		100		100		100			100	100
1	100		100		100		93			97	94.2 - 99.8
3/4	100		100		90		35			84	81.2 - 86.8
1/2											
3/8											
No. 4											
No. 8	91		10		0		0			36	33.2 - 38.8
No. 30											
No. 50											
No. 100											
No. 200	12		0		0		0			4	3.3 - 4.7

STEP 4. Calculate % Blend and combined gradation (Total Blend).

4.1 Calculate the individual proportions on each sieve for each of the three aggregates and enter in the column **% Blend**.

4.2 Add the % Blend for all bins and enter in the column Total Blend.

- ***% Blend*** = % Pass x Percent Aggregate Proportion
- *Note:* Change Percent Aggregate Proportion to a decimal)
- ***Total Blend*** = % Blend Bin 1 + % Blend Bin 2 + % Blend Bin 3 + % Blend Bin 4

Calculations:

% Blend:

Sieve	**Bin 1**	**Bin 2**	**Bin 3**	**Bin 4**
1 1/2	100 x .25 = 25	100 x .25 = 25	100 x .25 = 25	100 x .25 = 25
1	100 x .25 = 25	100 x .25 = 25	100 x .25 = 25	93 x .25 = 23.3
3/4	100 x .25 = 25	100 x .25 = 25	90 x .25 = 22.5	35 x .25 = 8.8
No. 8	91 x .25 = 22.8	10 x .25 = 2.5	0 x .25 = 0	0 x .25 = 0
No. 200	12 x .25 = 3.0	0 x .25 = 0	0 x .25 = 0	0 x .25 = 0

Total Blend:

Sieve	Bin 1	+	Bin 2	+	Bin 3	+	Bin 4	=	Total Blend
1 1/2	25	+	25	+	25	+	25	=	100
1	25	+	25	+	25	+	23.3	=	98.3 or 98
3/4	25	+	25	+	22.5	+	8.8	=	81.3 or 81
No. 8	22.8	+	2.5	+	0	+	0	=	25.3 or 25
No. 200	3	+	0	+	0	+	0	=	3.0

Worksheet results after Step 4.2:

Aggregate:	Bin 1		Bin 2		Bin 3		Bin 4				
% Used	25		25		25		25				
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Job Mix Formula**	**Accept Range**
1 1/2 in	100	25	100	25	100	25	100	25	100	100	100
1 in	100	25	100	25	100	25	93	23.3	98	97	94.2 – 99.8
3/4 in	100	25	100	25	90	22.5	35	8.8	81	84	81.2 – 86.8
1/2 in											
3/8 in											
No. 4											
No. 8	91	22.8	10	2.5	0	0	0	0	25	36	33.2 – 38.8
No. 30											
No. 50											
No. 100											
No. 200	12	3.0	0	0	0	0	0	0	3	4	3.3 – 4.7

STEP 5. Compare combined gradation in the **Total Blend** column with the Target Value in the **Job Mix Formula** column and acceptance range data in the **Accept Range** column.

Aggregate:	Bin 1		Bin 2		Bin 3		Bin 4				
% Used	25		25		25		25				
Sieve (in)	% Pass	% Blend	% Pass	% Blend	% Pass	% Blend	% Pass	% Blend	Total Blend	Job Mix Formula	Accept Range
1 1/2 in	100	25	100	25	100	25	100	25	100	100	100
1 in	100	25	100	25	100	25	93	23.3	98	97	94.2 – 99.8
3/4 in	100	25	100	25	90	22.5	35	8.8	81	84	81.2 – 86.8
1/2 in											
3/8 in											
No. 4											
No. 8	91	22.8	10	2.5	0	0	0	0	25	36	33.2 – 38.8
No. 30											
No. 50											
No. 100											
No. 200	12	3.0	0	0	0	0	0	0	3	4	3.3 – 4.7

Note that the No. 8 sieve Total Blend column value is below the Job Mix Formula column value and is outside of the acceptance range. As a result, we will need to make adjustments to the % Used values for each of the hot bins.

5.2 Use one sieve to make an adjustment before recalculating all sieves.

Aggregate:	Bin 1		Bin 2		Bin 3		Bin 4				
% Used	25		25		25		25		***Trial 1***		
% Used	30		25		20		25		***Trial 2***		
% Used	35		20		20		25		***Trial 3***		
Sieve (in)	% Pass	% Blend	% Pass	% Blend	% Pass	% Blend	% Pass	% Blend	Total Blend	Job-Mix Formula	Accept Range
No. 8 (T1)	91	22.8	10	2.5	0	0	0	0	25	36	33.2 – 38.8
No. 8 (T2)	91	27.3	10	2.5	0	0	0	0	30	36	33.2 – 38.8
No. 8 (T3)	91	31.9	10	2.0	0	0	0	0	34	36	33.2 – 38.8

<u>Conclusion from this table</u>: Use third trial to recalculate the rest of the sieves.

5.3. Recalculate Blend (using Trial 3). The results are illustrated in the worksheet below.

Aggregate:	Bin 1		Bin 2		Bin 3		Bin 4				
% Used	35		20		20		25				
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Job-Mix Formula**	**Accept Range**
1 1/2 in	100	35	100	20	100	20	100	25	100	100	100
1 in	100	35	100	20	100	20	93	23.3	98	97	94.2 – 99.8
3/4 in	100	35	100	20	90	18	35	8.8	82	84	81.2 – 86.8
1/2 in											
3/8 in											
No. 4											
No. 8	91	31.9	10	2	0	0	0	0	34	36	33.2 – 38.8
No. 30											
No. 50											
No. 100											
No. 200	12	4.2	0	0	0	0	0	0	4.2	4	3.3 – 4.7

Calculating Batch Weights

After determining the proportions required for each hot bin, we can calculate the weight of asphalt binder and the amount of aggregate to be pulled from each bin to produce a single batch of hot mix asphalt. The following section provides procedural information to accomplish this task.

Calculating Batch Weights

The following outlines the procedure for calculating batch weights:

- Determine batch size
- Determine asphalt content
- Obtain bin percentages
- Calculate the weight of the asphalt and aggregate
- Calculate the weight of the aggregate per bin
- Calculate the accumulative weight per bin

STEP 1. Determine batch size, which will be mainly dependent upon the pugmill capacity of the asphalt plant. (This is usually the manufacturer's rated pugmill capacity.) For example, a 6000 lb. pugmill has 6000 lb. batch size.

STEP 2. Determine asphalt content.

- This is obtained from TL-127 (example form is shown on page 7-4 of this chapter).
- Example: 4.2%

STEP 3. Determine the Bin Percentages through the Trial and Error method.

- For this example we will use: 35, 20, 20 and 25 percent, for bins 1, 2, 3 and 4 respectively.

STEP 4. Calculate the weight of the asphalt and aggregate.

- Weight of Asphalt = Pugmill Size x Asphalt Content
- *Note*: Remember to change Asphalt Content value to decimal format.
- Weight of Asphalt = 6000 lb. x .042 = 252 lb.
- Weight of Aggregate = Pugmill Size – Weight of Asphalt.
- Weight of Aggregate = 6000 lb. – 252 lb. = 5748 lb.

STEP 5. Calculate the weight of aggregate per bin.

- Weight per Bin = Weight of Aggregate x Bin Percentage
- *Note*: Remember to change the bin percentage to decimal.
- Weight Bin 1 = 5748 x .35 = 2011.8
- Weight Bin 2 = 5748 x .20 = 1149.6
- Weight Bin 3 = 5748 x .20 = 1149.6
- Weight Bin 4 = 5748 x .25 = 1437

STEP 6. Calculate the accumulative weight per bin.

- Bin 1 = Bin 1
- Bin 2 = Bin 1 + Bin 2
- Bin 3 = Bin 1 + Bin 2 + Bin 3
- Bin 4 = Bin 1 + Bin 2 + Bin 3 + Bin 4
- Bin 1 = 2011.8
- Bin 2 = 2011.8 + 1149.6 = 3161.4
- Bin 3 = 2011.8 + 1149.6 + 1149.6 = 4311
- Bin 4 = 2011.8 + 1149.6 + 1149.6 + 1437 = 5748

AWARENESS/IMPORTANT

The final accumulative bin weight should always equal the initial weight of aggregate.

Highlights a step in the procedure which is either unusual or very particular to this procedure.
May also indicate awareness (additional information) or a cautionary concern in the procedure.

Chapter Seven Knowledge Check

1. Where are the design range limits found for the different types of asphalt concrete mixtures?

2. If the job mix on the 1/2 inch sieve is 81% passing, what is the acceptance range for the eight tests?

3. To whom should the job mix be submitted?

4. The range from which the job mix is chosen is called:
   A. Standard deviation
   B. Design range
   C. Process tolerance
   D. Acceptance range

5. The “Trial and Error” method is commonly used to determine the relative proportions of different aggregates needed to produce a final gradation that meets specifications.
   A. True
   B. False

6. The target values for the combined gradation are provided by:
   A. The Asphalt Producer
   B. The District Materials Engineer
   C. The Asphalt Mix Design Technician
   D. Table II-13 in the *Road and Bridge Specifications*

Study Problem 1: Cold Feed Blending

Determine the Job Mix Formula (Total Blend).

Type Mix: **SM-12.5A**

Aggregate:	Screenings		Stone				
% Used:							
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Target Value**	**Design Range**
1 1/2 in							
1 in							
3/4 in	100		100			100	
1/2 in	100		98			98	
3/8 in	100		77			88	
No. 4							
No. 8	100		9			49	
No. 30							
No. 50							
No. 200	12		0			5.5	

Study Problem 2: Cold Feed Blending

Determine the Job Mix Formula (Total Blend).

Type Mix: IM-19.0D

Aggregate:	No. 10		1/2" Cr/ Run		No. 68				
% Used:									
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Target Value**	**Design Range**
1 1/2 in									
1 in	100		100		100			100	
3/4 in	100		99		96			98	
1/2 in	100		89		47			79	
3/8 in									
No. 4									
No. 8	99		41		9			49	
No. 30									
No. 50									
No. 200	10		2.5		0			4.5	

Study Problem 3: Cold Feed Blending

Determine the Job Mix Formula (Total Blend).

Type Mix: SM-12.5D

Aggregate:	No. 78		No. 10		Sand				
% Used:									
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Target Value**	**Design Range**
1 1/2 in									
1 in									
3/4 in	100		100		100			100	
1/2 in	96		99		100			98	
3/8 in	75		95		100			88	
No. 4									
No. 8	11		65		100			49	
No. 30									
No. 50									
No. 200	0		14		1.4			5.5	

Study Problem 4: Hot Bin Blending

Batch plant set up:

A. Determine hot bin proportions.

1. Determine the percentage to be pulled from each bin to meet the job mix formula.
2. Show blend determined under the **Total Blend** column.
3. Show acceptance range in the **Accept. Range** column.

Type Mix: BM-25.0

Aggregate:	Bin 1		Bin 2		Bin 3		Bin 4				
% Used:											
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Job-Mix Formula**	**Accept Range**
1 1/2 in	100		100		100		100			100	
1 in	100		100		99		91			98	
3/4 in	100		100		88		8			76	
1/2 in											
3/8 in											
No. 4											
No. 8	86		13		3		0			32	
No. 30											
No. 50											
No. 200	10		0		0		0			4	

B. Using the percentage determined to be pulled from each bin above and an asphalt content of 4.5%, calculate the weight of asphalt, weight of aggregates from each bin, and accumulative weights per bin to be pulled in an 8000 pound batch.

	Percent	**Weight of Aggregates per Bin**	**Accumulative Weights per Bin**
Bin 1			
Bin 2			
Bin 3			
Bin 4			
	Weight of Asphalt		

Study Problem 5: Hot Bin Blending

Batch Plant set up:

A. Determine hot bin proportions.

1. Determine the percentage to be pulled from each bin to meet the job mix formula.
2. Show blend determined under column listed "total blend".
3. Show acceptance range in column listed "acceptance range".

Type Mix: IM-19.0 A

Aggregate:	Bin 1		Bin 2		Bin 3		Bin 4				
% Used											
Sieve (in)	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**% Pass**	**% Blend**	**Total Blend**	**Job-Mix Formula**	**Accept Range**
1 1/2 in											
1 in	100		100		100		100			100	
3/4 in	100		100		93		91			97	
1/2 in	100		92		71		30			72	
3/8 in											
No. 4											
No. 8	87		37		18		5			37	
No. 30											
No. 50											
No. 200	24		1.5		0		0			6.5	

B. Using the percentage determined to be pulled from each bin above and an asphalt content of 4.7%, calculate the weight of asphalt, weight of aggregates from each bin, and accumulative weights per bin to be pulled in a 5500 pound batch.

	Percent	**Weight of Aggregates per Bin**	**Accumulative Weights per Bin**
Bin 1			
Bin 2			
Bin 3			
Bin 4			
	Weight of Asphalt		