5.18.02 BITUMINOUS MIX DESIGN

(a) Mixtures Containing Asphalt Cement.

(1) Scope.

This method covers the procedure for determining the optimum amount of asphalt cement in a given aggregate mixture. Since bituminous mixtures vary by type, and to some extent within type, these instructions must be considered as a general commentary. Judgement and experience must be used in interpreting the design information obtained by this method.

(2) General.

a. Marshall Tests: Conduct tests on mixtures of aggregate and asphalt using Marshall apparatus as described in Kansas Test Method KT-14, and plot the resulting data on KDOT Form No. 702, "Asphaltic Concrete Design Mix Curves." Report percent asphalt on a dry weight basis. [A computer program for the Marshall Mix Design has been developed and it may be used. Examples shown at the end of this section (**5.18.02**) were generated by this computer program.]

b. Interpretation of Test Results: Experience has shown that the results of Marshall tests can be excellent guidelines to use when determining the optimum asphalt content for a given mix. The mix designer must become familiar with Marshall criteria, learn to judge the significance of each parameter and be able to analyze the characteristics of the mixture from the results of the design calculations and test values. Marshall curves alone should not be used to determine the design asphalt content, but should be used in analyzing the characteristics of the mixture. When deciding upon the optimum asphalt content for a mixture, do not select a value that is obviously not in conformity with some portions of the data in question or with other values derived from the test.

(3) Significance of Properties:

It should remain foremost in the thinking of the mix designer that the design data consists of two general areas - volumetric and physical.

a. Volumeteric Considerations:

Voids in Mineral Aggregate (VMA). The VMA generally decreases to a minimum value then increases with increasing asphalt contents. As far as possible, the mixtures with higher VMA should be preferred because of the following advantages:

1. More asphalt can be incorporated in the mixture to increase durability.
2. Lower sensitivity to variation in asphalt content during production.

3. Mixtures with low VMA will flush if slightly excessive in asphalt content, and will be dry and brittle if slightly deficient in asphalt content.

Voids Filled with Asphalt (VFA). The VFA increases with increasing asphalt content. There is a maximum VFA for each aggregate blend and compaction effort. The VFA can not be increased above this maximum without increasing or otherwise changing the compaction effort. The VFA curve is usually convex upwards.

% Voids - Total Mixture. The percent of air voids decreases with increasing asphalt content, ultimately approaching a minimum void content in much the same manner as the VFA discussed above approaches a maximum value. The air voids curve is usually concave upwards. Voids are the air spaces within the mixture. It is important that a mixture contains sufficient voids to provide spaces for expansion of bitumen and a slight amount of additional densification (compaction) under traffic. Aggregate size, shape and gradation have an effect on the amount of voids developed in a mixture and in the amount of bitumen that a mixture can contain. The voids should be held to a minimum, consistent with the aggregate, yet large enough to permit expansion.

b. Physical Considerations:

Unit Weight (specimen). The Unit Weight of the compacted specimen increases with increasing asphalt content up to a certain point, after which it decreases.

Stability. The stability value increases with increasing asphalt content up to a maximum after which the stability decreases. The peak of the stability curve is normally (but not always) at a slightly lower asphalt content than the peak of the Unit Weight curve. Cases are not uncommon where no stability peak is obtained. Stability is a measure of resistance to deformation. It is necessary to have sufficient stability to meet the requirements of traffic without mat distortion or displacement. There are two forms of resistance, frictional or interlocking and cohesive resistance. Frictional or interlocking resistance is dependent on the aggregate framework. Cohesive resistance develops in the bitumen-binder portion of the mixture. It depends on the rate of loading, load and temperature. High stability is undesirable if it is due to high density and low voids. Mixtures of this type have an excess of filler and are deficient in bitumen. Such surfaces will have low resistance to cracking, are brittle in the winter, and tend to ravel under traffic.

Flow. This is an index of plasticity or the resistance to distortion. The amount of bitumen that fills the aggregate voids affects the flow. The flow value increases as the bitumen content of the mixture increases. Mixtures which contain high air voids usually develop excessive flow values before reaching the bitumen content which will produce a satisfactory density. Flow values will increase rapidly with small increases in asphalt in mixtures which contain a large amount of filler.

c. Generalized "Need" of a Durable Pavement:

Workability. This is a term which generally describes the spreadability and compactability of the mixture. Decreasing the percentage retained on the 2.36 mm (No. 8) sieve will reduce harshness. Decreasing the percentage of sand and filler will reduce stiffness. Reducing the bitumen content and filler content will reduce gumminess.

Skid Resistance. A measure of the sliding force exerted on a tire when the brakes are locked. Bituminous wearing courses must have the highest possible skid resistance obtainable. The type of aggregate used has a great effect on skid resistance.

Durability. A measure of resistance to disintegration by weather or traffic conditions. The most important factor with respect to durability is the amount of bitumen. A bituminous mixture is resistant to the action of air and water in direct proportion to the degree that they are kept out of the mixture. If the voids are completely filled with bitumen, the surfaces will become plastic and flushing will occur. It is, however, desirable that the mixture should contain as high a bitumen content as possible that is consistent with stability and voids. This will give the pavement maximum durability and prevent raveling because of a deficiency of bitumen. An asphalt content set totally on durability may produce a slippery surface. Therefore, a compromise between durability and skid resistance must often be accepted.

Flexibility. The ability of the bituminous mixture to bend repeatedly without cracking and to conform to changes in the base course. To have flexibility, a mixture must contain the proper amount of bitumen. Open graded mixtures are more flexible than dense graded mixtures. Flexibility decreases as the paving layer thickness increases. Flexibility increases with an increase of temperature.

(4) Types of Mixtures:

The types of mixtures encountered will generally fall within one of the following categories:

a. Balanced Mixture: The Marshall curves for a balanced mixture show that the maximum unit weight and maximum stability occur at nearly the same asphalt content.

b. Open Graded Mixture: This type of mixture has an open texture, low unit weight and a high percent of voids due to the type, particle shape and gradation of the aggregate. The maximum unit weight and maximum stability can occur at the same asphalt content, which will be much higher than for a balanced mixture.

c. Dense Graded Mixture: This type of mixture has high unit weight, low percentage of voids and often has no indicated stability peak. This is caused by the proportioning of graded coarse and fine aggregates to produce a mixture that will have maximum density and minimum voids.

Form 707 allows the gradation of the mix to be visually shown. Form 707 (Gradation Chart for Marshall Design, Sieve Sizes Raised to 0.45 Power) is completed as listed below and shown in the example at the end of this section (**5.18.02**).

a. Plot the Marshall Job Mix Single Point (for recycle mixes plot the Theoretical Combined Gradation, RAP Extracted Gradation, and the Virgin Aggregate Job Mix Single Point).

b. Determine the first sieve size with more than 10 percent retained in the Job Mix Single Point. (For recycle mixes determine the first sieve size with more than 10 percent retained on the Theoretical Combined Gradation).

c. Determine the Maximum Sieve Size. This is two sieve sizes larger than the first sieve with more than 10 percent retained.

d. Draw the maximum density line. This is a line drawn from the origin of the 0.45 power chart (lower left) to the point at which the Maximum Sieve Size intersects the 0 percent retained (100 percent passing) line.

e. Determine if the mix VMA falls in Zone 1 or Zone 2 using the instructions on **Form 707**.

f. Terminology definition - Normal Maximum Size is one sieve size smaller than the Maximum Size. This is also one size larger than the first sieve size with more than 10 percent retained on the Job Mix Single Point (Theoretical Combined Gradation for recycle mixes.)

(5) Asphalt Content Determination:

a. The recommended asphalt content should be one which best fits or satisfies the volumetric and physical parameters desired. Information needed for asphalt content selection may be found in the project specifications or plans when Marshall control is specified. When Marshall control is not specified, the best engineering practices should govern the selection.

For guidance, the following table may be used:

Traffic Category*	EAL<140		EAL 141-274		EAL>275	
Number of Blows	50		50 (Note 3)		75 (Note 1)	
Test Property	Min.	Max.	Min.	Max.	Min.	Max.
Stability Newtons** (lbs.)	3336 (750)		5338 (1200)		8006 (1800)	
Flow, 0.25mm (0.01")	8	18	8	16	8	14
Air Voids, %	3	5	3	5	3	5
VMA, %	(Note 2)		(Note 2)		(Note 2)	
VFA, %	70	80	65	78	65	75
Bearing Capacity						
kPa	690	1,725	1,035	2,070	1,205	2,070
(PSI)	(100)	(250)	(150)	(300)	(175)	(300)

* EAL values will be taken from the latest issue of the NOS condition survey.

** Stability values shown reflect the most recent data published by the Asphalt Institute. These values are considered valid only for those mixes with VMA values in Zone 1, KDOT Form No. 707. For those mixes with VMA values in Zone 2, KDOT Form No. 707, higher stabilities may be required to provide resistance to plastic deformation.

Note 1 - Use 75 blows for the top 100mm (4") of new construction in traffic lanes. Use 75 blows for all overlays, including hot recycle, in traffic lanes. Use 50 blows for all other lifts of new construction. (If 75 blow Marshall is required, it is to be specified in the contract.)

Note 2 - Zone 1, KDOT Form No. 707, corresponds to mixes which are considered to have sufficient aggregate voids space to provide both adequate room for asphalt and sufficient remaining air voids to prevent flushing. Zone 2 mixtures would be considered as potentially at risk of flushing due to lack of aggregate void space to accommodate sufficient asphalt for durability and insufficient air voids remaining to prevent flushing.

Note 3 - Use 75 blows for overlays on PCCP and composite pavements. (If 75 blow Marshall is required, it is to be specified in the contract.)

b. Using the data previously determined, the bar chart portion of **KDOT Form No. 701** is utilized as follows:

Step 1. Indicate by a horizontal line the range of asphalt contents which include the desired (or specified) properties.

Step 2. Indicate by vertical lines the area of "best convergence" of asphalt contents which satisfy the desirable (or specified) properties.

Step 3. Indicate by vertical line the computed value of P_b'max as shown in the supplemental calculations, Section **5.17.04 (g) (3).**

Step 4. Select tentative asphalt content within the "best convergence" zone, but not exceeding the value of P_b'max.

Step 5. Show this value (the tentative asphalt content) as the "Recommended % Asphalt."

Step 6. Show values for VMA, Air Voids, etc. corresponding to the "Recommended % Asphalt" in the last column at the right side of the bar chart.

A completed bar chart is shown as an example at the end of this section.

(b) Mixtures Containing Cutback Asphalt.

(1) Formulas:

A number of formulas have been devised to calculate the percent of cutback asphalt to be added to aggregate that is to be road-mixed. Two of these, the Nebraska and the New Mexico formulas are used in combination for work in Kansas. The asphalt content as calculated by these formulas will be a good indication of the proper value to use at the start of the work. It may be necessary to make adjustments based on judgment, and past experience in order to provide sufficient asphalt to coat the aggregate particles. Care must be taken not to have an excess amount of asphalt as this can result in an unstable pavement. The quantities of cutback asphalt should be increased to compensate for the amount of diluent that will be lost during mixing, aeration and curing.

a. New Mexico Formula:

$$P = 0.02a + 0.07b + 0.15c + 0.20d$$

Where:

P = Percent of bituminous material by weight of dry aggregate.
a = Percent of material retained on the 300µm (No. 50) sieve.
b = Percent of material between 300µm (No. 50) and 150µm (No. 100) sieves.
c = Percent of material between 150µm (No. 100) and 75µm (No. 200) sieves.
d = Percent of material passing the 75µm (No. 200) sieve.

When aggregates with an appreciable amount of water absorption are used, the amount of cutback asphalt added to the mixture should be increased by approximately two-thirds (2/3) of the amount of water absorbed by the aggregate.

b. Nebraska Formula:

$$P = AG(0.02a) + 0.06b + 0.10c + Sd$$

Where:

P = Percent of bituminous material by weight of dry aggregate.

A = Absorption factor, equal to 1 for sand-gravel and 1 + 2/3 the water absorption of other aggregates.

G = Specific Gravity Correction Factor. This factor equals 1.0 for aggregate mixtures that have a average specific gravity of 2.61. For aggregate mixtures having a different average specific gravity, this factor is inversely proportional to the average specific gravity of the combined aggregate.

a = Percent of material retained on 300µm (No. 50) sieve.

b = Percent of material retained between the 300µm (No. 50) and 150µm (No. 100) sieves.

c = Percent of material retained between the 150µm (No. 100) and 75µm (No. 200) sieves, plus C_1.

d = Percent of fines determined by the average of the percent passing the 75µm (No. 200) sieve dry screened, and the percent passing the 75µm (No. 200) on wash test in separate determinations.

C_1 = The percent of material equal to the difference between the percent of material passing the 75µm (No. 200) sieve on wash test and "d".

S = 0.2, except for volcanic ash, in which case the "S" factor shall be 0.27.

NOTE: The quantity "d" shall be found by separate determinations on two similar samples of combined material; one sample shall be dry screened only, and the other sample shall be tested by the wash test plus dry screening after washing.

(2) Determination of Asphalt Content:

Example: Assume a predominantly sand-gravel BM-6 mixture containing some crushed stone and volcanic ash.

Gradation Percent Retained - Square Mesh Sieves									
19mm	9.5mm	4.75 mm	2.36 mm	1.18 mm	600μm	300μm	150μm	75μm	Dry Sieve 75μm
(3/4")	(3/8")	(#4)	(#8)	(#16)	(#30)	(#50)	(#100)	(#200)	(#200)
0	3	11	32	55	71	84	89	90	93

Water Absorption = 2.0% (Avg. of Combined Material)
Specific Gravity = 2.58 (Avg. of Combined Material)
S Factor = 0.27

a. Asphalt Content by New Mexico Formula:

P = (0.02 x 84)+(0.07 x 5)+(0.15 x 1)+(0.20 x 10)
P = 1.68 + 0.35 + 0.15 + 2.0 = 4.18%

Increase the amount of bituminous material by 2/3 the amount of water absorption of the aggregate.

P = 4.18 + (0.67 x 2.0) = 5.52%

b. Asphalt Content by the Nebraska Formula:

A = 1 + (0.67 x 2.0) = 2.34 = Absorption Factor

$$\frac{1}{G} = \frac{2.58}{2.61}$$

$$G = \frac{2.61}{2.58} = 1.0116 = \text{Gravity Correction Factor}$$

$Ag = 2.34 \times 1.0116 = 2.37$

$d = \frac{10 + 7}{2} = 8.5$

$C_1 = 10 - 8.8 = 1.5$

$C = 1 + 1.5 = 2.5$

$P = 2.37 \ (0.02x84) + (0.06x5) + (0.10x2.5) + (0.27x8.5)$

$P = 3.98 + 0.30 + 0.25 + 2.30 = 6.83\%$

The results of the above calculations using the New Mexico and Nebraska formulas show a calculated asphalt range (after aeration) of between 5.52% and 6.83% based on dry weight of aggregate. Since a cutback asphalt is to be used, the percent of total bituminous material must be increased an amount equal to the amount of diluent which will be lost during aeration and curing.

Thus if it is estimated that 50% of the volatiles will be removed and if the cutback contains 14% volatiles, then 7% volatiles by weight of asphalt will be removed. Then the above percentages should be increased as follows:

$$\frac{5.52}{(1-0.07)} = 5.94\% \qquad \frac{6.83}{(1-0.07)} = 7.34\%$$

The results of the above calculations furnish the basis for establishing a starting asphalt content (on the basis of residue after aeration and curing).

As previously mentioned, after mixing is started, judgment and experience may dictate adjustments in the percentage of asphalt actually used.

(c) Mixtures Containing Emulsified Asphalt.

A standard method of calculating the proper amount of emulsified asphalt to be used in bituminous mixtures has not been developed at this time. Consequently, the amount of emulsified asphalt to be added at the start of the work is currently being determined from the results of District Laboratory test and observations made on the aggregates and emulsions which will be used on each project.

KANSAS DEPARTMENT OF TRANSPORTATION
MARSHALL TEST RESULTS

No. of Blows: 50
Single Point to the tenth (Y/N)?: No

Contract #:594066008
Project: 99-115 K 4615-01 County: ZOLAN Lab. No.: 9B99099A
Mix Designation: BM-2 Mix Material Code: 002030500
Specification 1990, Sec. 1103 & 90p-88R3 Contractor: XYZ CONST. CO., INC.
Asphalt Source: TOTAL Producer: XYZ CONST. CO., INC
Asphalt Grade: AC-10 Date Rec./Rep.: / March 21, 1995

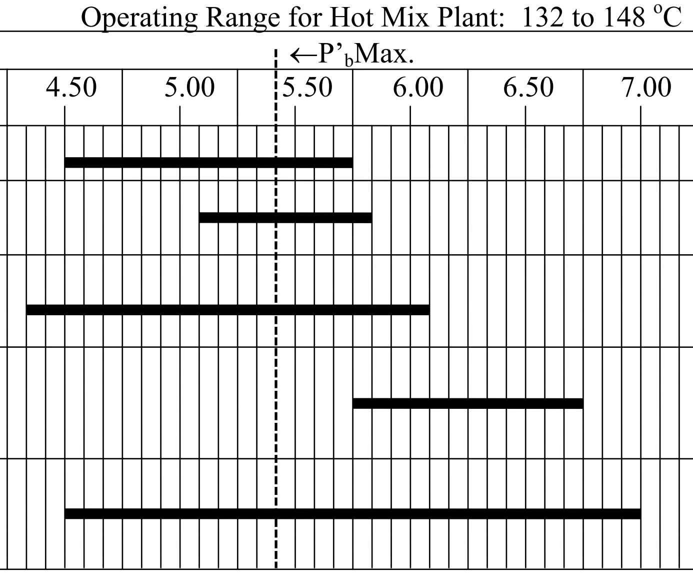
Percent Retained Square Mesh Sieves

	1½" 37.5 mm	1" 25 mm	¾" 19 mm	½" 12.5 mm	⅜" 9.5 mm	4 4.75 mm	8 2.36 mm	16 1.18 mm	30 600 µm	50 300 µm	100 150 µm	200 75 µm
Job Mix Spec. Band			0		11 23	25 37	42 54	58 68	72 82	85 93	90 98	92.0 96.0
Job Mix Single Pt.			0	9	17	31	48	63	77	89	94	94.0
Marshall Gradation			0	9	18	31	48	65	76	88	94	95.0

Test Data

Range Tested (% AC)	Increment (% AC)	Marshall Mixing Temperature Range (^{o}C)	Marshall Compaction Temperature Range (^{o}C)
4.50 to 7.00	0.50	spec. 143 to 148	132 to137

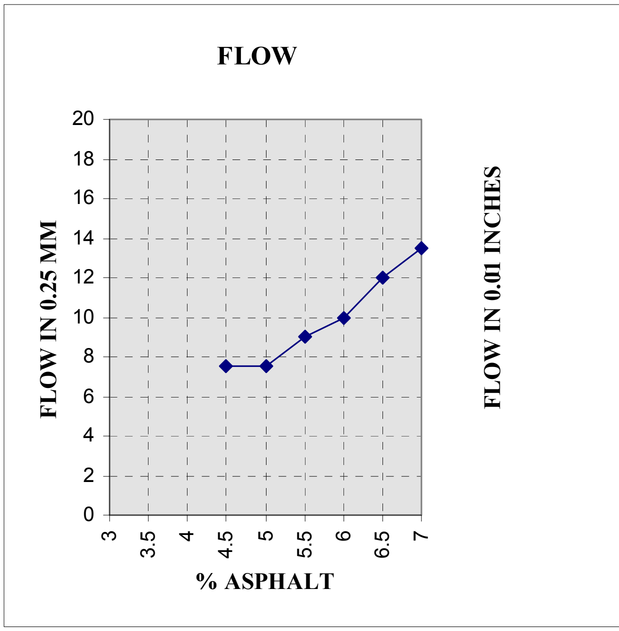
Operating Range for Hot Mix Plant: 132 to 148 ^{o}C

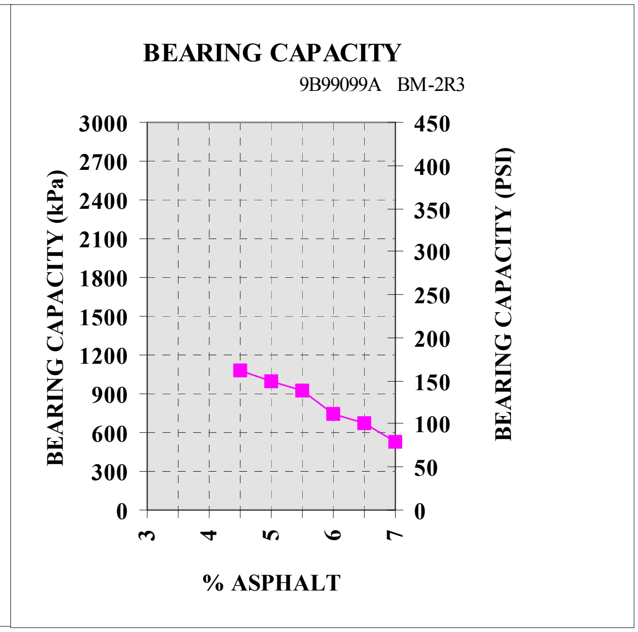


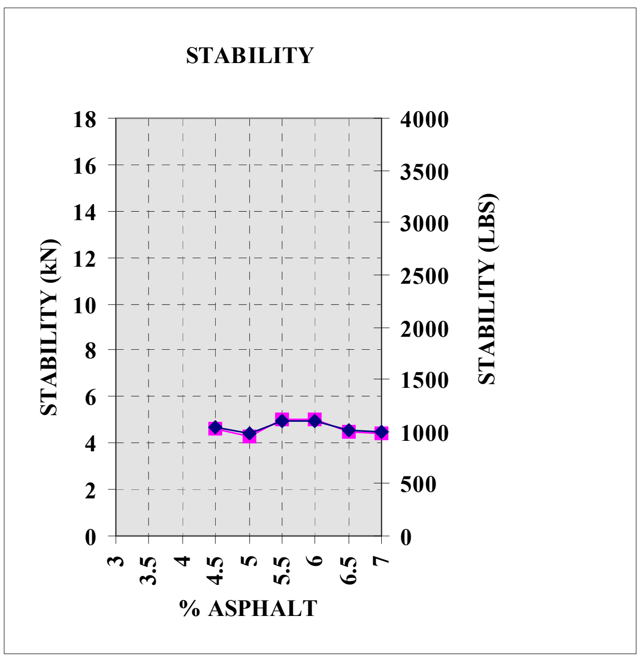
	#Recommend
Asphalt Content%	5.25
Air Voids(3 to 5%)	3.98
VFA (.=70% 80%)	72.70
Bearing Capacity (690-1725 kPa)	988
Density Kg/m^3 (Peak+/-0.5%)	2315
Stability Minimum 3336 N	4638

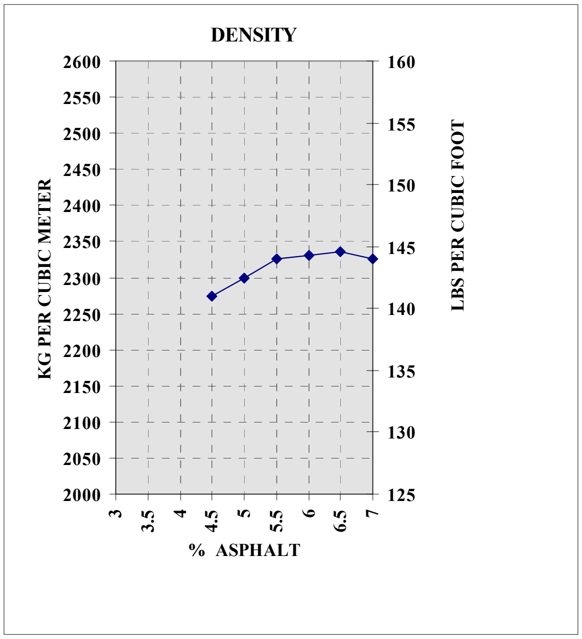
Values at Recommended Asphalt Content
Filler/Binder Ratio: 1.14 Eff. Film Thick.: 7.76 P'$_b$ Max: 5.42
V.M.A.: 14.30/Zone 2 Max. Sp. Gr.: 2.410 Theo. Max Density: 2410 Kg/m^3

District Materials Engineer


FLOW
FLOW IN 0.25 MM
FLOW IN 0.01 INCHES
20
18
16
14
12
10
8
6
4
2
0
3
3.5
4
4.5
5
5.5
6
6.5
7
% ASPHALT


BEARING CAPACITY
9B99099A BM-2R3
BEARING CAPACITY (kPa)
BEARING CAPACITY (PSI)
3000
2700
2400
2100
1800
1500
1200
900
600
300
0
450
400
350
300
250
200
150
100
50
0
3
4
5
6
7
% ASPHALT


STABILITY
STABILITY (kN)
STABILITY (LBS)
18
16
14
12
10
8
6
4
2
0
4000
3500
3000
2500
2000
1500
1000
500
0
3
3.5
4
4.5
5
5.5
6
6.5
7
% ASPHALT


DENSITY
KG PER CUBIC METER
LBS PER CUBIC FOOT
2600
2550
2500
2450
2400
2350
2300
2250
2200
2150
2100
2050
2000
160
155
150
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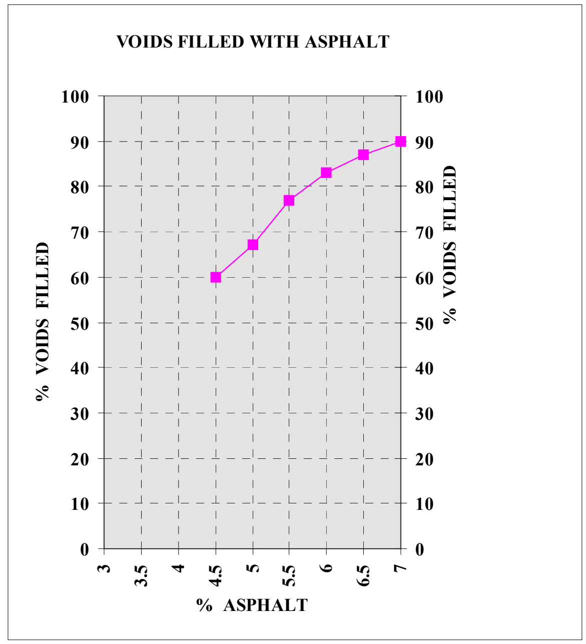
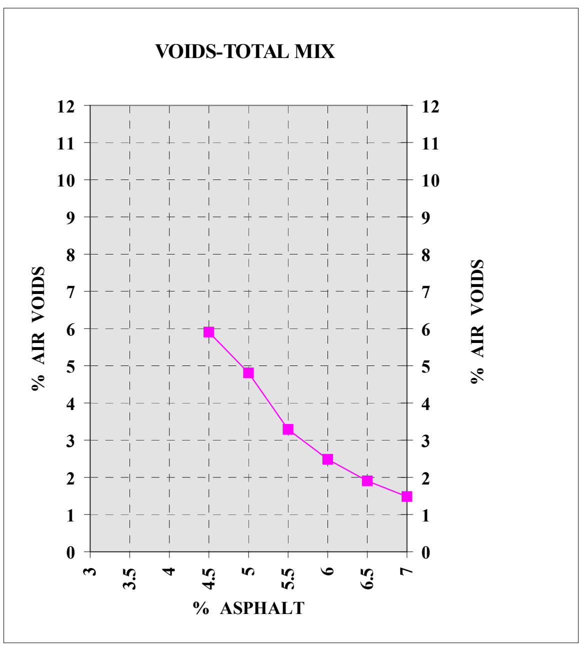
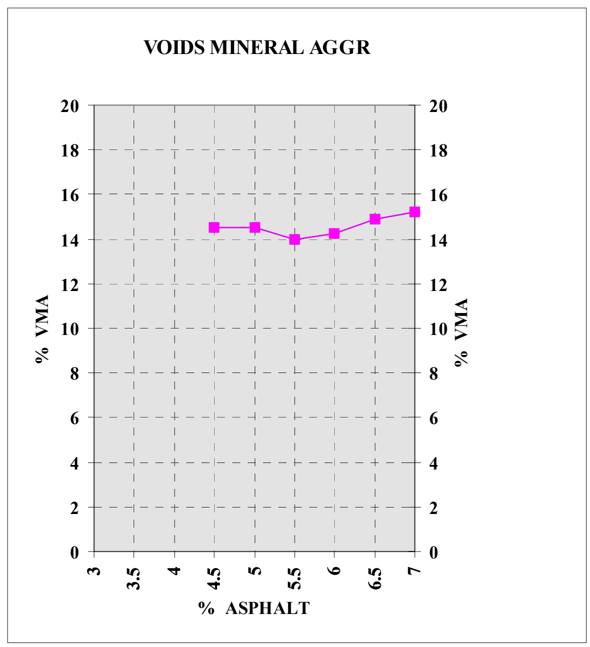
6
6.5
7
% ASPHALT


VOIDS FILLED WITH ASPHALT
% VOIDS FILLED
% VOIDS FILLED
100
90
80
70
60
50
40
30
20
10
0
3
3.5
4
4.5
5
5.5
6
6.5
7
% ASPHALT


VOIDS-TOTAL MIX
% AIR VOIDS
% AIR VOIDS
12
11
10
9
8
7
6
5
4
3
2
1
0
3
3.5
4
4.5
5
5.5
6
6.5
7
% ASPHALT


VOIDS MINERAL AGGR
% VMA
% VMA
20
18
16
14
12
10
8
6
4
2
0
3
3.5
4
4.5
5
5.5
6
6.5
7
% ASPHALT

KANSAS DEPARTMENT OF TRANSPORTATION

Lab No.: 9B99099A

DESIGN JOB-MIX COMPUTATION SHEETS

Contract #: 594066008

Mix Desig.: BM-2

Material Code : 002030500

Project: 99-115 K 4615-01

County: ZOLAN

Specifications: 1990 STD. & 90P-88R3

1. AGGREGATES

AGGR. TYPE MAT'L CODE	% IN MIX	PRODUCER NAME PRODUCER CODE #	LEGAL DESCRIPTION	COUNTY
CS-1 002010117	20.00	HAMM QUARRY 00800933	NE 1/4 S10,T072,R10E	POTTAWATOMIE
CS-2 002010217	30.00	MARTIN-MARIETTE 00802414	SE 1/4 S33,T10S,R09E	RILEY
SSG	50.00	BLUE RIVER	NE 1/4 S25,T05S, R07E	MARSHALL
AC-10 021110000		TOTAL 00002801		

2. INDIVIDUAL AGGREGATE SINGLE POINTS

TYPE	% IN MIX	1½ 37.5 mm	1 25 mm	¾ 19 mm	½ 12.5 mm	⅜ 9.5 mm	4 4.75 mm	8 2.36 mm	16 1.18 mm	30 600 µm	50 300 µm	100 150 µm	200 75 µm
CS-1	20.00	0	0	0	46	80	93	96	97	97	97	97	97.0
CS-2	30.00	0	0	0	0	1	26	50	64	73	79	82	84.0
SSG	50.00	0	0	0	0	1	10	28	48	72	92	99	99.0
DESIGN SINGLE POINT		0	0	0	9	17	31	48	63	77	89	94	94.0

2A. INDIVIDUAL AGGREGATE GRADATIONS (AS SUBMITTED)

TYPE	% IN MIX	1½ 37.5 mm	1 25 mm	¾ 19 mm	½ 12.5 mm	⅜ 9.5 mm	4 4.75 mm	8 2.36 mm	16 1.18 mm	30 600 µm	50 300 µm	100 150 µm	200 75 µm
CS-1	20.00	0	0	0	46	80	93	96	97	97	97	97	97.0
CS-2	30.00	0	0	0	0	1	26	50	64	73	79	82	84.0
SSG	50.00	0	0	0	0	1	10	28	48	72	92	99	99.0
THEO COMB GRAD		0	0	0	9	17	31	48	63	77	89	94	94.1

DOT FORM 703

Project: 99-115 K 4615-01 Lab No.: 9B99099A

3. DESIGN JOB MIX GRADING

			1½ 37.5 mm	1 25 mm	¾ 19 mm	½ 12.5 mm	⅜ 9.5 mm	4 4.75 mm	8 2.36 mm	16 1.18 mm	30 600 µm	50 300 µm	100 150 µm	200 75 µm
		0.00	0.00											
SINGLE POINT					0	9	17	31	48	63	77	89	94	94.0
TOLERANCE							6	6	6	5	5	4	4	2
	No													
BM-2R3	LOWER						11	25	42	58	72	85	90	92.0
BM-2R3	UPPER				0		23	37	54	68	82	93	98	96.0

4. MASTER GRADING LIMITS

		37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	600 µm	300 µm	150 µm	75 µm
BM-2R3	LOWER					8		42		64			90
BM-2R3	UPPER			0		30		72		88			97

5. INDIVIDUAL AGGREGATE LIMITS

TYPE	% IN MIX	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	600 µm	300 µm	150 µm	75 µm
			0	0	10	60	96	96	97	97	97	97	97
CS-1	20.00	0	0	0	28	77	99	99	99	99	99	99	100
			0	0	0	0	22	45	60	70	77	80	81
CS-2	30.00	0	0	0	0	5	34	55	69	78	84	88	88
			0	0	0	0	5	22	45	68	87	97	98
CS-3	50.00	0	0	0	0	5	15	32	55	77	95	100	100

6. INDIVIDUAL AGGREGATE COMBINED LIMITS

LOWER		0	0	2	12	28	44	60	74	86	92	93
UPPER	0	0	0	6	19	38	52	68	82	93	96	96

7. CHECK OF MIX SPECIFICATIONS

	SPECS	DESIGN
% CRUSHED AGGREGATE IN MIX	50 MIN.	50.00
% UNCRUSHED -75µm NATURAL SAND	30 MAX.	8.47
% -2.36mm +75µm NATURAL SAND	15 MIN.	35.50
SAND EQUIVALENT	45 MIN.	53

Design Job Mix Single Point Meets
the Screen Spread Limits Specification.

DOT Form 704

Calculations for Items 7 Form 704

8.A. Natural Sand: Passing No. 2.38 mm and Retained on No. 75µm

Single Point Gradation (From Item 2)
(0.50) (99.00 - 28.00) = 35.5% Sand

Lower & Upper Limits (Lowest Calculated Value) (From Item 5)
(0.50) (98.00 - 32.00) = 33.0% Sand

8.B. Uncrushed Minus 75µm

Single Point Gradation (From Item 2A)

$$\frac{(100.00\ -\ 99.00)\ (0.50)\ (100)}{(100 - 94.1)} = 8.47\%\ \textit{Uncrushed}$$

Lower & Upper Limits (Highest Calculated Value) (From Item 5)

SSG	50% (100-98)	= 1.00	Uncrushed
CS-1	20% (100-100)	= 0.00	Crushed
CS-2	30% (100-88)	= 3.60	Crushed
Total Minus 75µm		= 4.60	

Uncrushed Minus 75µm

$$\frac{1.00\ (100)}{4.60} = 21.8 = 22\%\ \textit{Uncrushed}$$

WORKSHEET FOR ANALYSIS OF COMPACTED PAVING MIXTURE

Contract #: 594066008
Project Number: 99-115 K 4615-01 — Date: March 21, 1995
Mix Designation: BM-2 — Lab No.: 9B99099A

% AC by Wt. Aggr.	4.50	5.00	5.50	6.00	6.50	7.00	Pb’
% AC by Wt. Mix	4.306	4.762	5.213	5.660	6.103	6.542	Pb=A
% Aggr. by Wt. Mix	95.694	95.238	94.787	94.340	93.897	93.458	Ps=B
S. G. of Asphalt	1.0180	1.0180	1.0180	1.0180	1.0180	1.0180	Gb=c
S. G. of Aggr. (bulk)	2.566	2.566	2.566	2.566	2.566	2.566	Gsb=D
Max. S. G. Mix (KT-39)	2.434	2.417	2.405				Gmm
(computed)	2.434	2.418	2.403	2.387	2.372	2.358	E
Theo. Max. Kg/m^3	2434	2418	2403	2387	2372	2358	F(SI) =F
Eff. S. G. of Aggr.	2.597	2.597	2.597	2.597	2.597	2.597	Gse=G
% Abs. Asphalt	0.474	0.474	0.474	0.474	0.474	0.474	Pba=H
Eff. Asph. Content	3.852	4.311	4.764	5.213	5.658	6.099	Pbe=I
% V. M. A.	14.49	14.45	14.15	14.41	14.78	15.43	VMA=J
S. G. of plugs (KT-15)	2.293	2.305	2.323	2.328	2.329	2.322	Gmb=K
Lab Plugs Kg/m^3	2293	2305	2323	2328	2329	2322	L(SI)=L
% Air Voids	5.79	4.67	3.29	2.47	1.81	1.53	Pa=M
% Voids Filled	59.88	67.55	76.86	82.73	87.58	90.16	VFA=N
P’b Max	5.51	5.49	5.36	5.47	5.63	5.90	O
Eff. Film Thickness	6.54	7.36	8.17	8.98	9.79	10.61	P
Filler/Binder Ratio	1.33	1.20	1.09	1.00	0.92	0.86	Q

COMBINED AGGREGATE SP. GR.

	APPARENT	BULK	%
+4.75 mm	2.652	2.484	31
-4.75 mm	2.669	2.754	69
Theo. Comb.	2.664		

$$PB = A = \frac{P'B * 100}{100 + P'B}$$

$$PS = B = 100 - A$$

$$F = 1000\ E$$

$$GSE = G = \frac{B}{\frac{100}{E} - \frac{A}{C}}$$

$$L = 1000\ K$$

$$PBA = H = 100 * \frac{G - D}{D * G} * C$$

$$P\ A = M = 100 * \frac{E - K}{E}$$

$$PBE = I = A - \frac{H}{100} * B$$

$$VFA = N = \frac{100 * \frac{I}{C}}{\frac{J}{K}}$$

$$VMA = J = 100 - \frac{K * B}{D}$$

KANSAS DEPARTMENT OF TRANSPORTATION
HOT MIX DESIGN DATA (MARSHALL METHOD)

Contract: 594066008
Project: 99-115 K 4615-01 County: Zolan Date: March 21, 1995 Lab No. 9B99099A

Mix Designation: BM-2 Asphalt Grade: AC-10 Sp. Gr. AC: 1.0180 Compaction, Blows/Side: 50

Deg.C / % AC		Comapct Temp. (C)	Specimen Height (MM)	Weight, Grams Dry In Air	In Water	S.S.D In Air	S.S.D In Water	Water Absorbed %	SP. GR. Compact Mix	KG/ Cubic Meter	Water Bath (C)	Stability Dial. Reading	Corr.	Adjust (N)	Flow (0.25) (MM)	Bearing Capacity (kPa)
	A	137	63.900	1175.1	661.7				2.289		59	117	1.00	4589	7.5	
148	B	136	63.700	1183.8	669.2				2.300		59	143	1.00	5679	7.5	Error
	C	134	63.600	1174.2	661.5				2.290		61	122	1.00	4799	7.5	
4.50						Average			2.293	2293				4694	7.5	1091
	A	137	63.800	1185.0	671.3				2.307		60	105	1.00	4087	7.5	
148	B	137	63.500	1187.7	674.0				2.312		60	117	1.00	4589	7.5	
	C	136	63.200	1179.4	665.8				2.296		60	112	1.00	4380	7.5	
5.00						Average			2.305	2305				4352	7.5	1012
	A	133	63.300	1187.1	675.7				2.307		60	117	1.00	4589	8.0	
148	B	133	63.200	1186.6	676.2				2.325		60	127	1.00	5009	9.0	
	C	134	62.900	1187.1	676.7				2.326		60	131	1.00	5176	9.5	
5.50						Average			2.324	2324				4925	8.8	965
	A	134	63.300	1193.6	680.6				2.327		59	131	1.00	5176	10.5	
148	B	136	62.700	1183.9	675.6				2.329		59	122	1.04	4991	9.5	
	C	136	63.300	1190.0	679.1				2.329		60	116	1.00	4548	9.5	
6.00						Average			2.328	2328				4905	9.8	855
	A	137	62.700	1190.5	679.2				2.328		60	114	1.04	4642	12.5	
148	B	136	62.900	1184.8	675.6				2.327		60	122	1.00	4799	11.5	
	C	137	63.100	1186.1	677.6				2.333		60	112	1.00	4380	11.5	
6.50						Average			2.329	2329				4607	11.8	655
	A	137	62.900	1184.5	674.7				2.323		59	119	1.00	4673	14.0	
148	B	136	63.100	1184.3	672.9				2.316		60	105	1.00	4087	13.5	
	C	134	63.600	1189.2	677.8				2.325		60	118	1.00	4631	13.5	
7.00						Average			2.322	2322				4464	13.7	537

Specific Gravity Method: I

ERROR = PLUG OUT OF ALLOWED RANGE

D.O.T. FORM 705

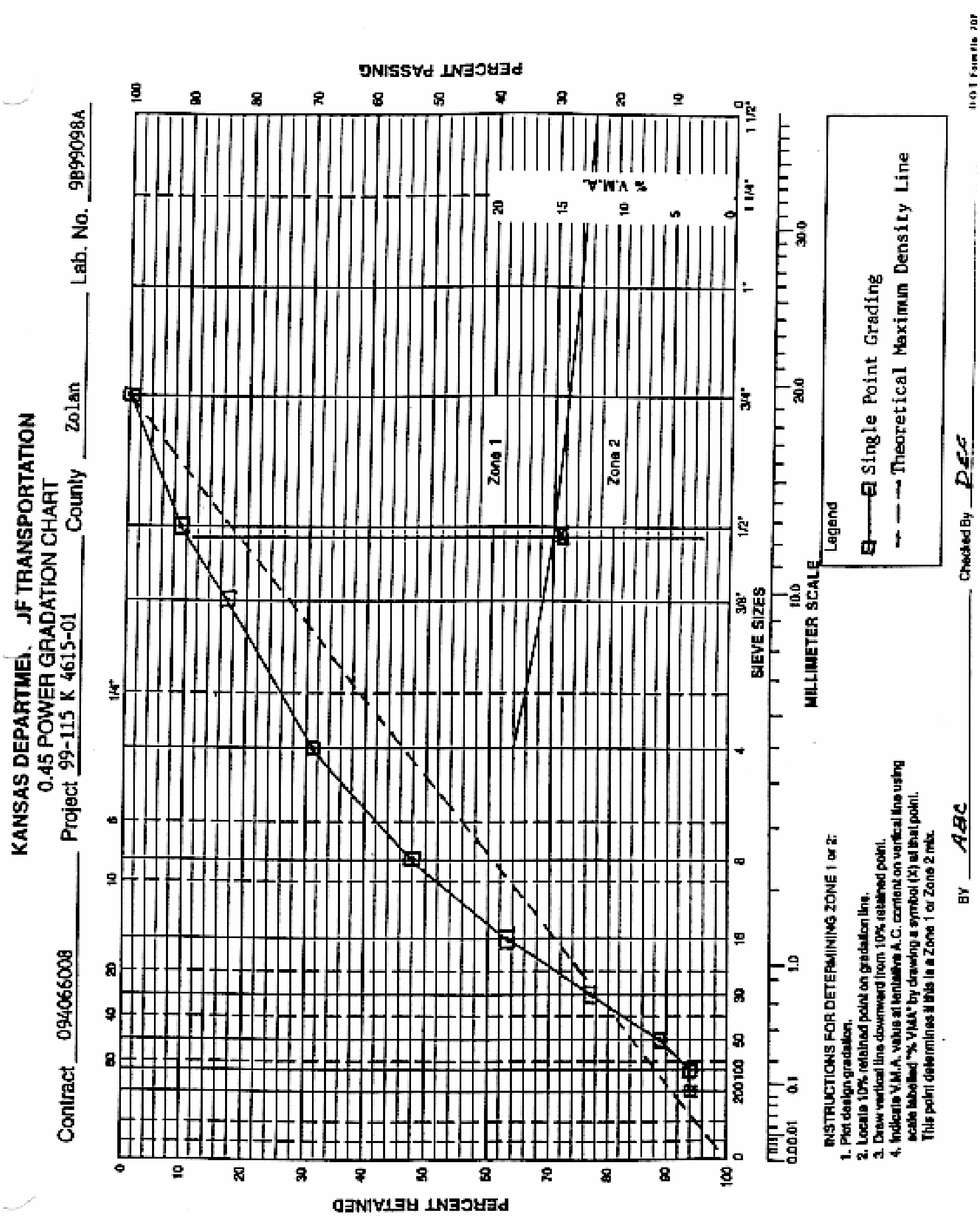
KANSAS DEPARTMENT OF TRANSPORTATION

THEORETICAL MAXIMUM SPECIFIC GRAVITY OF PAVING MIXTURES

References: ASTM D 2041 (Rice's Method) and Kansas Test Method KT-39 Date: March 21, 1995
Contract Number: 594066008
Project Number: 99-115 K 4615-01 County: Zolan Lab No: 9B99099A

Bowl # Sample #	4.50 A	4.50 B	5.00 A	5.00 B	5.50 A	5.50 B
Mass of Sample & Bowl in Air, Grams	3646.5	3698.3	3720.3	3709.2	3681.9	3673.7
Mass of Bowl in Air, Grams	2144.0	2141.9	2173.7	2149.5	2114.6	2112.2
Mass of Sample in Air, Grams (A)	1502.5	1556.4	1546.6	1559.7	1567.3	1561.5
Temp. of Bath, Sample and Bowl after 10 Minutes	78.8	78.6	77.9	78.0	77.5	77.6
Mass of Sample and Bowl in Water, Grams	2240.4	2258.9	2270.3	2260.2	2251.9	2246.7
Mass of Bowl in Water, Grams	1368.2	1365.1	1386.9	1362.7	1337.8	1335.4
Mass of Sample in Water, Grams (C)	872.2	893.8	883.4	897.5	914.1	911.3
Maximum Sp. Gr. of Mix (Rice's) A/(A-C)	2.3838	2.3489	2.3320	2.3553	2.3994	2.4015
Average Max. Sp. Gr. of Mix	2.366		2.344		2.400	

D.O.T Form 706


KANSAS DEPARTME. JF TRANSPORTATION
0.45 POWER GRADATION CHART
Contract 094066008
Project 99-115 K 4615-01
County Zolan
Lab. No. 9B99098A
PERCENT PASSING
PERCENT RETAINED
% V.M.A.
Zone 1
Zone 2
SIEVE SIZES
MILLIMETER SCALE
Legend
Single Point Grading
Theoretical Maximum Density Line
INSTRUCTIONS FOR DETERMINING ZONE 1 or 2:
1. Plot design gradation.
2. Locate 10% retained point on gradation line.
3. Draw vertical line downward from 10% retained point.
4. Indicate V.M.A. value at tentative A.C. content on vertical line using scale labelled "% VMA" by drawing a symbol (X) at that point. This point determines if this is a Zone 1 or Zone 2 mix.
BY ABC
Checked By DEF

KANSAS DEPARTMENT OF TRANSPORTATION
MARSHALL TEST RESULTS

No. of Blows: 50
Single Point to the tenth (Y/N)?: No

Contract #:094066008
Project: 99-115 K 4615-01 County: ZOLAN_____________ Lab. No.: 9B99099A
Mix Designation: BM-2_____ Mix Material Code: 002030500
Specification 1990, Sec. 1103 & 90P-88R3___ Contractor: XYZ CONST. CO., INC.________________________
Asphalt Source: TOTAL____________ Producer: XYZ CONST. CO., INC________________________
Asphalt Grade: AC-10__ Date Rec./Rep.:_________________________/__March 21, 1995_________________

Percent Retained Square Mesh Sieves

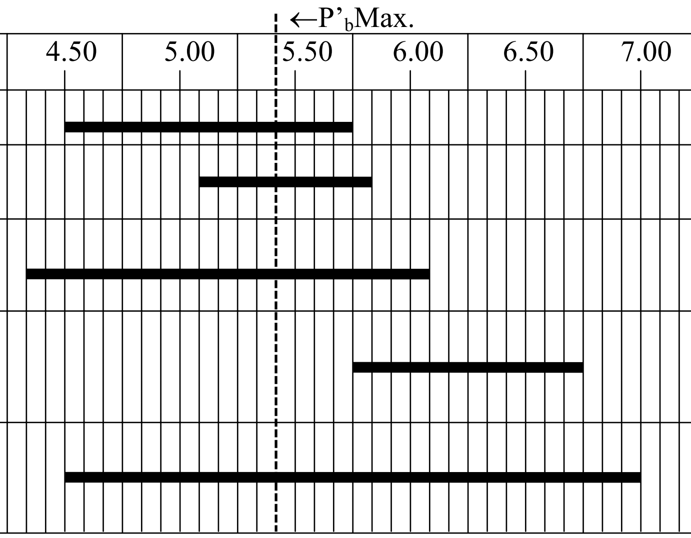
	1½" 37.5 mm	1" 25 mm	¾" 19 mm	½" 12.5 mm	⅜ 9.5 mm	4 4.75 mm	8 2.36 mm	16 1.18 mm	30 600 µm	50 300 µm	100 150 µm	200 75 µm
Job Mix Spec. Band			 0		11 23	25 37	42 54	58 68	72 82	85 93	90 98	92.0 96.0
Job Mix Single Pt.			0	9	17	31	48	63	77	89	94	94.0
Marshall Gradation			0	9	18	31	48	65	76	88	94	95.0

Test Data

Range Tested (% AC)	Increment (% AC)	Marshall Mixing Temperature Range (°F)	Marshall Compaction Temperature Range (°F)
4.50 to 7.00	0.50	spec. 289 to 298	270 to279

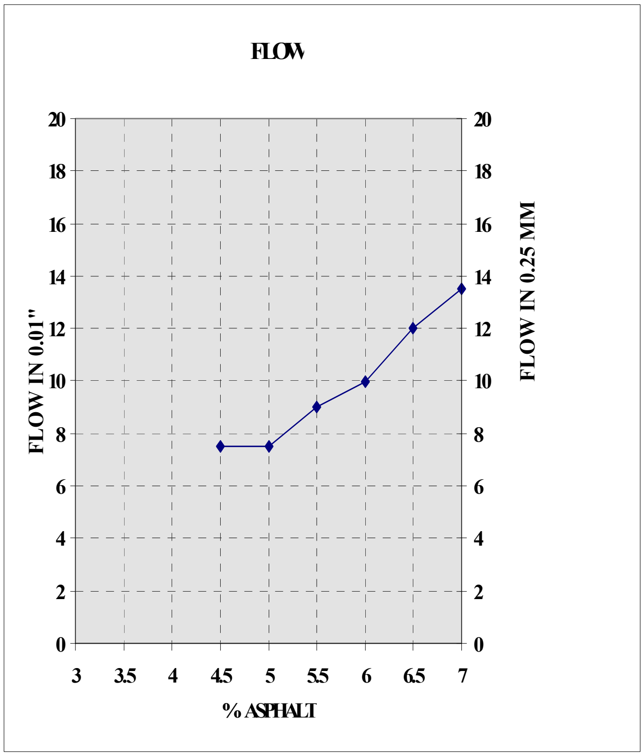
Operating Range for Hot Mix Plant: 270 to 298 °F

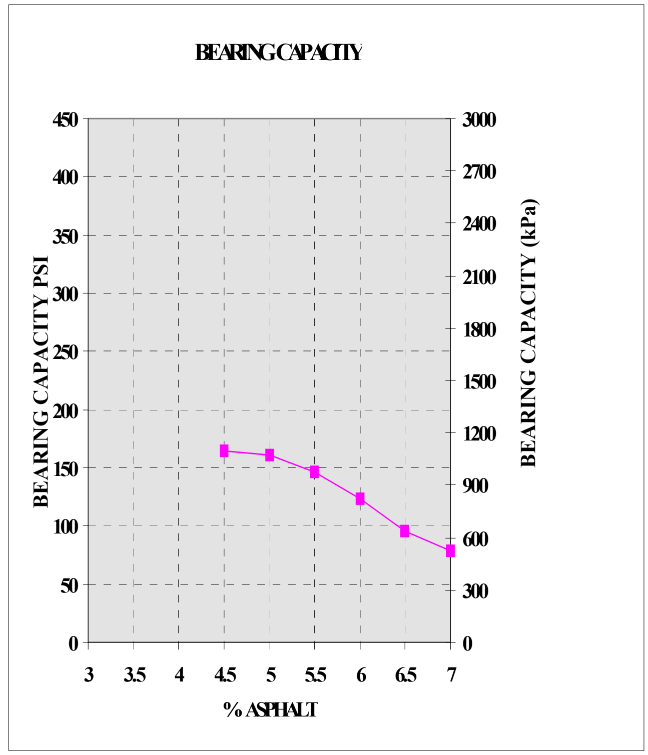
	←P'$_b$Max.	#Recommend
Asphalt Content%	4.50 5.00 5.50 6.00 6.50 7.00	5.25
Air Voids(3 to 5%)		3.98
VFA (.=70% 80%)		72.70
Bearing Capacity (690-1725 PSI)		143
Density (lbs/ft^3) (Peak+/-0.5%)		144.42
Stability Minimum 750 lbs.		1043

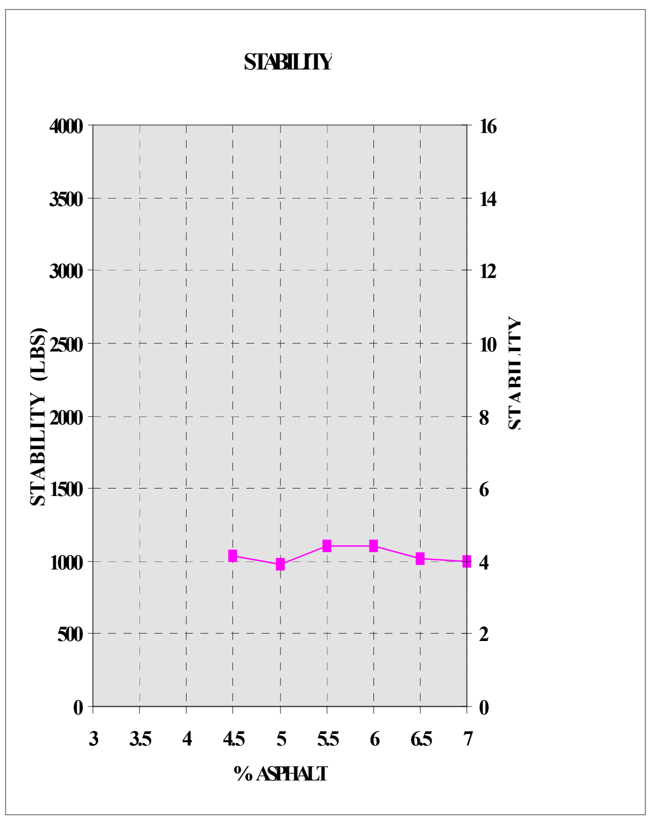


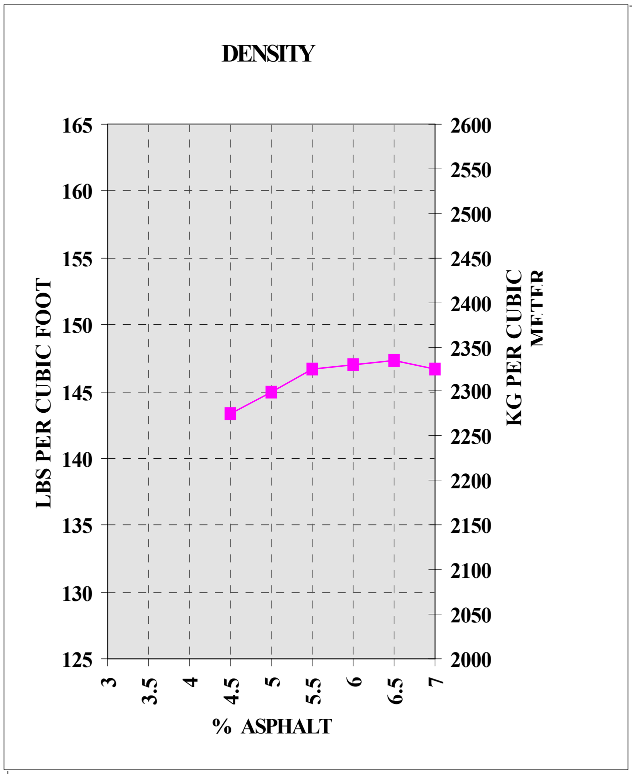
Values at Recommended Asphalt Content
Filler/Binder Ratio: 1.14 Eff. Film Thick.: 7.76 P'$_b$ Max: 5.42
V.M.A.: 14.30/Zone 2_ Max. Sp. Gr.: 2.410 Theo. Max Density: 150.38 lbs/ft^3

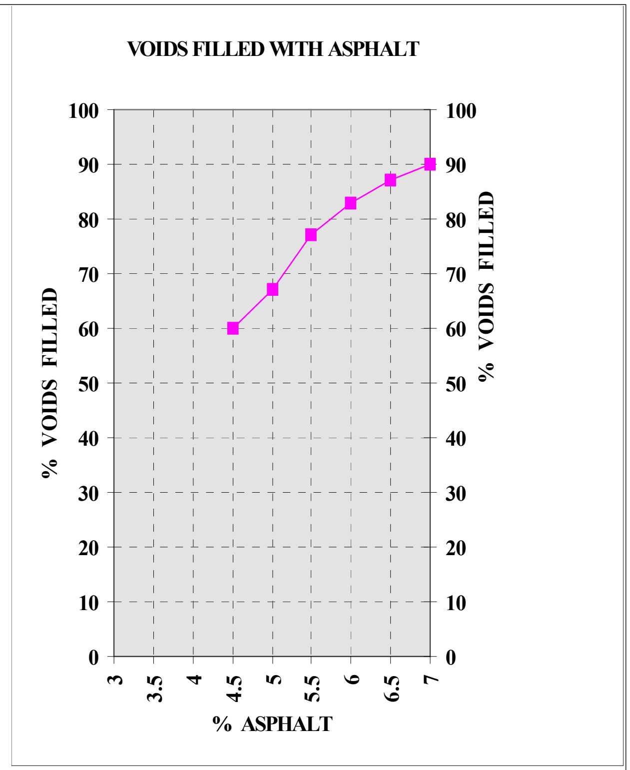
____
District Materials Engineer

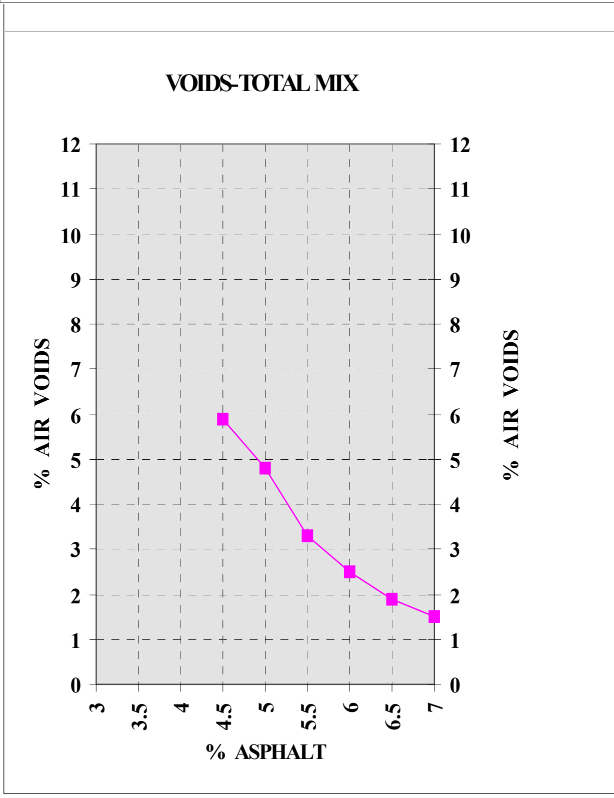

FLOW
FLOW IN 0.01"
FLOW IN 0.25 MM
% ASPHALT
0 2 4 6 8 10 12 14 16 18 20
3 3.5 4 4.5 5 5.5 6 6.5 7

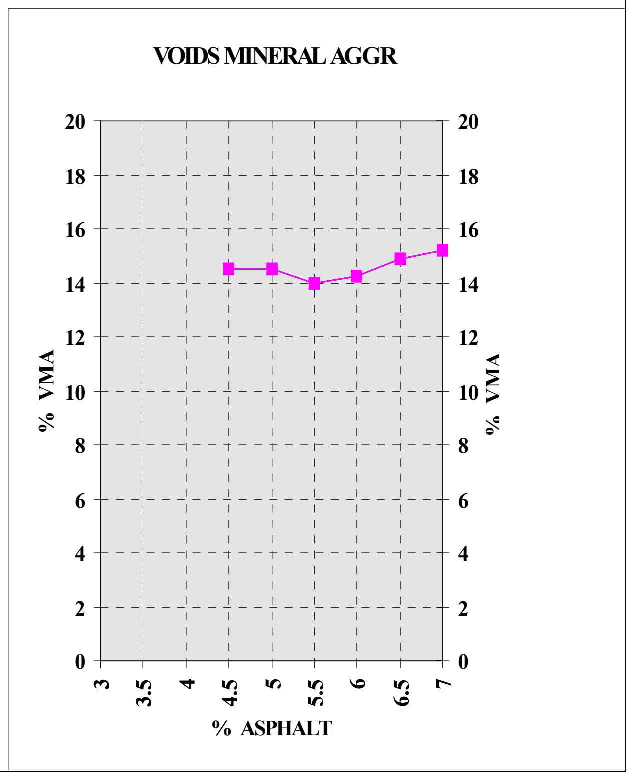

BEARING CAPACITY
BEARING CAPACITY PSI
BEARING CAPACITY (kPa)
% ASPHALT
0 50 100 150 200 250 300 350 400 450
0 300 600 900 1200 1500 1800 2100 2400 2700 3000
3 3.5 4 4.5 5 5.5 6 6.5 7


STABILITY
STABILITY (LBS)
STABILITY
% ASPHALT
0 500 1000 1500 2000 2500 3000 3500 4000
0 2 4 6 8 10 12 14 16
3 3.5 4 4.5 5 5.5 6 6.5 7


DENSITY
LBS PER CUBIC FOOT
KG PER CUBIC METER
% ASPHALT
165
160
155
150
145
140
135
130
125
2600
2550
2500
2450
2400
2350
2300
2250
2200
2150
2100
2050
2000
3
3.5
4
4.5
5
5.5
6
6.5
7


VOIDS FILLED WITH ASPHALT
% VOIDS FILLED
% VOIDS FILLED
% ASPHALT
100
90
80
70
60
50
40
30
20
10
0
3
3.5
4
4.5
5
5.5
6
6.5
7


VOIDS-TOTAL MIX
% AIR VOIDS
% AIR VOIDS
% ASPHALT
12
11
10
9
8
7
6
5
4
3
2
1
0
3
3.5
4
4.5
5
5.5
6
6.5
7


VOIDS MINERAL AGGR
% VMA
% VMA
% ASPHALT
20
18
16
14
12
10
8
6
4
2
0
3
3.5
4
4.5
5
5.5
6
6.5
7

KANSAS DEPARTMENT OF TRANSPORTATION

Lab No. : 9B99098A

DESIGN JOB-MIX COMPUTATION SHEETS

Contract #: 904066008

Mix Design : BM-2

Material Code : 002030500

Project: 99-115 K 4615-01

County: Zolan

Specifications: 1990 STD. & 90P-88 R 3

1. AGGREGATES

AGGR. TYPE MAT'L CODE	% IN MIX	PRODUCER NAME PRODUCER CODE	LEGAL DESCRIPTION	COUNTY
CS-1 002010117	20.00	Hamm Quarry 00800933	NE 1/4 S10,T07S,R10E	Pottawatomie
CS-2 002010217	30.00	Martin-Marietta 00802414	SE 1/4 S33,T10S,R09E	Riley
SSG	50.00	Blue River	NE 1/4 S25,T05S,R07E	Marshall

AC-10 TOTAL
021110000 00002801

2. INDIVIDUAL AGGREGATE SINGLE POINTS

TYPE	% IN MIX	1 1/2	1	3/4	1/2	3/8	4	8	16	30	50	100	200
CS-1	20.00	0	0	0	46	80	93	96	97	97	97	97	97.0
CS-2	30.00	0	0	0	0	1	26	50	64	73	79	82	84.0
SSG	50.00	0	0	0	0	1	10	28	48	72	92	99	99.0
DESIGN SINGLE POINT		0	0	0	9	17	31	48	63	77	89	94	94.0

2A. INDIVIDUAL AGGREGATE GRADATIONS (AS SUBMITTED)

TYPE	% IN MIX	1 1/2	1	3/4	1/2	3/8	4	8	16	30	50	100	200
CS-1	20.00	0	0	0	46	80	93	96	97	97	97	97	97.0
CS-2	30.00	0	0	0	0	1	26	50	64	73	79	82	84.0
SSG	50.00	0	0	0	0	1	10	28	48	72	92	99	99.0
THEO COMB GRAD		0	0	0	9	17	31	48	63	77	89	94	94.1

D.O.T FORM 703

Project: 99-115 K 4615-01 Lab No. 9B99098A

3. DESIGN JOB MIX GRADING

		1 1/2	1	3/4	1/2	3/8	4	8	16	30	50	100	200
SINGLE POINT		0	0	0	9	17	31	48	63	77	89	94	94.0
TOLERANCE						6	6	6	5	5	4	4	2
BM-2R3	LOWER					11	25	42	58	72	85	90	92.0
BM-2R3	UPPER			0		23	37	54	68	82	93	98	96.0

4. MASTER GRADING LIMITS

		1 1/2	1	3/4	1/2	3/8	4	8	16	30	50	100	200
BM-2R3	LOWER					0		42		64			90
BM-2R3	UPPER			0		30		72		88			97

5. INDIVIDUAL AGGREGATE LIMITS

TYPE	% IN MIX	1 1/2	1	3/4	1/2	3/8	4	8	16	30	50	100	200
		0	0	0	10	60	96	96	97	97	97	97	97
CS-1	20.00	0	0	0	28	77	99	99	99	99	99	99	100
		0	0	0	0	0	22	45	60	70	77	80	81
CS-2	30.00	0	0	0	0	5	34	55	69	78	84	88	88
			0	0	0	0	5	22	45	68	87	97	98
SSG	50.00	0	0	0	0	5	15	32	55	77	95	100	100

6. INDIVIDUAL AGGREGATE COMBINED LIMITS

LOWER		0	0	2	12	28	44	60	74	86	92	93
UPPER	0	0	0	6	19	38	52	68	82	93	96	96

7. CHECK OF MIX SPECIFICATIONS

	SPECS	DESIGN
% CRUSHED AGGREGATE IN MIX	50 MIN.	50.00
% UNCRUSHED -200	30 MIN.	8.47
% -8 +200 NATURAL SAND	15 MIN.	35.50
SAND EQUIVALENT	45 MIN.	53

DESIGN JOB MIX SINGLE POINT MEETS
THE SCREEN SPREAD LIMITS SPECIFICATION.

D.O.T. FORM 704

Calculations for Items 7 Form 704

8.A. Natural Sand: Passing No. 8 and Retained on #200

Single Point Gradation (From Item 2)
50% (99.00 - 28.00) = 35.5% Sand

Lower & Upper Limits (Lowest Calculated Value) (From Item 5)
50% (98.00 - 32.00) = 33.0% Sand

8.B. Uncrushed Minus #200

Single Point Gradation (From Item 2A)

$$\frac{(100.00 - 99.00)(0.50)(100)}{(100 - 94.1)} = 8.47\% \text{ Uncrushed}$$

Lower & Upper Limits (Highest Calculated Value)(From Item 5)

SSG	50% (100-98)	= 1.00 Uncrushed
CS-1	20% (100-100)	= 0.00 Crushed
CS-2	30% (100-88)	= 3.60 Crushed
Total Minus #200		= 4.60

Uncrushed Minus #200

$$\frac{1.00\ (100)}{4.60} = 21.8 = 22\% \text{ Uncrushed}$$

WORKSHEET FOR ANALYSIS OF COMPACTED PAVING MIXTURE

Contract #: 594066008
Project Number: 99-115 K 4615-01 Date: March 21, 1995
Mix Designation: BM-2 Lab No.: 9B99099A

% AC by Wt. Aggr.	4.50	5.00	5.50	6.00	6.50	7.00	Pb'
% AC by Wt. Mix	4.306	4.762	5.213	5.660	6.103	6.542	Pb=A
% Aggr. by Wt. Mix	95.694	95.238	94.787	94.340	93.897	93.458	Ps=B
S. G. of Asphalt	1.0180	1.0180	1.0180	1.0180	1.0180	1.0180	Gb=c
S. G. of Aggr. (bulk)	2.566	2.566	2.566	2.566	2.566	2.566	Gsb=D
Max. S. G. Mix (KT-39)	2.434	2.417	2.405				Gmm
(computed)	2.434	2.418	2.403	2.387	2.372	2.358	E
Theo. Max. PCF	151.88	150.88	149.95	148.95	148.01	147.14	F
Eff. S. G. of Aggr.	2.597	2.597	2.597	2.597	2.597	2.597	Gse=G
% Abs. Asphalt	0.474	0.474	0.474	0.474	0.474	0.474	Pba=H
Eff. Asph. Content	3.852	4.311	4.764	5.213	5.658	6.099	Pbe=I
% V. M. A.	14.49	14.45	14.15	14.41	14.78	15.43	VMA=J
S. G. of plugs (KT-15)	2.293	2.305	2.323	2.328	2.329	2.322	Gmb=K
Lab Plugs PCF	143.08	143.83	145.02	145.27	145.33	144.89	L
% Air Voids	5.79	4.67	3.29	2.47	1.81	1.53	Pa=M
% Voids Filled	59.88	67.55	76.86	82.73	87.58	90.16	VFA=N
P'b Max	5.51	5.49	5.36	5.47	5.63	5.90	O
Eff. Film Thickness	6.54	7.36	8.17	8.98	9.79	10.61	P
Filler/Binder Ratio	1.33	1.20	1.09	1.00	0.92	0.86	Q

$$PB = A = \frac{P'B * 100}{100 + P'B}$$

COMBINED AGGREGATE SP. GR.

	APPARENT	BULK	%
+4	2.652	2.484	31
-4	2.669	2.578	69
Theo. Comb.	2.664	2.566	

$$PS = B = 100 - A$$

$$F = E*62.4$$

$$GSE = G = \frac{B}{\frac{100}{E} - \frac{A}{C}}$$

$$L = K*62.4$$

$$P\,A = M = 100 * \frac{E - K}{E}$$

$$PBA = H = 100 * \frac{G - D}{D * G} * C$$

$$PBE = I = A - \frac{H}{100} * B$$

$$VFA = N = \frac{100 * \frac{I}{C}}{\frac{J}{K}}$$

$$VMA = J = 100 - \frac{K * B}{D}$$

KANSAS DEPARTMENT OF TRANSPORTATION
HOT MIX DESIGN DATA (MARSHALL METHOD)

Contract: 594066008
Project: 99-115 K 4615-01 County: Zolan Date: March 21, 1995 Lab No. 9B99099A

Mix Designation: BM-2 Asphalt Grade: AC-10 Sp. Gr. AC: 1.0180 Compaction, Blows/Side: 50

Deg.C / % AC		Comapct Temp. (C)	Specimen Height (MM)	Weight, Grams Dry In Air	In Water	S.S.D In Air	S.S.D In Water	Water Absorbed %	SP. GR. Compact Mix	KG/ Cubic Meter	Water Bath (C)	Stability Dial. Reading	Corr.	Adjust (N)	Flow (0.25) (MM)	Bearing Capacity (kPa)
	A	279	2.516	1175.1	661.7				2.289		139	117	1.00	1032	7.5	
298	B	277	2.506	1183.8	669.2				2.300		139	143	1.00	1277	7.5	Error
	C	274	2.497	1174.2	661.5				2.290		141	122	1.00	1079	7.5	
4.50					Average				2.293	143.08				1056	7.5	158
	A	279	2.512	1185.0	671.3				2.307		140	105	1.00	919	7.5	
298	B	278	2.500	1187.7	674.0				2.312		140	117	1.00	1032	7.5	
	C	276	2.487	1179.4	665.8				2.296		140	112	1.00	985	7.5	
5.00					Average				2.305	143.83				979	7.5	147
	A	272	2.493	1187.1	675.7				2.307		140	117	1.00	1032	8.0	
298	B	272	2.487	1186.6	676.2				2.325		140	127	1.00	1126	9.0	
	C	274	2.476	1187.1	676.7				2.326		140	131	1.00	1164	9.5	
5.50					Average				2.324	145.02				1107	8.8	140
	A	276	2.492	1193.6	680.6				2.327		139	131	1.00	1164	10.5	
298	B	276	2.468	1183.9	675.6				2.329		139	122	1.04	1122	9.5	
	C	276	2.492	1190.0	679.1				2.329		140	116	1.00	1022	9.5	
6.00					Average				2.328	145.27				1103	9.8	124
	A	279	2.469	1190.5	679.2				2.328		140	114	1.04	1044	12.5	
298	B	277	2.478	1184.8	675.6				2.327		140	122	1.00	1079	11.5	
	C	278	2.486	1186.1	677.6				2.333		140	112	1.00	985	11.5	
6.50					Average				2.329	145.33				1036	11.8	95
	A	279	2.478	1184.5	674.7				2.323		139	119	1.00	1051	14.0	
298	B	276	2.485	1184.3	672.9				2.316		140	105	1.00	919	13.5	
	C	274	2.503	1189.2	677.8				2.325		140	118	1.00	1041	13.5	
7.00					Average				2.322	144.89				1004	13.7	78

Specific Gravity Method: I

ERROR = PLUG OUT OF ALLOWED RANGE

D.O.T. FORM 705

KANSAS DEPARTMENT OF TRANSPORTATION

THEORETICAL MAXIMUM SPECIFIC GRAVITY OF PAVING MIXTURES

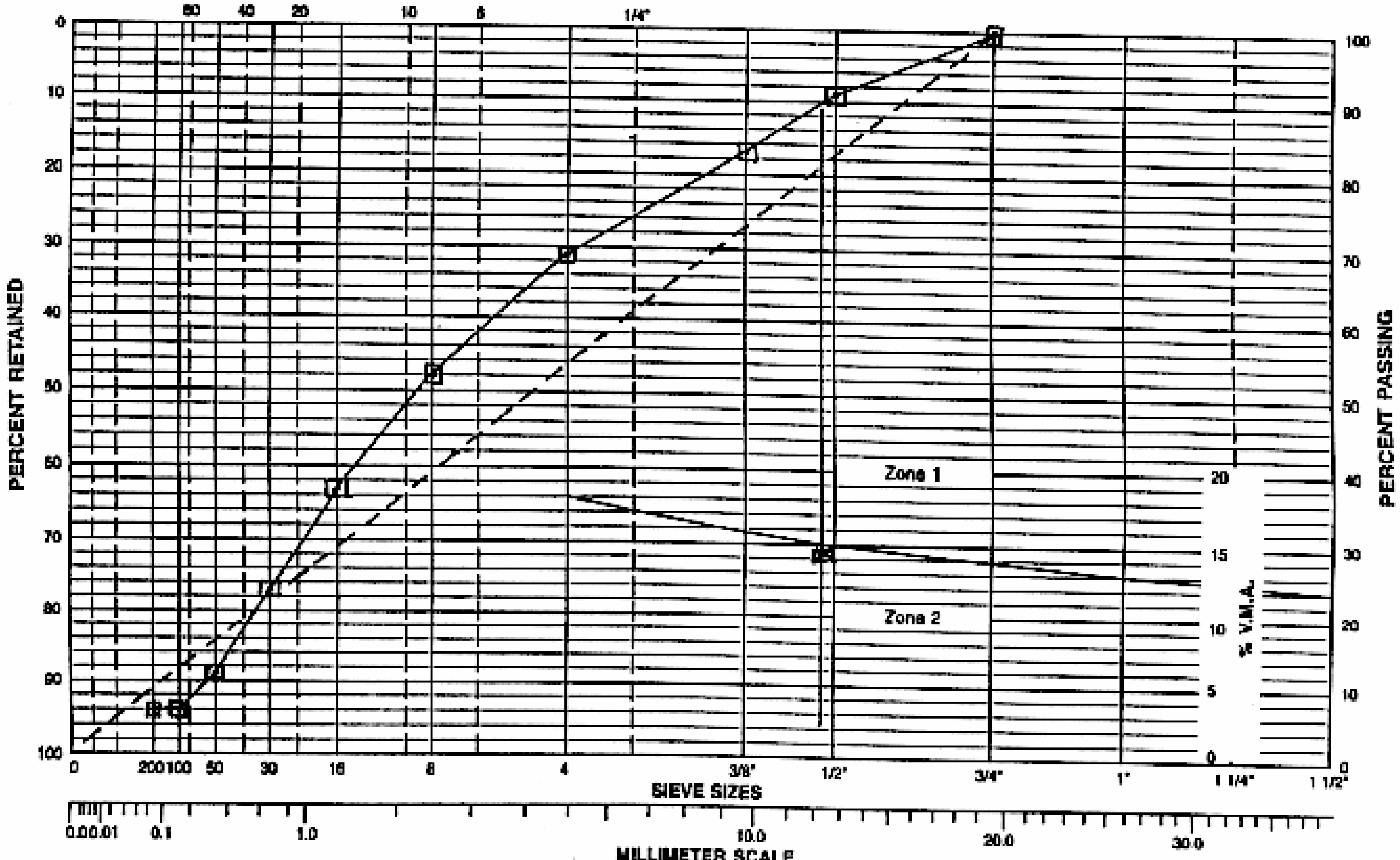
References: ASTM D 2041 (Rice's Method) and Kansas Test Method KT-39 Date: March 21, 1995
Contract Number: 594066008
Project Number: 99-115 K 4615-01 County: Zolan Lab No: 9B99099A

Bowl # Sample #	4.50 A	4.50 B	5.00 A	5.00 B	5.50 A	5.50 B
Mass of Sample & Bowl in Air, Grams	3646.5	3698.3	3720.3	3709.2	3681.9	3673.7
Mass of Bowl in Air, Grams	2144.0	2141.9	2173.7	2149.5	2114.6	2112.2
Mass of Sample in Air, Grams (A)	1502.5	1556.4	1546.6	1559.7	1567.3	1561.5
Temp. of Bath, Sample and Bowl after 10 Minutes	78.8	78.6	77.9	78.0	77.5	77.6
Mass of Sample and Bowl in Water, Grams	2240.4	2258.9	2270.3	2260.2	2251.9	2246.7
Mass of Bowl in Water, Grams	1368.2	1365.1	1386.9	1362.7	1337.8	1335.4
Mass of Sample in Water, Grams (C)	872.2	893.8	883.4	897.5	914.1	911.3
Maximum Sp. Gr. of Mix (Rice's) A/(A-C)	2.3838	2.3489	2.3320	2.3553	2.3994	2.4015
Average Max. Sp. Gr. of Mix	2.366		2.344		2.400	

D.O.T Form 706

KANSAS DEPARTME... OF TRANSPORTATION
0.45 POWER GRADATION CHART

Contract 094066008 Project 99-115 K 4615-01 County Zolan Lab. No. 9B99098A



INSTRUCTIONS FOR DETERMINING ZONE 1 or 2:

1. Plot design gradation.
2. Locate 10% retained point on gradation line.
3. Draw vertical line downward from 10% retained point.
4. Indicate V.M.A. value at tentative A.C. content on vertical line using scale labelled "% VMA" by drawing a symbol (X) at that point. This point determines if this is a Zone 1 or Zone 2 mix.

Legend

- Single Point Grading
- Theoretical Maximum Density Line

BY ABC Checked By DEF

D.O.T. Form No. 707