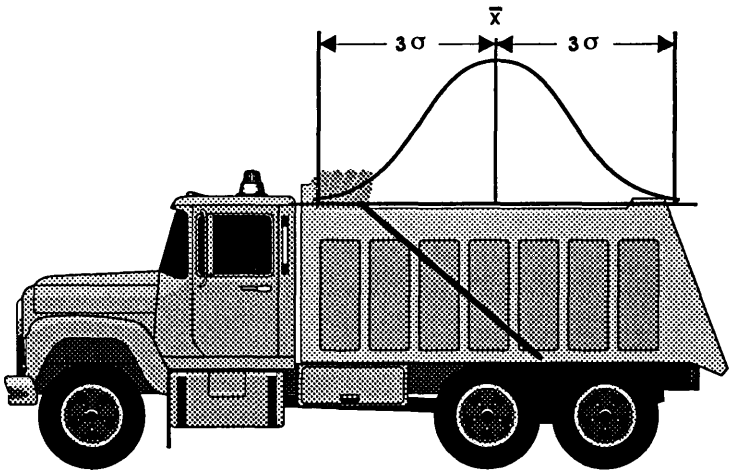
TECHNICAL
ASSISTANCE REPORT

RESULTS FROM VDOT'S PILOT PROJECT USING VOLUMETRIC PROPERTIES AND ASPHALT CONTENT FOR ACCEPTANCE OF ASPHALT CONCRETE



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Technical Assistance Report

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Virginia Transportation Research Council
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INTRODUCTION

In 1994 the Virginia Department of Transportation (VDOT) developed a specification for the acceptance of asphalt concrete based largely on Marshall compacted volumetric properties of the mix. A copy of the Special Provision is shown in the Appendix. The development of this specification is consistent with national efforts such as AASHTO and the SHRP asphalt program, emphasizing volumetric properties as being more related to performance than gradation results.

A pilot project was placed on I-95 in the Fredericksburg District by Virginia Paving Co. in June 1994. Over a 3-week period, approximately 24,000 tons of mix were placed in accordance with the Special Provision.

This report summarizes the results relative to acceptance and compares results obtained from the contractor, from the VDOT Elko Materials laboratory, and from several VDOT district materials laboratories.

ACCEPTANCE RESULTS

The acceptance plan essentially uses four tests from a 2,000-ton lot. The properties used to determine acceptability are asphalt content determined by a nuclear gauge and the volumetric properties of voids total mix (VTM) and voids in the mineral aggregate (VMA) from a Marshall 75-blow compactive effort. Another volumetric property, voids filled with asphalt (VFA), is measured for information but is not used in the acceptance function.

The specification uses the percent within limits (PWL) concept contained in the 1994 AASHTO QA Guide Specifications. This concept uses the sample average and standard deviation from each lot to determine the quality index (QI), which is used to estimate the PWL. The PWL is, in turn, used to determine the pay factor, through an equation, for the lot. The lowest estimated PWL for asphalt content, VTM, and VMA determine the pay factor. It is important in the PWL concept to produce a uniform product within each lot. As the results show, the contractor on this project evidently understood the importance of this concept very well.

For the pilot study, in addition to asphalt contents determined by the nuclear gauge, asphalt contents were also measured by the reflux extraction method, which is being used as the standard acceptance procedure. The asphalt content by this procedure was determined solely for information and analysis, not for acceptance.

As stated in the special provision, the acceptable quality level (AQL) was set at 90 PWL and the rejectable quality level (RQL) at 40 PWL. The Special Provision requires that any lot of material with less than 40 PWL be rejected and removed from the road. The specification limits are applied to the job mix formula (JMF) as determined by the mix design and shown in Table 1.

Table 1

Specification Limits for Marshall Volumetric Properties and Asphalt Content

Property	Lower Spec Limit (LSL)	Upper Spec Limit (USL)
VMA	Target -0.7	--
VTM	Target -1.2	Target +1.2
Asphalt Content	Target -0.3	Target +0.3

Table 2 shows the statistical properties and resulting pay factor by lot. All lots but numbers 3, 7, and 9 received 100 percent pay. These three lots had slight price adjustments. The price adjustments, interestingly, were due to the VMA PWL being slightly less than 90. The Special Provision allows the contractor to request an adjustment of the JMF target for VMA based on expected changes in plant-produced material. It is recognized that the VMA determined during mix design is an approximation of that determined from plant-produced material, and this recognition is addressed in the Special Provision. It is typical that the VMA of plant-produced material may be less than that obtained in the design process. The Special Provision allows the contractor to request a slightly lower VMA based on plant-produced material. For this project, the contractor chose to use the VMA determined during mix design. The three lots with price adjustments had reasonably low standard deviations, but the averages were sufficiently close to the specification limit to cause the PWL to be below 90.

However, the contractor should be congratulated on the uniformity of the product produced during the pilot study. This uniformity demonstrates that the Special Provision can be met consistently by a conscientious contractor.

Table 2

Statistics and Pay Factors by Lot

Lot #	A.C. %		VTM %		VMA %		Pay Factor
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	%
JMF	5.2	--	4.5	--	16.6	--	--
1	5.19	0.211	4.75	0.532	16.25	0.252	100.00
2	5.29	0.039	3.88	0.150	16.10	0.082	100.00
3	5.22	0.046	3.88	0.479	16.10	0.216	98.17
4	5.23	0.128	4.57	0.427	16.48	0.263	100.00
5	5.23	0.100	4.45	0.370	16.85	0.412	100.00
6	5.16	0.097	4.70	0.183	16.65	0.208	100.00
7	5.18	0.077	4.25	0.265	16.25	0.300	99.91
8	5.05	0.076	4.35	0.265	16.10	0.116	100.00
9	5.08	0.125	4.65	0.520	16.25	0.300	99.91
10	5.06	0.093	4.80	0.294	16.45	0.311	100.00
11	5.11	0.120	4.32	0.275	16.15	0.129	100.00
12 & 14	5.25	0.156	4.08	0.325	16.28	0.204	100.00

COMPARISON BETWEEN CONTRACTOR AND ELKO RESULTS

The pilot study afforded the opportunity to sample and test much more frequently than can normally be done. Samples were split and run by the contractor and by the VDOT Materials Division's lab at Elko. As will be discussed later, most samples were also tested by VDOT district laboratories.

It is important in a quality assurance program to be able to repeat test results, within acceptable limits, on material tested in different laboratories by different technicians. The ability

to do this improves the creditability of the laboratories and testing procedures and personnel.

Table 3 shows the volumetric properties and asphalt contents of the acceptance tests performed by both Virginia Paving and Elko. The number of tests, *n*, average, and standard deviation are shown. Also shown are the *F* and *t* test results, which compare the standard deviations and averages, respectively, of Virginia Paving and Elko.

Table 3

Comparison of Volumetric Properties and Asphalt Contents

Virginia Paving and Elko

	VTM		VMA		Nuclear AC	
	Va. Paving	Elko	Va. Paving	Elko	Va. Paving	Elko
n	50	50	50	50	50	50
$\bar{X}$	4.372	4.664	16.32	16.30	5.177	5.033
s	0.4545	0.8644	0.3119	0.6903	0.127	0.2057
F crit.	2.11		2.11		2.11	
F calc.	3.62* Yes		4.9* Yes		2.61* Yes	
t crit.	2.64		2.65		2.64	
t calc.	2.11 No		0.187 No		4.22* Yes	

F crit. is the value that when exceeded indicates the standard deviations as measured by the variances, s^2, are statistically different at an $\alpha = 0.01$, which means that there is only a 1 percent chance that a statistical difference does not exist when the critical value is exceeded. *F calc.* is the value from the *F* test. In this case as well as the analysis of the *t* test that follows, a computer program developed by Richard Weed of New Jersey DOT for the FHWA Demo 89 project was used. Similarly to the *F* test, *t crit.* is the value that when exceeded indicates the averages are statistically different at an $\alpha = 0.01$. *t calc.* is the value from the *t* test.

As Table 3 shows, the variances (and thus standard deviations) were significantly different for VTM, VMA, and AC. This indicates that sources of variability acting in the sampling and testing program produce different magnitudes of variability.

However, even with these differences in variability, the comparison of the averages using the *t* test were not significantly different for the VTM or VMA. This is a favorable indication that the two labs are producing approximately equivalent results on the average. The average VMA values for the two labs were extremely close, 16.32 percent for the average of Virginia Paving and 16.30 percent for Elko. The average of the VTM results differed by about 0.3 percent. The averages of the nuclear asphalt content results were significantly different, with the average from Elko being 0.14 percent lower than that from Virginia Paving. The reason that this relatively small difference is statistically significant is that the variabilities of both labs were relatively small.

The differences in averages for asphalt contents are consistent in direction with the VTM. That is, Elko's asphalt contents were lower for both nuclear and reflux, as shown in Table 4, than Virginia Paving, and the VTM was slightly, but not significantly, higher.

An additional analysis comparing the population parameters of the nuclear vs. reflux asphalt contents for both Virginia Paving and Elko was also done. The results are shown in Table 4. Neither the *F* test nor the *t* test both using an $\alpha = 0.01$ indicated a significant difference between the populations. For Elko, the reflux asphalt content standard deviation was slightly less and the average slightly higher than the nuclear asphalt content. For Virginia Paving, both the reflux asphalt content standard deviation and average were slightly higher than those for the nuclear asphalt content.

Table 4

Comparison of Nuclear and Reflux Asphalt Contents

	Va. Paving		Elko	
	Nuclear	Reflux	Nuclear	Reflux
n	50	50	50	50
$\bar{x}$	5.175	5.217	5.033	5.097
s	.1281	.1585	.2057	.1766
F crit.	2.11		2.11	
F calc.	1.53 No		1.36 No	
t crit.	2.63		2.63	
t calc.	1.46 No		1.64 No	

As a further analysis, the reflux asphalt contents for the two labs were compared, as the results in Table 5 show. The standard deviations were not significantly different, but the averages were at an $\alpha = 0.01$.

Table 5

Comparison of Reflux Asphalt Contents

Virginia Paving and Elko

	Va. Paving	Elko
n	50	50
$\bar{x}$	5.217	5.097
s	.1585	.1766
F crit.	2.11	
F calc.	1.25 No	
t crit.	2.63	
t calc.	3.58* Yes	

COMPARISONS BETWEEN CONTRACTOR AND DISTRICT LAB RESULTS

Joe Love, VDOT Transportation Engineering Programs Supervisor, sent portions of the split samples to various district labs, allowing an analysis of the statistical comparisons between the contractor and district lab results, shown in Table 6. As in the previous analyses, an α of 0.01 was used.

Table 6
Comparisons of Volumetric Properties and Asphalt Contents
Virginia Paving and Districts

DISTRICT						VA PAVING				
Lot No's	VTM	VMA	VFA	AC %		VTM	VMA	VFA	AC %	
				Nuc.	Ref.				Nuc.	Ref.
3 & 4 (Staunton District) $n = 7$										
$\bar{X}$	3.89	16.2	76.1	5.29	5.30	4.20	16.3	74.4	5.23	5.28
s	0.805	0.56	4.36	0.186	0.177	0.603	0.28	3.16	0.095	0.141
5 & 10 (Lynchburg District) $n = 8$										
$\bar{X}$	4.60	16.3	71.8	5.03	5.02	4.62	16.6	72.1	5.14	5.18
s	0.415	0.45	2.44	0.166	0.184	0.362	0.40	2.03	0.126	0.201
6 & 7 (Salem District) $n = 8$										
$\bar{X}$	4.85	16.2	70.0	4.89*	5.25	4.48	16.4	72.9	5.17*	5.14
s	0.507	0.72	2.62	0.213	0.125	0.320	0.321	1.64	0.082	0.101
8 & 9 (Suffolk District) $n = 8$										
$\bar{X}$	4.96	16.0	68.8*	4.78*	5.02	4.50	16.2	72.0*	5.06*	5.15
s	0.441	0.33	2.12	0.09	0.13	0.414	0.225	2.20	0.100	0.100
11, 12, & 14 (Bristol District) $n = 10$										
$\bar{X}$	3.89	15.5*	75.0	4.99	5.20	4.15	16.2*	74.1	5.21	5.25
s	0.651	0.54*	4.00	0.280	0.250	0.366	0.183*	1.85	0.144	0.177

*Significant difference at $\alpha = 0.01$

Of 40 comparisons, only 5 indicated statistically significant differences. Both Salem and Suffolk had significantly lower results for the average of the nuclear asphalt content. Since the reflux asphalt contents were not significantly different, this may indicate that the difference is due to calibration of the nuclear gauge. Suffolk also had a significantly different (lower) average VFA. In this comparison, the Bristol average VMA and VMA variability was significantly different than Virginia Paving results.

COMPARISONS BETWEEN ELKO AND DISTRICT LAB RESULTS

The comparison of the districts and Elko shown in Table 7 is particularly encouraging. The only significant difference occurred between Bristol and Elko on the averages of the VMA results. The other average results for Bristol are consistent in direction; for example, the VTM tends to be lower and the VFA higher than Elko, although not statistically significant. The large number of comparable results is probably due, at least in part, to the periodic round-robin testing that the Elko lab does with all the district labs as well as with the Virginia Transportation Research Council. The round-robin testing allows deviations from correct procedure and faulty equipment to be identified and corrected.

Table 7
Comparison of Volumetric Properties and Asphalt Contents
Elko and Districts

DISTRICT						ELKO				
Lot No's	VTM	VMA	VFA	AC %		VTM	VMA	VFA	AC %	
				Nuc.	Ref.				Nuc.	Ref.
3 & 4 (Staunton District) $n = 7$										
$\bar{X}$	3.89	16.2	76.1	5.29	5.30	4.46	16.3	73.1	5.13	5.28
s	0.805	0.56	4.36	0.186	0.177	0.858	0.78	4.38	0.181	0.141
5 & 10 (Lynchburg District) $n = 8$										
$\bar{X}$	4.60	16.3	71.8	5.03	5.02	5.09	16.6	68.8	5.02	5.182
s	0.415	0.45	2.44	0.166	0.184	0.716	1.01	2.49	0.228	0.201
6 & 7 (Salem District) $n = 8$										
$\bar{X}$	4.85	16.2	70.0	4.89	5.25	5.16	16.8	69.5	5.02	5.14
s	0.507	0.72	2.62	0.213	0.125	0.571	0.570	2.56	0.130	0.101
8 & 9 (Suffolk District) $n = 8$										
$\bar{X}$	4.96	16.0	68.8	4.78	5.02	4.95	16.2	69.6	4.87	5.15
s	0.441	0.33	2.12	0.09	0.13	0.555	0.43	3.07	0.171	0.100
11, 12, & 14 (Bristol District) $n = 10$										
$\bar{X}$	3.89	15.5*	75.0	4.99	5.20	4.60	16.2*	72.3	5.08	5.15
s	0.651	0.54	4.00	0.280	0.250	0.821	0.32	4.22	0.169	0.317

*Significant difference at $\alpha = 0.01$

SUMMARY

The pilot study afforded the opportunity to sample and test in more labs than can be done under normal contract conditions. In addition to the increased frequency on the part of VDOT, split samples were obtained and tested in several labs to provide data for statistical comparisons among the contractor, the Elko asphalt lab, and district labs.

It is obvious from the tests that the contractor maintained a high degree of uniformity during the production of the mix. It was demonstrated that the QI specification is reasonable and can be met consistently.

The comparison of results between the contractor and Elko, between the contractor and district labs, and between Elko and the district labs indicates that, by and large, the labs produce comparable results.

It is important that some degree of comparison sampling and testing between contractor and VDOT labs be continued.

APPENDIX

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION FOR
SECTION 211 ASPHALT CONCRETE USING MARSHALL
VOLUMETRIC PROPERTIES

January 4, 1994

SECTION 211 of the Specifications is completely replaced by the following:

SECTION 211.01 DESCRIPTION - Asphalt concrete shall consist of a combination of mineral aggregate and asphalt material mixed mechanically in a plant specifically designed for such purpose.

Asphalt concrete shall conform to the requirements for the type designated.

SECTION 211.02 MATERIALS

(a) Asphalt materials shall conform to Section 210 of the specifications.

(b) Coarse aggregate shall be Grade A or B, conforming to Section 203 of the Specifications for quality.

(c) Fine aggregate shall conform to the requirements of Section 202 of the Specifications and shall have a minimum sand equivalent value of 30 when tested in accordance with AASHTO T176.

(d) Fine or coarse aggregates which tend to polish under traffic will not be permitted in any surface exposed to traffic except in areas where the posted speed is 15 mph or less, and as permitted elsewhere in these specifications.

(e) Mineral filler shall conform to Section 201 of the Specifications

(f) Aggregate for asphalt concrete shall be provided in sufficient sizes to produce a uniform mixture. The Contractor shall indicate on the proposed job-mix formula, the separate approximate sizes of aggregate to be used. Where segregation or non-uniformity is evidenced in the finished pavement, the Engineer reserves the right to require the Contractor to discontinue the use of crusher run or aggregate blends and to furnish separate sizes of open graded aggregate material.

(g) An antistripping additive will be approved and accepted by one of the two following methods:

(1) Hydrated lime shall be used in all mixes in accordance with

Section 211.02(h) and the mixture shall produce a tensile strength ratio (TSR) value not less than 0.75 when tested in accordance with VTM-62. However, the contractor may use an approved chemical additive if it produces a TSR value as great as 0.75 and as great as the TSR value of the same mix using one percent of hydrated lime. Tests shall use the same materials that are to be used in the production mix and shall be conducted in a Department approved laboratory.

In the event the TSR is less than 0.75 the Contractor shall increase the hydrated lime content, use a chemical additive, or use a combination of the two to produce a TSR not less than 0.75.

During production of a mix which uses a chemical antistripping additive, the TSR value shall be not less than 6 percent below the TSR value obtained with 1 percent hydrated lime prior to production and not less than 0.75. During production of a mix which uses hydrated lime as the antistripping additive, the TSR shall be not less than 0.75.

(2) The mixture must produce a TSR not less than 0.85 for the design and production tests. The Contractor may use either at least 1 percent hydrated lime in accordance with Section 211.02(h), an approved chemical additive, or a combination of both. When a chemical additive is used, it shall be added to the asphalt prior to introduction into the mix. Any chemical additive or particular concentration of chemical additive found to be harmful to the asphalt material or which changes the viscosity of the original asphalt cement more than 400 poises or the penetration more than -4 or +10 shall be changed to obtain compliance with these values.

The Contractor shall bear all costs associated with the described testing and no extension of time will be granted for conducting these tests.

(h) **Hydrated lime** shall conform to the requirements of ASTM C977. Hydrated lime shall be added at a rate of not less than one percent by weight of the total dry aggregate.

A separate bin or tank and feeder system shall be provided to store and accurately proportion the lime into the aggregate in either dry or slurry form. The lime and aggregate shall be mixed by pugmill or other approved means to achieve a uniform lime coating of the aggregate prior to adding the asphalt material to the mixture. In the event lime is added in dry form, the aggregate shall contain at least 3 percent free moisture. The stockpiling of lime treated aggregate will not be permitted.

The feeder system shall be controlled by a proportioning device which shall be accurate to within plus or minus 10

percent of the specified amount. The proportioning device shall have a convenient and accurate means of calibration and shall be interlocked with the aggregate feed or weigh system so as to maintain the correct proportion. A flow indicator or sensor shall be provided and interlocked with the plant controls such that production of the mixture will be interrupted if there is a stoppage of the lime feed.

The method of introducing and mixing the lime and aggregate shall be subject to approval by the Engineer prior to beginning production.

(I) **Reclaimed asphalt pavement material** may be used as a component material of asphalt mixtures in conformance with the following:

1. Reclaimed asphalt pavement material shall not exceed 25 percent by weight of the total aggregate.

2. The final asphalt mixture shall conform to the requirements for the type specified.

3. During the production process, reclaimed asphalt pavement material shall not be allowed to contact open flame.

4. Reclaimed asphalt pavement material shall be handled, hauled and stored in a manner which will minimize contamination. Further, the material shall be stockpiled and used in such manner that variable asphalt contents and asphalt penetration values will not adversely affect the consistency of the mixture.

5. Reclaimed asphalt pavement shall be processed in such a manner as to ensure that the maximum top size introduced into the mix shall be 2 inches. The Engineer may require smaller sized particles be introduced into the mix if the reclaimed particles are not broken down or uniformly distributed throughout the mixture during heating and mixing.

SECTION 211.03 JOB-MIX FORMULA - The Contractor shall submit or have the supplier submit for the Engineer's approval, a job-mix formula for each mixture to be supplied. The job-mix formula shall be within the design range specified. The job-mix formula shall establish a single percentage of aggregate and a single temperature at which the mixture is to be produced. Each approved job-mix formula shall remain in effect for the current and subsequent construction seasons, provided the results of tests performed on material currently being produced consistently meet the requirements of the job-mix formula for gradation, asphalt content and temperature as well as field Marshall requirements.

(a) In conjunction with the submittal of a job-mix formula, the Contractor shall submit complete Marshall Design test data

prepared by an approved testing laboratory for mixes to be used in surface, intermediate and base courses.

(b) The Marshall Design test data shall include but not be limited to the following information

1. Grading data for each aggregate component of the mixture shown as percent passing for sieves 2", 1-1/2", 1", 3/4", 1/2", 3/8", #4, #8, #30, #50, #100 and #200. The grading shall be reported to the nearest 1.0 percent, except the #200 to the nearest 0.1 percent.

2. The percentage of each aggregate component as compared to the total aggregate in the asphalt mixture.

3. The aggregate grading in the asphalt mixture as determined by extracting the asphalt from a laboratory prepared sample. The laboratory sample shall be batched on the basis of component percentages as indicated in (b)2, and at the proposed job-mix asphalt content. The extraction shall be in accordance with VTM-36 or VTM 91. Sieves noted in (b)1 shall be reported, beginning with the top size for that mix type.

4. The following volumetric properties of the compacted mixture (calculated on the basis of the mixture's maximum specific gravity determined by AASHTO T-209 and the bulk specific gravity of the specimens determined by AASHTO T-166, Method A) for each asphalt content tested. Properties shall be determined and reported in accordance with VTM-58.

    a. Voids in total mix (VTM)
    b. Voids in mineral aggregate (VMA)
    c. Voids filled with Asphalt (VFA)

5. The value of the maximum specific gravity of the asphalt mixture used in (b)4 shall be reported to three decimal places.

6. The stability and flow of the compacted asphalt mixture shall be determined by VTM-57 for each asphalt content tested.

7. At least four different asphalt contents shall be evaluated for the properties noted in (b)4 and (b)6 and the results plotted on graphs furnished by the Department. The asphalt contents evaluated shall approximate the proposed job-mix asphalt content and contents

approximately 0.5% above and below this value.

(c) The Marshall Design test data shall be plotted on graphs furnished by the Department and shall show that the proposed job-mix formula conforms to the requirements of the mix type.

(d) A determination will be made that any new asphalt concrete mixture being produced conforms to the job-mix formula approved by the Department. The Department will test the mixture using samples removed from production. The following tests will be run to determine the properties listed:

1. Asphalt Content and Gradation using one of the following procedures:
   a) VTM-36 and AASHTO T-30
   b) VTM-91 and T-164 Method C
2. Asphalt Content VTM-93
3. Marshall Properties VTM-58

In the event the Department determines that the mixture being produced does not conform to the approved job mix formula, the Contractor shall immediately cease paving with that mixture.

Subsequent paving operations, using either a revised or other job-mix formula which has not been verified as described herein, shall be limited to a test run of 100 to 300 tons of mixture if such material is to be placed in Department work. No further paving for the Department is to occur until the acceptability of the mixture being produced has been verified using the 100 to 300 ton test run constraint.

Asphalt concrete mixtures used in surface, intermediate and base courses shall conform to the following requirements when tested in accordance with VTM-57 and VTM-58:

TABLE II-13
MIX DESIGN CRITERIA

MIX TYPE	VTM (%)	VFA (%)	MIN. VMA (%)	MIN. STABILITY (lbs.)	FLOW (0.01")	AC VISC. GRADE	MARSHALL BLOW
SM-1	4-8	65-80	17	1000	8-16	AC-20	50
SM-2A	3-6	65-80	15	1200	8-16	AC-20	50
SM-2B	3-6	65-80	15	1500	8-16	AC-20	75
SM-2C	3-6	65-80	15	1500	8-16	AC-30	75
SM-3A	3-6	65-80	14	1500	8-16	AC-20	50
SM-3B	3-6	65-80	14	1500	8-16	AC-20	75
SM-3C	3-6	65-80	14	1800	8-16	AC-30	75
IM-1A	3-6	65-80	14	1500	8-16	AC-20	50
IM-1B	3-6	65-80	14	1500	8-16	AC-20	75
BM-1	3-6	65-80	14	400	24 max.	AC-20	50
BM-2	3-6	65-80	13	3000	24 max.	AC-20	75
BM-3	3-6	65-80	12	3000	24 max.	AC-20	75

Maximum F/A ratio shall be 1.2:1 on all surface and intermediate mixtures.
Maximum F/A ratio shall be 1.4:1 on all base mixtures.
Minimum F/A ratio shall be 0.6:1 on all surface and intermediate mixtures.
Asphalt Content shall be selected at the mid point of VTM range.
Base mixes shall have a minimum asphalt content of 4.0 percent determined by Marshall Design as specified herein the special provisions.

The Engineer reserves the right to require adjustments in the job-mix formula based upon a plot of aggregate grading and the maximum density line on a 0.45 power graph where such plot indicates gap grading.

SECTION 211.04 ASPHALT CONCRETE MIXTURES shall conform to the requirements of Table II-12 and the following:

(a) Type SM-1 Asphalt Concrete shall consist of siliceous fine aggregate, granite, slag, gravel screenings or combination thereof combined with asphalt cement.

At least 20 percent Grading A sand shall be used conforming to Section 202 of the Specifications.

(b) Type SM-2A, SM-2B and SM-2C Asphalt Concrete shall consist of crushed stone, crushed slag, or crushed gravel and fine aggregate, slag or stone screenings, or a combination thereof combined with asphalt cement.

For mixtures SM-2B and SM-2C at least 10 percent sand conforming to Section 202 of the Specifications for Grading A, F, G or a combination thereof shall be used. Natural sand shall not exceed 20%.

No more than 5 percent of the aggregate retained on the No. 4 and no more than 20 percent of the total aggregate may be polish susceptible.

(c) Type SM-3A, SM-3B AND SM-3C Asphalt Concrete shall consist of crushed stone, crushed slag or crushed gravel and fine aggregate, slag, or crushed screenings, or combination thereof combined with asphalt cement.

For mixtures SM-3B and SM-3C at least 10 percent sand conforming to Section 202 of the Specifications for Grading A, F, G or a combination thereof shall be used. Natural sand shall not exceed 20%.

No more than 5 percent of the aggregate retained on the No. 4 sieve shall be polish susceptible. All material passing the No. 4 sieve may be polish susceptible.

(d) Type IM-1A and IM-1B Asphalt Concrete shall consist of crushed stone, crushed slag or crushed gravel and fine aggregate, slag, or stone screenings, or combination thereof combined with asphalt cement.

(e) Type BM-1 Asphalt Concrete shall consist of local pit material. Addition of mineral filler, not to exceed 5%, or other aggregates will be permitted to conform to specification requirements.

(f) Type BM-2 and BM-3 Asphalt Concrete shall consist of coarse aggregate (crushed stone, crushed slag, or crushed gravel); fine aggregate (slag, stone screenings, gravel screenings), or a combination thereof.

(g) Type C Asphalt Concrete (Curb Mix) shall consist of a blend of No. 78 crushed aggregate, No. 10 crushed aggregate, fine aggregate, mineral filler and a powdered asphalt or other approved material; combined with 6.0 - 9.0 percent asphalt cement, viscosity grade AC-20.

(h) Type P Asphalt Patch material shall consist of open graded crushed stone and Grading A fine aggregate (15 percent minimum) combined with MC-400 cut-back asphalt. The job mix shall have a residual asphalt cement content of 4.5 - 6.5 percent. Production tolerance

of residual asphalt cement shall be ± 0.5%.

An antistripping additive from the Department's approved list shall be added to the cut-back asphalt at a rate of 1 percent by weight.

Tall oil pitch or equal shall be added to the cut-back asphalt at a rate of 2% by weight. The mixture shall have a minimum stockpile life of six months. Additional tall oil, up to 5% by weight may be added to extend stockpile life.

NOTE: Tall oil may be substituted for the tall oil pitch.

The asphalt content shall be approved by the Engineer prior to production.

The aggregate moisture content shall not exceed 0.5 percent. If necessary, the aggregate shall be allowed to cool until temperature is not less than 125°F nor more than 175°F before mixing with cut-back asphalt, unless otherwise specified by the Engineer.

SECTION 211.05 - TESTING - The Contractor shall provide the quality assurance necessary for the Department to determine conformance with the required Marshall volumetrics, asphalt content and temperature properties for asphalt concrete.

The Contractor shall have a certified Asphalt Concrete Technician present at the plant during initial set-up and subsequent production and shall utilize such Technician for sampling, testing, designing and adjusting mixes as necessary. The certified Asphalt Concrete Technician is that person who is capable of designing and making necessary adjustments in the asphalt concrete mixes at the mixing plant. The Technician shall be capable of sampling the material and conducting any tests necessary to put the plant into operation and to produce a mixture within the requirements of these specifications. Certification will be awarded by the Department upon satisfactory completion of an examination.

The Contractor shall maintain all records and test results associated with the material production and shall maintain appropriate current quality control charts. All test results and control charts shall be available for review by the Engineer.

The Contractor shall execute a quality control plan of process control inspections and tests, including the extracted asphalt content and gradation of the completed mixture. This testing will be performed using either VTM 36 and AASHTO T-30 or VTM-91 (using a vacuum extractor and an extraction chemical from the Department's non-chlorinated solvent approved list) and

AASHTO T-164, METHOD C. The results of this testing shall be used by the Contractor, along with the results of other quality control efforts, to control the quality of the mixture being produced.

An extracted asphalt content and aggregate gradation analysis on the completed mix shall be performed at least once per lot on a sample of completed mixture. The sample of mix for this testing shall be obtained by quartering a sufficiently large sample of mix to allow the use of one quarter for quality assurance nuclear asphalt content and Marshall volumetric testing, one quarter for extracted asphalt content and aggregate gradation testing and one half of the sample to be retained for monitor testing by the Department. The Contractor shall retain the Department's portion of this sample and shall clearly label the sample to allow comparison of the Department's and the Contractor's test results. The results of this testing will be used to evaluate the acceptability of the asphalt mixture.

In the event that any extracted asphalt content and/or aggregate gradation testing do not meet the tolerances shown in Table II-14, the Department may require that production be stopped until necessary corrective action is taken by the Contractor. The aggregate gradation and asphalt content testing results shall be within the following tolerances for one sample.

TABLE II-14
PROCESS TOLERANCE

No. Tests	Top Size	1-1/2"	3/4"	1/2"	3/8"	No.4	No.8	No.30	No.50	No.200	A.C.
1	0.0	8.0 ±	±8.0	±8.0	±8.0	±8.0	±8.0	±6.0	±5.0	±2.0	±.60

SECTION 211.06 TESTS - The Department may sample materials entering into the composition of the asphalt concrete, sample the mixture, or sample the completed pavement. The Contractor shall cooperate with the Engineer in obtaining these samples. When samples are obtained from the pavement, the resulting voids shall be filled and refinished by the Contractor without additional compensation.

The asphalt cement, when extracted and recovered in accordance with AASHTO T170, shall have a recovered penetration of not less than 35 and a ductility at 77°F of not less than 40 cm.

SECTION 211.07 PLANT INSPECTION - The preparation of asphalt concrete mixtures will be accepted by a quality assurance plan. The Contractor

shall provide a laboratory as specified in Section 106.06 of the Specifications.

SECTION 211.08 ACCEPTANCE - Acceptance shall be made under the Department's quality assurance program which includes the testing of production samples by the Contractor and monitor samples by the Department. Sampling and testing for the determination of Marshall volumetrics properties, nuclear asphalt cement content and temperature shall be performed by the contractor. The Department will perform independent monitor testing of the asphalt mixture at a laboratory of its choice. The Contractor shall provide copies of test results to the Department on forms approved by the Department. If the Contractor's test results indicate that the mixture conforms to the Marshall volumetrics properties, nuclear asphalt cement content and mixture temperature requirements, the mixture will be acceptable. Nothing here shall be construed as waiving the requirements of Sections 106.06 and 200.02 or relieving the Contractor of his obligation to furnish and install a finished functional product that conforms to the requirements of the Contract. If a statistical comparative analysis of the Contractor's test results and the Department's monitor test results indicates a statistically significant difference in the results and either of the results indicates that the material does not conform to the volumetric and asphalt cement content requirements, an investigation will be made to determine the reason for the difference. If it is determined that the material does not conform to the requirement of the Contract, price adjustments will be made in accordance with Section 211.09.

Acceptance for Marshall volumetrics properties and asphalt cement content will be based on the Quality Index (QI) calculated using the results of four tests performed on samples taken in a stratified random manner from each 2,000 ton lot (4000 ton lots may be used when the normal daily production of the source from which the material is being obtained is in excess of 2,000 tons). Calculations to determine pay factors for a lot will normally be based on test results of 4 samples (n=4). When the sample size is less than n=4, the following procedure will be used

If the sample size obtained from a lot is n=3, the PWL will be determined based on the Quality Index computed from the average and standard deviation of the 3 samples and the corresponding PWL table for n=3. If either one or two samples are obtained from a lot, these results will be combined with the previous lot, making the sample size either n=5 (based on the addition of one sample) or n=6 (based on the addition of two samples). Under either circumstance the PWL will be determined based on the Quality Index computed from the average and standard deviation and the corresponding table for n=5 or =6. If the Contractor elects to terminate a lot prior to obtaining 4 samples, he must immediately inform the Department. The Contractor may elect to remove and replace defective asphalt concrete representing all or a portion of a lot any time at his discretion.

Samples shall be obtained from the approximate center of randomly selected quadrants of truckloads of material. Any statistically acceptable method of randomization may be used to determine the time and location of the stratified random sample to be taken. The Department shall be advised of the method to be used prior to the beginning of production.

The QI uses both the average and standard deviation within each lot to estimate the population and determine the percentage of the lot within the specification limits (PWL). The Acceptable Quality Level (AQL) is that quality receiving 100% pay. The Rejectable Quality Level (RQL) is that quality requiring removal and replacement. The AQL has been established at 90 Percent Within Limits (PWL) and the RQL at 40 PWL.

All material in the lot that has a pay factor less than 66% (40 PWL) shall be rejected and removed from the road. For material with a pay factor greater than or equal to 66% that the contractor does not elect to remove and replace, the unit bid price shall be computed in accordance with Section 211.09.

The specification limits are shown in Table II-15.

TABLE II-15

Specification Limits for
Marshall Volumetrics (%) and Asphalt Content (%)

	lower spec. limit (LSL)	upper spec. limit (USL)
Voids in Mineral Aggregate (VMA)	target VMA(-0.7) (Table II-13)	
Voids in Total Mix (VTM)	target VTM(-1.2) (Table II-13)	target VTM(+1.2) (Table II-13)
Asphalt Content	JMF-0.3	JMF+0.3

PWL and pay factor are determined as follows:

1. Calculate the Q1 and Qu using the equations below:

$$Q_1 = \frac{\bar{X} - LSL}{s}$$

$$Q_u = \frac{USL - \bar{X}}{s}$$

Where:

Q_l is the lower Quality Index
Q_u is the upper Quality Index

$\bar{X}$ is the lot average
s is the lot standard deviation
LSL is the lower specification limit
USL is the upper specification limit

2. Use Q_l and Q_u to enter Tables II-16 (n=3,4,5 or 6), Estimation of Lot PWL, to determine the Lower Percent Within Limits (LPWL) and the Upper Percent Within Limits (UPWL). For VMA, that does not have an upper specification limit, use UPWL = 100.0%.

3. Calculate the Total Percent Within Limits (TPWL).

$$TPWL = (LPWL + UPWL) - 100.$$

4. If the TPWL is greater than 40 and less than 90, use the TPWL in the Pay Factors equation in Section 211.09 to determine the pay factor for the lot. The lowest value of TPWL calculated for VTM, VMA and asphalt content will be used to determine the pay factor.

5. If the TPWL is equal to or greater than 90, the Contractor shall be paid at 100% of the unit bid price.

6. If the TPWL is less than or equal to 40, the Contractor shall be required to remove and replace the materials represented by that lot.

Chemical extraction and gradation analyses shall be performed by the Department during the production of the approved job mixtures designed by the Marshall method. If the results of any extraction and gradation test fail to conform to the limits specified in Section 211.05, the Department may require that production be stopped until necessary corrective action is taken by the Contractor.

If a visual examination by the Engineer reveals that the material in any load or portion of the paved roadway is obviously contaminated or segregated, that load or portion of the paved roadway will be rejected without additional sampling or testing of the lot. If it is necessary to determine the volumetrics or nuclear asphalt content of the material in any load or portion of the paved roadway, samples will be taken and tested and the results will be compared to the requirements of the approved job-mix formula. The results obtained in the testing will apply only to the mixture in question.

TABLE II-16
ESTIMATION OF LOT PERCENT WITHIN LIMITS

Sample size = 3

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.28	50.55	50.83	51.10	51.38	51.65	51.93	52.21	52.48
0.1	52.76	53.04	53.31	53.59	53.87	54.15	54.42	54.70	54.98	55.26
0.2	55.54	55.82	56.10	56.38	56.66	56.95	57.23	57.51	57.80	58.08
0.3	58.37	58.65	58.94	59.23	59.51	59.80	60.09	60.38	60.67	60.97
0.4	61.26	61.55	61.85	62.15	62.44	62.74	63.04	63.34	63.65	63.95
0.5	64.25	64.56	64.87	65.18	65.49	65.80	66.12	66.43	66.75	67.07
0.6	67.39	67.72	68.04	68.37	68.70	69.03	69.37	69.70	70.04	70.39
0.7	70.73	71.08	71.43	71.78	72.14	72.50	72.87	73.24	73.61	73.98
0.8	74.36	74.75	75.14	75.53	75.93	76.33	76.74	77.16	77.58	78.01
0.9	78.45	78.89	79.34	79.81	80.27	80.75	81.25	81.75	82.26	82.79
1.0	83.33	83.89	84.47	85.07	85.69	86.34	87.02	87.73	88.49	89.29
1.1	90.16	91.11	92.18	93.40	94.92	97.13	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q, THE QUALITY INDEX. FOR Q VALUES LESS THAN ZERO, THE TABLE VALUE MUST BE SUBTRACTED FROM 100.

Sample Size =4

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.33	50.67	51.00	51.33	51.67	52.00	52.33	52.67	53.00
0.1	53.33	53.67	54.00	54.33	54.67	55.00	55.33	55.67	56.00	56.33
0.2	56.67	57.00	57.33	57.67	58.00	58.33	58.67	59.00	59.33	59.67
0.3	60.00	60.33	60.67	61.00	61.33	61.67	62.00	62.33	62.67	63.00
0.4	63.33	63.67	64.00	64.33	64.67	65.00	65.33	65.67	66.00	66.33
0.5	66.67	67.00	67.33	67.67	68.00	68.33	68.67	69.00	69.33	69.67
0.6	70.00	70.33	70.67	71.00	71.33	71.67	72.00	72.33	72.67	73.00
0.7	73.33	73.67	74.00	74.33	74.67	75.00	75.33	75.67	76.00	76.33
0.8	76.67	77.00	77.33	77.67	78.00	78.33	78.67	79.00	79.33	79.67
0.9	80.00	80.33	80.67	81.00	81.33	81.67	82.00	82.33	82.67	83.00
1.0	83.33	83.67	84.00	84.33	84.67	85.00	85.33	85.67	86.00	86.33
1.1	86.67	87.00	87.33	87.67	88.00	88.33	88.67	89.00	89.33	89.67
1.2	90.00	90.33	90.67	91.00	91.33	91.67	92.00	92.33	92.67	93.00
1.3	93.33	93.67	94.00	94.33	94.67	95.00	95.33	95.67	96.00	96.33
1.4	96.67	97.00	97.33	97.67	98.00	98.33	98.67	99.00	99.33	99.67
1.5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

VALUES IN BODY OF TABLE ARE ESTIMATES OF PERCENT WITHIN LIMITS CORRESPONDING TO SPECIFIC VALUES OF Q, THE QUALITY INDEX. FOR Q VALUES LESS THAN ZERO, THE TABLE VALUE MUST BE SUBTRACTED FROM 100.

Sample size = 5

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.36	50.71	51.07	51.42	51.78	52.13	52.49	52.85	53.20
0.1	53.56	53.91	54.27	54.62	54.98	55.33	55.69	56.04	56.39	56.75
0.2	57.10	57.46	57.81	58.16	58.52	58.87	59.22	59.57	59.92	60.28
0.3	60.63	60.98	61.33	61.68	62.03	62.38	62.72	63.07	63.42	63.77
0.4	64.12	64.46	64.81	65.15	65.50	65.84	66.19	66.53	66.87	67.22
0.5	67.56	67.90	68.24	68.58	68.92	69.26	69.60	69.94	70.27	70.61
0.6	70.95	71.28	71.61	71.95	72.28	72.61	72.94	73.27	73.60	73.93
0.7	74.26	74.59	74.91	75.24	75.56	75.89	76.21	76.53	76.85	77.17
0.8	77.49	77.81	78.13	78.44	78.76	79.07	79.38	79.69	80.00	80.31
0.9	80.62	80.93	81.23	81.54	81.84	82.14	82.45	82.74	83.04	83.34
1.0	83.64	83.93	84.22	84.52	84.81	85.09	85.38	85.67	85.95	86.24
1.1	86.52	86.80	87.07	87.35	87.63	87.90	88.17	88.44	88.71	88.98
1.2	89.24	89.50	89.77	90.03	90.28	90.54	90.79	91.04	91.29	91.54
1.3	91.79	92.03	92.27	92.51	92.75	92.98	93.21	93.44	93.67	93.90
1.4	94.12	94.34	94.56	94.77	94.98	95.19	95.40	95.61	95.81	96.01
1.5	96.20	96.39	96.58	96.77	96.95	97.13	97.31	97.48	97.65	97.81
1.6	97.97	98.13	98.28	98.43	98.58	98.72	98.85	98.98	99.11	99.23
1.7	99.34	99.45	99.55	99.64	99.73	99.81	99.88	99.94	99.98	100.00

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Sample size = 6

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	50.37	50.73	51.10	51.47	51.84	52.20	52.57	52.94	53.30
0.1	53.67	54.04	54.40	54.77	55.14	55.50	55.87	56.23	56.60	56.96
0.2	57.32	57.69	58.05	58.41	58.78	59.14	59.50	59.86	60.22	60.58
0.3	60.94	61.30	61.66	62.02	62.38	62.73	63.09	63.45	63.80	64.16
0.4	64.51	64.86	65.21	65.57	65.92	66.27	66.62	66.96	67.31	67.66
0.5	68.00	68.35	68.69	69.04	69.38	69.72	70.06	70.40	70.74	71.07
0.6	71.41	71.75	72.08	72.41	72.74	73.08	73.40	73.73	74.06	74.39
0.7	74.71	75.04	75.36	75.68	76.00	76.32	76.63	76.95	77.26	77.58
0.8	77.89	78.20	78.51	78.82	79.12	79.43	79.73	80.03	80.33	80.63
0.9	80.93	81.22	81.51	81.81	82.10	82.39	82.67	82.96	83.24	83.52
1.0	83.80	84.08	84.36	84.63	84.91	85.18	85.45	85.71	85.98	86.24
1.1	86.50	86.76	87.02	87.28	87.53	87.78	88.03	88.28	88.53	88.77
1.2	89.01	89.25	89.49	89.72	89.96	90.19	90.42	90.64	90.87	91.09
1.3	91.31	91.52	91.74	91.95	92.16	92.37	92.58	92.78	92.98	93.18
1.4	93.37	93.57	93.76	93.95	94.13	94.32	94.50	94.67	94.85	95.02
1.5	95.19	95.36	95.53	95.69	95.85	96.00	96.16	96.31	96.46	96.60
1.6	96.75	96.89	97.03	97.16	97.29	97.42	97.55	97.67	97.79	97.91
1.7	98.02	98.13	98.24	98.34	98.45	98.55	98.64	98.73	98.82	98.91
1.8	98.99	99.07	99.15	99.22	99.29	99.36	99.43	99.49	99.54	99.60
1.9	99.65	99.70	99.74	99.78	99.82	99.85	99.88	99.91	99.93	99.95
2.0	99.97	99.98	99.99	100.00	100.00	100.00	100.00	100.00	100.00	100.00

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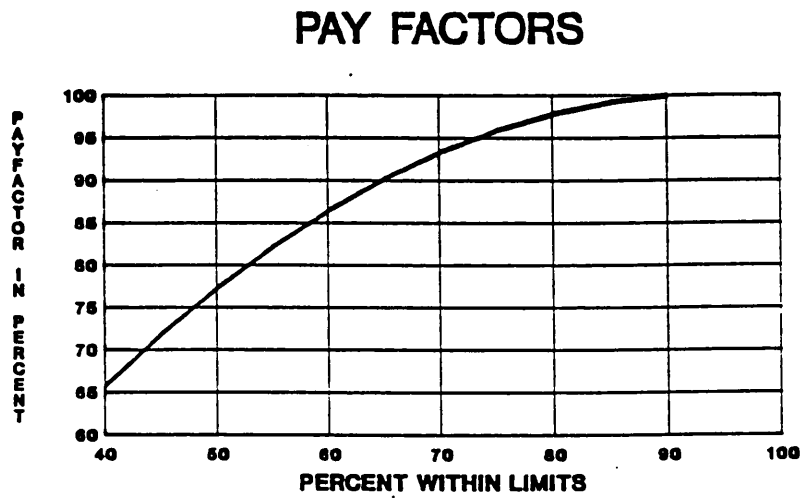
211.09 - Pay Factors

Payment for Asphalt Concrete conforming to the requirements of Section 211.07 will be calculated as follows:



Pay Factor = -0.01168x^2 + 2.2039x - 3.716

x = Percent Within Limits

211.10 - Referee System

In the event the test results obtained for any of the samples taken to evaluate a particular lot appear to be questionable, the contractor or Engineer may request the Referee System. The accuracy of the test results on the questionable samples shall be determined by testing split samples of the samples in question that have been retained by the Contractor. In the event that split samples have not been retained, testing shall be conducted on the samples taken from randomly selected locations in the road within the sublots that had the questionable results. An independent testing laboratory shall perform the testing. The unquestioned results from the plant, if any, and the results from the questionable sublots shall be used to compute a new pay factor. Payment of the independent testing firm shall be the responsibility of the Department when the overall pay factor of the lot increases as a result of the referee testing. In the event the pay factor remains the same or decreases, the Contractor shall pay for the independent testing. When additional samples must be obtained from the roadway for referee testing, samples of the size shown herein shall be saw cut by the Contractor, without the use of liquids, for testing.

nominal max. size aggregate sieve size (in.)	minimum size of sample
3/8", 1/2", 3/4"	40 lbs.
1", 1 1/2"	70 lbs.

EXAMPLE OF DETERMINING PAY FACTOR

The following example is provided to show the effect on TPWL when Q is both positive and negative. A negative Q value indicates that the lot average of the property is outside the specification limits. If the Contractor is performing quality control testing and reacting to them in a timely manner, negative Q values should not occur.

VTM

JMF = 4.5% LSL = 3.3% USL = 5.7%

n = 4 $\bar{X}$ = 5.1 s = 1.11

$Q1 = \frac{5.1 - 3.3}{1.11} = 1.62$ LPWL = 100.0

$Qu = \frac{5.7 - 5.1}{1.11} = 0.54$ UPWL = 68.00

TPWL = (LPWL - UPWL) - 100 = (100.00 + 68.0) - 100 = 68.0%

VMA

JMF = 15.2 LSL = 14.5 no USL

n= 4 $\bar{X}$ = 14.4 s = 0.8

$QL = \frac{14.4 - 14.5}{0.8} = -0.125$ LPWL = (100.0 - 54.17) = 45.83

UPWL = 100.0 (assumed)

TPWL = (100.00 + 45.83) - 100 = 45.83%

ASPHALT CONTENT

JMF = 5.8% LSL = 5.5 USL = 6.1

n = 4 $\bar{X}$ = 5.6 s = 0.28

$Q1 = \frac{5.6 - 5.5}{0.28} = .35$ LPWL = 61.67

$Qu = \frac{6.1 - 5.6}{0.28} = 1.79$ UPWL = 100.00

TPWL = (61.67 - 100.00) - 100 = 61.67%

PWL for VMA is lowest TPWL (45.83), therefore is used in Pay Factor Equation.

Pay Factor = $-.01168\ x^2 + 2.2039x - 3.716$
$= -.01168(45.83)^2 + 2.2039(45.83) - 3.716$

Pay factor = 72.76%

SECTION 211.11 HANDLING AND STORING AGGREGATES - Aggregates shall be handled, hauled and stored in a manner which will minimize segregation and avoid contamination. Aggregates shall be stockpiled in the vicinity of the plant and on ground that is denuded of vegetation, hard and well drained, or otherwise prepared to protect the aggregate from contamination. Placing aggregate directly from the crusher bins into the cold feed may be permitted, provided the material is consistent in gradation. When different size aggregates are stockpiled, the stockpiles shall be positively separated.

SECTION 211.12 ASPHALT CONCRETE MIXING PLANT - Plants used for the preparation of asphalt concrete mixtures shall conform to the following requirements:

(a) Plant Scales - Scales shall be approved in accordance with the requirements of Section 109.01 of the Specifications.

(b) Drier - The plant shall include a drier or driers which continuously agitate the aggregate during the heating and drying process. The aggregate shall be dried to a point at which the moisture content of the completed mixture does not exceed 1 percent as determined from samples taken at the point of discharge from the mixing operation.

(c) Feeder for Drier - The plant shall be equipped with accurate mechanical means for uniformly feeding the aggregate into the drier so that uniform production and uniform temperature will be obtained. Where different size aggregates are required to meet grading specifications, they must be proportioned by feeding into the cold elevator through a multiple compartment feeder bin (one bin for each size used) equipped with positive action gates that can be securely locked to maintain desired proportioning.

(d) Bins - When bins are used, adequate and convenient facilities shall be provided to make possible the sampling of representative aggregate material for each bin. Each compartment shall be provided with an overflow pipe of such size and at such location to prevent contamination of the aggregate in adjacent compartments and shall be provided with individual outlet gates which, when closed, will allow no leakage.

(e) **Thermometric Equipment** - The plant shall be equipped with an approved thermometric instrument so placed at the discharge chute of the drier as to register automatically or indicate the temperature of the heated aggregate or the completed mix if the drier drum mixing plant is used.

An approved thermometric device shall be fixed in the asphalt feed line at a suitable location near the charging valve at the mixer unit.

All thermometric devices shall be maintained in good working condition and shall be subject to checking against the laboratory thermometer. Any instrument which does not operate or register properly shall be removed and repaired or replaced.

(f) **Pollution Control** shall conform to Section 107.14 of the Specifications.

(g) **Equipment for Preparation of Asphalt Material** - Tanks for the storage of asphalt material shall be equipped with a heating system capable of heating and holding the material at the required temperatures. The heating system shall be designed to heat the contents of the tank by means of steam, electricity or other approved means so that no flame is in contact with the heating surface of the tank. The circulating system for the asphalt material shall be designed to assure proper and continuous circulation during the operating period and to minimize oxidation. All pipe lines shall be steam jacketed or insulated to prevent undue loss of heat. Storage facilities for asphalt material shall be sufficient for at least one day's operation or an equivalent means of supply shall be provided which will insure continuous operation. Provision shall be made for measuring and sampling storage tanks. When asphalt material is proportioned by volume, the temperature of the asphalt material in storage shall be maintained uniform ($\pm$20°F) during operation of the plant by means of an approved automatic temperature control device.

(h) **Asphalt Control** - Asphalt material shall be accurately proportioned by volume or weight. When volumetric methods are used, measurements shall be made by means of approved meters or pumps, calibrated for accuracy. The section of the asphalt line between the charging valve and the spray bar shall be provided with an outlet valve for checking the meter.
When proportioned by weight, the asphalt material shall be weighed on approved scales. Dial scales shall have a

capacity of not more than 15 percent of the capacity of the mixer. The value of the minimum graduation shall not be greater than 2 pounds.

Except when drier-drum mixing plant is used, the asphalt material bucket, its valves and spray bar shall be steam jacketed or heated by other approved means. The bucket shall have a capacity of at least 115 percent of the weight of the asphalt material required in any mixture and shall be supported by fulcrums.

The asphalt shall be delivered to the mixer in uniform, multiple streams for the full width of the mixer.

(i) **Proportioning Aggregates** - Mineral filler and any bag house fines the Contractor uses shall be metered or introduced by means of an approved device for uniform proportioning by weight or by volume.

The weigh hopper shall be of sufficient size to hold the maximum required weight of aggregate for one batch without hand raking or running over. Sufficient clearance between the weigh hopper and supporting devices shall be provided to prevent accumulation of foreign materials.

The discharge gate of the weigh hopper shall be situated in such a manner that the aggregates will not segregate when dumped into the mixer. Gates on the bins and weigh hopper shall be constructed to prevent leakage when closed.

(j) **Drum Mixer** - The aggregate shall be proportioned by a positive weight control at the cold aggregate feed by use of a belt scale which will automatically regulate the supply of material being fed and permit instant correction of variations in load. The cold feed flow shall be automatically coupled with the asphalt flow to maintain the required proportions.

(k) **Batch Mixer** - The batch mixer shall be of a twin pugmill or other approved type, steam jacketed or heated by other approved means and capable of producing uniform mixtures within the specified tolerances. It shall be equipped with a sufficient number of paddles or blades, operated at such speeds as to produce a properly and uniformly mixed batch. The number and arrangement of the mixer paddles shall be subject to the approval of the Engineer. Badly worn or defective blades shall not be used in mixing operations.

The mixer shall be provided with an approved time lock which will lock the discharge gate after the aggregates and asphalt have been placed in mixer and will not release the gate until the specified time has elapsed.

Batch type mixing plants used to produce asphalt concrete shall be equipped with approved automatic proportioning devices. Such devices shall include equipment for accurately proportioning batches of the various components of the mixture by weight or volume in the proper sequence and for controlling the sequence and timing of mixing operations. The automated system shall be designed to interrupt and stop the batching operation at any time batch quantities are not satisfied for each of the materials. A means shall be provided for observing the weight of each material during the batching operation.

The aggregate may be proportioned by cold feed controls in lieu of plant screens provided the cold aggregate feed meets all the requirements specified in Section 211.12(j). Should the automatic proportioning devices become inoperative, the plant may be allowed to batch and mix asphalt materials for a period of not more than 48 hours from the time the breakdown occurs provided alternate proportioning facilities are approved by the Engineer. Written permission of the Engineer will be required for operation without automatic proportioning facilities for periods longer than 48 hours.

(1) **Continuous Mixing Plant** - Continuous mixing plant shall include a means for accurately proportioning each size of aggregate either by weighing or volumetric measurement. When gradation control is by volume, the unit shall include a feeder mounted under the compartment bins. Each bin shall have an accurately controlled individual gate to form an orifice for volumetrically measuring the material drawn from each respective bin compartment. The orifice shall be rectangular, with one dimension adjustable by positive mechanical means and shall be provided with a lock. Indicators shall be provided to show the individual gate opening in inches. The plant shall be equipped with a satisfactory revolution counter.

The plant shall include a means for calibrating gate openings by weight. The materials fed out of the bins through individual orifices shall be bypassed to a suitable test box, with each component material confined in a separate section. The plant shall be equipped to conveniently handle test samples weighing up to 200 pounds per bin and accurate platform scales shall be provided for this purpose.

Positive interlocking control shall be provided between the flow of aggregate from the bins and the flow of asphalt material from the meter or other proportioning device. This shall be accomplished by approved interlocking devices or other approved positive means.

Accurate control of the asphalt material shall be obtained by weighing, metering or volumetric measurement.

The aggregate may be proportioned by cold feed controls in lieu of plant screens provided the cold aggregate feed meets all the requirements specified in Section 211.12(j).

The plant shall include a continuous mixer of an approved type which is steam jacketed or heated by other approved means. The paddles shall be of any adjustable type for angular position on the shafts and reversible to retard the flow of the mixture.

There shall be interlock cutoff circuits to interrupt and to stop the proportioning and mixing operations when the aggregate level in the plant or the asphalt material in storage fall below that necessary to produce the specified mixture.

(m) Trucks, Truck Scales, and Automatic Printer System shall conform to Section 109.01 of the Specifications.

SECTION 211.13 PREPARATION OF MIXTURE - The asphalt and aggregate shall be introduced into the mixer at a temperature that will produce a mixture within the requirements of the job-mix formula; however, in no case shall the temperature of the asphalt material exceed 350°F at the time of introduction into the mixer.

After the required amounts of aggregate and asphalt material have been introduced into the mixer, the materials shall be mixed until a uniform coating of asphalt and a thorough distribution of the aggregate throughout the mixture is secured within the requirements of the Ross Count procedure described in AASHTO T195. Wet mixing time, based on the procedures of AASHTO T195, shall be determined by the Contractor at the beginning of production and approved by the Engineer for each individual plant or mixer and for each type of aggregate used; however, in no case shall the wet mixing time be less than 20 seconds. The wet mixing time is the interval of time between the start of introduction of the asphalt material into the mixer and the opening of the discharge gate. A wet mixing time which will result in fully coating a minimum of 95 percent of the coarse particles, based on the average of the 3 samples, and provided that none of the 3 samples result in fully coating less than 92 percent of the coarse particles, shall be the minimum wet mixing time requirement. A dry mixing

time of up to 15 seconds may be required by the Engineer to accomplish the degree of aggregate distribution necessary to obtain complete and uniform coating of the aggregate with asphalt.

During production of asphalt concrete, the quality control extraction and aggregate gradation test results will be used to determine the F/A ratio. If the F/A representing the first lot exceeds the specified minimum or maximum F/A ratio, the Contractor shall take corrective action. If test results from subsequent lots exceed the specified F/A ratio, the Contractor shall cease production until changes have been made to comply with the approved mix design requirements.

SECTION 211.14 STORAGE SYSTEM - In the event the Contractor elects to use a storage system, the system shall be capable of conveying the mix from the plant to the storage bins and storing the mix without a loss in temperature, segregation or oxidation of the mix. Storage time shall be limited by the ability of the bins to maintain the mix within the quality requirements specified herein with a maximum time limit not to exceed 10 days. Material may be stored in bins for no more than 24 hours without an approved heating system.

The conveyer system may be a continuous type or skip bucket type. Continuous type conveyers shall be enclosed so that the mix temperature is maintained.

The storage bins shall be designed in such a manner as to prevent segregation of the mix during discharge from the conveyer into the bins and shall be equipped with discharge gates that will not cause segregation of the mix while loading the mix into the trucks.

Approval for the use of storage bins may be withdrawn by the Engineer in the event there is an excessive amount of heat loss, segregation or oxidation of the mix.