

**OKLAHOMA DEPARTMENT OF TRANSPORTATION SPECIAL PROVISIONS
FOR
PERCENT WITHIN LIMITS (PWL)
ACCEPTANCE PROCEDURES FOR ASPHALT CONCRETE PAVEMENTS**

These Special Provisions revise, amend, and where in conflict, supersede applicable sections of the 2009 Standard Specifications for Highway Construction, English and Metric.

411.01 DESCRIPTION *(Add the following:)*

Percent within limits (PWL) will apply to permanent pavements as herein specified for acceptance procedures for asphalt pavements.

411.04 CONSTRUCTION METHODS

N. Mix Properties

(2) Acceptance *(Replace with the following:)*

While the Contractor shall be fully and exclusively responsible for producing an acceptable product, acceptance responsibility rests with the Engineer. The entire lot of asphalt as defined in Subsection 411.04.N(2)(f), "Lot and Sublot Selection" will be accepted or rejected and paid for on the basis of acceptance test results. The Engineer will make the test results available to the Contractor within 48 hours of sampling the material. Pay factors will be determined using the Department's common asphalt program for PWL lots (<http://www.odot.org/materials/comnasphss.htm>).

(a) General

The following characteristics will be considered when determining the acceptability and pay factors for plant mixed asphalt concrete pavement.

- Roadway Density
- Air Voids
- Asphalt Cement Content
- Voids in the Mineral Aggregate (VMA)

All of the requirements of the Standard Specifications on materials and workmanship, except those superseded by Special Provisions in this Contract, will remain in effect.

(b) Criteria for Lot Acceptance and Payment

Conformance with these specifications will be judged on the basis of the estimated PWL with respect to roadway density, air voids, asphalt cement content, and VMA. The PWL with respect to a particular quality characteristic is the amount of materials and construction which

falls within the specified limits listed in the following tables (where “JMF” refers to the corresponding values from the Job Mix Formula):

Table 411:3A Upper and Lower Limits for Density, Air Voids, AC Content, and VMA		
Characteristic	Lower Specification Limit (LSL)	Upper Specification Limit (USL)
Roadway Density	JMF ¹ - 2.00%	JMF ¹ + 3.00%
Air Voids (lab molded)	JMF ¹ - 1.35%	JMF ¹ + 1.35%
Asphalt Cement Content	JMF - 0.40%	JMF + 0.40%
VMA	JMF - 0.50%	JMF + 3.00%

¹ JMF for roadway density for Superpave mixtures is typically 94. Other JMF's are shown on the mix design.

(c) Acceptable and Rejectable Quality Levels

A lot is considered to be of acceptable quality with respect to a particular characteristic if the PWL is no less than 90 percent. A lot is considered to be of rejectable quality with respect to a particular characteristic if the PWL is less than 50 percent. Lots exceeding the acceptable quality level will be considered for positive pay adjustments as defined in Subsections 411.06.A and 411.06.B. Lots exceeding the rejectable quality level, but falling below the acceptable quality level, will be considered for negative pay adjustments as defined in Subsections 411.06.A and 411.06.B. If a lot fails to exceed the rejectable quality level in one or more characteristics, the Engineer may require its removal and replacement at the Contractor’s expense. If this option is not exercised the Contractor may elect to remove and replace the lot at no additional cost to the Department, or leave the lot in place subject to pay factors in accordance with Subsections 411.06.A and 411.06.B.

(d) Determination of PWL

The PWL with respect to each of the characteristics of roadway density, air voids, asphalt cement content, and VMA will be determined by ODOT software/spreadsheets. A detailed description of the PWL computation(s) can be reviewed on the ODOT website (<http://www.odot.org/materials/comnasphss.htm>) and Appendix A of this special provision.

(e) Extreme Values (Outliers)

Test results that appear to be inconsistent with the results of the majority of tests will also be closely examined by the Engineer in order to determine their validity. The examination will cover the procedures used in sampling and testing, and if necessary, a mathematical analysis performed in accordance with ASTM E 178 (upper 2.5% significance level). Test results determined to be outliers may be discarded by the Engineer if it is deemed that the outlier is not

representative of the material being evaluated. The remaining test results will then be supplemented if necessary. (Example computations are shown in Appendix D.)

(f) Lot and Sublot Selection

The asphalt concrete will be randomly sampled and tested for all control test characteristics on a lot-to-lot basis. Any load of mixture which is visually unacceptable due to excessive segregation, or improper aggregate coating will be rejected for use in the work. Furthermore, sections of completed pavement which, from visual observation or known deficiencies, appear to be seriously inadequate will be tested. The results of such tests will not be used for pay adjustment purposes, but will be used to determine whether the section is totally unacceptable and must be removed. In the event that it is determined to be unacceptable, remove and replace the section at no additional cost to the Department.

A standard size lot at the asphalt plant consist of four (4) equal sublots of 1,000 tons [metric tons] each. Subject to prior notification, the Contractor may reduce the lot size to 2,750 tons [metric tons] or increase the lot size to 6,250 tons [metric tons]. When a lot contains two (2) or less sublots, combine the lot with the previous or next lot. When time delays of seven (7) or more calendar days occur, and less than 2,750 tons were laid, the standard 1,000 ton lot spreadsheets on the ODOT website may be used. No bonus would apply.

On a Contract with multiple (tied) projects, the lots of the asphalt may carry over from project to project within the same Contract. All acceptance testing shall be performed at a random location or time interval within each sublot in accordance with OHD L-56.

Once a lot has been defined, maintain its identity throughout the mixing and placement process.

(g) Engineer's Acceptance Procedures

As a minimum, comply with the following schedule for sampling and testing (Table 411:5).

Table 411:5 Sampling and Testing Schedule	
Quality Characteristic	Frequency
Roadway Density	Three (3) specimens per sublot randomly selected and considered as one (1) test.
Air voids (NMS mixes)	One (1) test per sublot randomly selected. Two (2) specimens shall be averaged and considered as one (1) test.
Asphalt Cement Content and Gradation	One (1) specimen randomly selected per sublot.

Table 411:5 Sampling and Testing Schedule	
Quality Characteristic	Frequency
VMA (except NMS mixes)	One (1) test per subplot randomly selected. Two (2) specimens shall be averaged and considered as one (1) test.

(h) Plant Startup Requirements

See Subsection 411.04.C of the Standard Specifications.

(i) Control Strip Requirements

See Subsection 411.04.D of the Standard Specifications.

(j) Conflicts Between Engineer's and Contractor's Test Results

Since the Engineer's test results will be used to determine pay factors, the Contractor is encouraged to compare test procedures and results with the Engineer throughout the duration of the Contract.

In the event that any of the Engineer's test results are determined to be incorrect, the incorrect results will be discarded. The remaining results will be used for pay adjustment purposes, taking into account the increased allowable average deviations resulting from the decrease in number of test results. If the remaining test results are too few to represent the material being evaluated, the Engineer may test additional samples.

If the differences between the Engineer and the Contractor test results cannot be resolved, the Contractor may request referee testing by the Department's Materials & Research Division. Submit such request(s) in writing to the Engineer within fifteen (15) days after testing is complete for the lot and results have been shared with the Contractor. Such testing will be independent from any previous testing by either the Engineer or the Contractor, and the results shall be considered final. Should the referee testing result in a higher combined pay factor for the lot, the additional testing costs will be absorbed by the Department. Otherwise, the entire cost, including administrative costs, shall be borne by the Contractor.

411.06 BASIS OF PAYMENT *(Add the following:)*

A. Pay Factors for Lot Quality Characteristics (PWL)

If *PWL* is greater than or equal to 50 percent, compute the pay factor (*PF*) for each quality characteristic using the equation:

$$PF = 0.024 \times (PWL) - 0.0001 \times (PWL)^2 - 0.35$$

If the *PWL* is less than 50 percent, and the Engineer does not require removal and replacement of the lot, the lot may be left in place subject to a pay factor of zero for the respective quality characteristic (Subsection 411.04.N(c)).

B. Pay Adjustment for Lots

When a lot is completed, the individual pay factors for roadway density, air voids, asphalt content, and VMA will be used to calculate a combined pay factor and a pay adjustment for the subject lot as follows:

$$CPF = \frac{4PF_D + 3PF_V + 2PF_A + PF_{VMA}}{10}$$

where:

- CPF* = Combined pay factor
- PF_D* = Pay factor for roadway density,
- PF_V* = Pay factor for air voids,
- PF_A* = Pay factor for asphalt content, and
- PF_{VMA}* = Pay factor for voids in the mineral aggregate.

The pay adjustment for the completed lot will be determined in accordance with the following formula:

$$PA_{Lot} = (CPF-1) \times CUP \times Q_{Lot}$$

where:

- PA_{Lot}* = Pay adjustment for the lot,
- CPF* = Combined pay factor,
- CUP* = Contract unit price (\$/Ton [\$/Metric Ton]), and
- Q_{Lot}* = Quantity of asphalt concrete in the lot (Tons [Metric Tons])

APPENDIX A
DETERMINATION OF PERCENT WITHIN LIMITS (PWL)

The percent within limits (PWL) with respect to roadway density, air voids, asphalt content, and VMA will be determined by the PWL program located on the Department website (<http://www.odot.org/materials/comnasphss.htm>). This Appendix includes an example of the computations used in the PWL program. With regard to rounding, the values shown in the PWL program shall be used.

STEP 1

Compute the sample mean (\bar{X}) and the sample standard deviation (S') of the test results (X_i):

$$\bar{X} = \frac{\sum X_i}{n} \quad \text{Equation 411:1}$$

$$S' = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n-1}} \quad \text{Equation 411:2}$$

STEP 2

Using the sample standard deviation (S''), compute the upper quality index (Q_U) and the lower quality index (Q_L) corresponding to the upper and lower specification limits listed in Table 411:3A. Round the quality index to two (2) decimal places.

$$Q_U = \frac{USL - \bar{X}}{S''} \quad \text{Equation 411:3}$$

$$Q_L = \frac{\bar{X} - LSL}{S''} \quad \text{Equation 411:4}$$

STEP 3

Compute the percent within limits using the quality index and number of tests (n) as shown in Table 411:6 for a lot size of four (4) sublots.

Table 411:6	
Sublot	n, Density, Air Voids, Asphalt Cement Content, VMA
1	-
2	-
3	3
4	4
5	5
6	6

Use the appropriate percent defective tables (Appendix B) for the sample size to determine the percentage of materials and construction falling outside the specification limits PD_U and PD_L associated with Q_U and Q_L , respectively. Add these two values to obtain the lot percent defective (PD):

$$PD = PD_U + PD_L \qquad \text{Equation 411:5}$$

STEP 6

Determine the percentage of materials and construction falling within the specification limits PWL as follows:

$$PWL = 100 - PD \qquad \text{Equation 411:6}$$

APPENDIX C PAY FACTOR COMPUTATIONS

The formulas and precision used in the latest version of the PWL (411-9QA) common asphalt file located at, <http://www.odot.org/materials/comnasphss.htm>, will govern. Example computational steps follow which show how the file is used and the intermediate steps it performs. These steps can be used to calculate the results using a simple handheld calculator except for the betadist() function. Betadist() values, or pay deduction (PD) values, are also shown in Appendix A for information.

STEP 1

Given the following example data from the “Pay Factors” worksheet:

DESIGN		SUBLOT 1	SUBLOT 2	SUBLOT 3	SUBLOT 4	SUBLOT 5	SUBLOT 6	PFs	Reason to Waive PF
SIEVE SIZE	JMF	Test Result	Test Result	Test Result	Test Result	Test Result	Test Result		
1"	100	100	100	100	100				
3/4"	100	100	100	100	100				
1/2"	98	99	98	97	99				
3/8"	90	92	90	89	92				
No. 4	57	58	57	55	60				
No. 8	38	37	37	35	40				
No. 16	26	25	25	24	28				
No. 30	19	18	19	18	21				
No. 50	13	12	13	12	14				
No. 100	7	7	7	7	8				
No. 200	4.8	4.4	4.9	4.6	5.4				
% AC	5.0	5.0	5.2	4.7	5.3			1.02	
% VMA	14.0	14.5	14.5	14.9	14.3			1.05	
% Air Voids	4.0	3.9	3.4	5.1	2.8			0.99	
PG _{min} Core 1		92.3	92.0	93.2	92.5				
PG _{min} Core 2		94.0	93.0	91.9	93.7				
PG _{min} Core 3		93.0	92.1	92.4	93.9				
Avg. PG _{min}	94.0	93.1	92.4	92.5	93.4			1.05	
Final PFs	PG _{min}	1.05	% Air Voids	0.99	% AC	1.02	VMA	1.05	
CPF	1.03	CUP	\$63.81		Pay Adjustment on Lot	\$7,657.20			

STEP 2

Information about the % AC (percent asphalt cement) pay factor:

The formula used in the Excel file to obtain the pay factor of 1.02 is:

$$=IFERROR(PF\text{old}PWL(C25, D25: I25, 0.4, -0.4, 0.16, -0.16),)$$

Substituting numbers in this example:

= IFERROR(PFoldPWL(5.0, {5.0, 5.2, 4.7, 5.3, 0, 0}, .04, -0.4, 0.16, -0.16), "")

PFoldPWL() is a UDF (User-Defined Function). As with any Excel built-in formula, a UDF can show the input parameters and values by selecting that cell, click in the UDF in the formula toolbar and pressing the key combination Shift+F3 or click the fx icon button on the ribbon. If the file was unlocked, you could see this below. One would scroll the dialog to see other input parameters and their values.



where:

- RJMF = Required Job-Mix Formula for percent roadway density in this case,
- RResults = Set average percent roadway density values for all six (6) sublots,
- US = USL offset from JMF,
- LS = LSL offset from JMF,
- UT = UTL offset from JMF,
- LT = LTL offset from JMF, and
- tfDebug = True or false to show.

The optional tfDebug parameter value is set to True for Department programmers to view the intermediate computational results and False otherwise. Results for each of those intermediate steps and results are what will make up the bulk of what is detailed in the following steps for the asphalt cement pay factor only.

The Department will not unlock the Excel file so viewing the dialog above is not possible. The Department will share UDF's in this file if requested though they are subject to change without notice. They will be

included in the latest version as explained earlier. This formula and others have the specifications (spec) and target limits hard coded but shown in the input parameter values which can be viewed in the formula bar. If an error is observed, please contact the Department promptly.

STEP 3

Compute the mean (\bar{X}) using Equation 411:1.

$$\bar{X} = \frac{\sum X_i}{n}$$

$$\frac{(3.0 + 3.82 + 4.2 + 3.0)}{4} = 3.500 = 3.5$$

Note: $n = 4$ because there are only four sublots in the example data, the usual lot size.

STEP 4

Compute the sample standard deviation using Equation 411:2.

$$S' = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n-1}}$$

$$S' = \sqrt{\frac{(3.0 - 3.5)^2 + (3.8 - 3.5)^2 + (4.2 - 3.5)^2 + (3.0 - 3.5)^2}{4 - 1}}$$

$$S' = \sqrt{0.36} = 0.6000000000000000 = 0.6$$

(rounding varies by calculator)

STEP 5

Compute the USL and LSL.

$$USL = JMF + Offset \rightarrow 4 + (1.35) = 5.35$$

$$LSL = JMF + Offset \rightarrow 4 + (-1.35) = 2.65$$

STEP 6

Compute upper and lower quality index values, Q_U and Q_L . Use Equations 411:3 and 411:4.

$$Q_U = \frac{USL - \bar{X}}{S''} = \frac{535 - 35}{0.6} \approx 3.08$$

$$Q_L = \frac{\bar{X} - LSL}{S''} = \frac{35 - 2.65}{0.6} \approx 1.42$$

STEP 7

Compute and sum the pay deductions for the upper and lower quality index values and number of samples (sublots) using Equation 411:5.

$$PD = PD_U + PD_L$$

The tables provided in Appendix B can be used for quick calculations of the pay deductions with a calculator. The Excel formula that determines those pay deductions values (PD_U and PD_L) are of the form:

$$=Round(BetaDist(0.5 - Q * N ^ 0.5 / (2 * (N - 1)), N / 2 - 1, N / 2 - 1) * 100, dp)$$

where:

- Q = upper or lower quality index,
- N = number of samples (sublots), and
- dp = number decimal places to round (2).

When calculating the pay deductions more simply, the tables in Appendix B are used with the following input parameters. Lookup the pay deduction value using the input parameters previously computed. The values are rounded to two decimal places to make table lookup easier.

For n = 4 table in Appendix B:

$$PD_U(Q_U, n) \rightarrow PD_U(3.08, 4) \rightarrow 0.00$$

Note that the table and betadist(), when $Q \geq 1.50$, pay deductions values equal 0.

$$PD_L(Q_L, n) \rightarrow (1.42, 4) \rightarrow 2.67$$

$$\therefore PD = PD_U + PD_L \rightarrow 0.00 + 2.67 = 2.67$$

STEP 8

Compute the percent within limits (*PWL*) using Equation 411:6.

$$PWL = 100 - PD \rightarrow 100 - 2.67 = 97.33$$

STEP 9

Compute the pay factor for the lot's quality characteristic PG_{mm} . If the *PWL* found in STEP 8 was less than 50 percent, the pay factor equals 0.00. Since it is not in this example, use Equation 411:7.

$$PF = 0.024(PWL) - 0.0001(PWL)^2 - 0.35 \quad \text{Equation 411:7}$$

$$PF = 0.024(97.33) - 0.0001(97.33)^2 - 0.35$$

$$PF = 2.33592 - 0.0001(9473.1289) - 0.35$$

$$PF = 2.2581 - 0.94731289 - 0.35$$

$$PF = 1.38860711 - 0.35$$

$$PF = 1.03860711 \rightarrow 1.04$$

STEP 10

Compute the composite or combined pay factor using Equation 411:8 below.

$$(\text{Pay Factors: } PF_D = 1.05, PF_V = 1.04, PF_A = 1.05, PF_{VMA} = 1.05) \quad \text{Equation 411:8}$$

$$CPF = \frac{4PF_D + 3PF_V + 2PF_A + PF_{VMA}}{10}$$

$$CPF = \frac{4(1.05) + 3(1.04) + 2(1.05) + 1.05}{10}$$

$$CPF = \frac{4.2 + 3.12 + 2.1 + 1.05}{10}$$

$$CPF = \frac{10.47}{10} = 1.047 \rightarrow 1.05$$

STEP 11

Compute the pay adjustment for the lot using Equation 411:9.

The contract unit price shown in STEP 1 is \$63.81. The tons in this lot is 4,000.00.

$$PA_{Lot} = (CPF - 1)(CUP)(Q_{Lot})$$

Equation 411:9

$$PA_{Lot} = (1.05 - 1)(\$63.81)(4,000)$$

$$PA_{Lot} = (0.05)(\$63.81)(4,000)$$

$$PA_{Lot} = \$12,762.00$$

A negative value or a value with ()'s around it (accounting notation), is the deduction required for the pay adjustment for the lot. A positive value for the pay adjustment is a bonus.

APPENDIX D OUTLIER COMPUTATIONS

The following example uses data from Appendix C. The Excel file can mark and unmark outliers in a magenta color with a simple click of a button on the “Pay Factors” worksheet.

STEP 1

Evaluate each of the four quality characteristics based on the summary of pay factor results for the number of sublots in the lot. A minimum of three (3) to a maximum of six (6) sublots are required per lot. In this example, only % Air Voids is evaluated.

STEP 2

Determine the number (n) of sublots in the lot, number of samples, or number of observations.

$$n = 4$$

STEP 3

Compute the mean (\bar{X}) of the % Air Voids results using Equation 411:1.

$$\bar{X} = 5.05$$

STEP 4

Compute the sample standard deviation using Equation 411:2.

$$S' = 0.6000000000000000, \text{ or}$$

$$S' = 0.6$$

STEP 5

Compute the test criterion (T_n) for each of the % Air Voids values.

Since the value could fall on either side of the mean, this formula can be used.

$$T_n = \left| \frac{(x_i - \bar{X})}{S'} \right|$$

Equation 411:10

where:

x_i = the individual sample result, and
 T_n = test criterion number for one sample.

For each % Air Voids 3.0, 3.8, 4.2, and 3.0 (only need to calculate once).

$$T_n = \left| \frac{(3.0 - 3.5)}{0.6} \right| = \left| \frac{-0.5}{0.6} \right| \approx |-0.8333333333333333| \approx 0.833$$

$$T_n = \left| \frac{(3.8 - 3.5)}{0.6} \right| = \left| \frac{0.3}{0.6} \right| \approx |0.5000000000| \approx 0.5$$

$$T_n = \left| \frac{(4.2 - 3.5)}{0.6} \right| = \left| \frac{-0.7}{0.6} \right| \approx |-1.166666666667| \approx 1.167$$

STEP 6

Look up the appropriate one-sided test critical (T_c) from Table 1 (upper 2.5% significance level) in ASTM E 178. The table below shows T_c values for $n = 1$ to 6. There is a minimum of three (3) sublots per lot.

n	T_c
1	0
2	0
3	1.155
4	1.481
5	1.715
6	1.887

$\therefore T_c = 1.481$ (for $n = 4$)

STEP 7

Perform the comparisons of T_n to T_c using Equation 411:11 below. If the comparison evaluates to true, then the test value “may” be an outlier.

$$T_n \geq T_c \qquad \text{Equation 411:11}$$

$(0.833 \geq 1.481) = \text{False} \therefore$ Sublot 1's percent asphalt cement is not an outlier.

$(0.500 \geq 1.481) = \text{False} \therefore$ Sublot 2's percent asphalt cement is not an outlier.

$(1.167 \geq 1.481) = \text{False} \therefore$ Sublot 3's percent asphalt cement is not an outlier.

$(0.833 \geq 1.481) = \text{False} \therefore$ Sublot 4's percent asphalt cement is not an outlier.