Validation of Contractor HMA Testing Data in the Materials Acceptance Process

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by

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This study was conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration.

16. Abstract

This study conducted an analysis of the SCDOT HMA specification. A Research Steering Committee comprised of SCDOT, FHWA, and Industry representatives provided oversight of the process. The research process included a literature review, a brief survey to which 42 highway agencies replied, in-person interviews with a few selected agencies, and extensive statistical analyses of test data supplied by SCDOT.

Analyses were conducted to determine appropriate standard deviation values to represent the variability of each of the acceptance characteristics used by SCDOT. A total of 1,260 density test results were provided from 22 different projects. A total of 1,775 asphalt content (AC) tests and 1,343 air voids (AV) and VMA tests were provided from 30 different projects.

In addition, SCDOT verification test results were obtained from 10 projects and were analyzed and compared with their corresponding contractor acceptance tests. The previous and current SCDOT verification procedures were evaluated and issues concerning each were presented and discussed.

Ranges for the appropriate values to use for the within-lot standard deviations for Density, AC, AV, and VMA were also developed. The analysis of verification tests results resulted in new verification testing procedures that were recommended for consideration by SCDOT.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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CHAPTER 1 — INTRODUCTION

Background

In the late 1980's, industry and the Federal Highway Administration (FHWA) encouraged states to move away from method specifications towards statistically based specifications and greater contractor quality control (QC) and Acceptance. After conducting initial research in this area, in the mid 1990's the SCDOT began implementing its first contractor QC/Acceptance program. This move was bolstered by the 1997 performance audit that recommended that the SCDOT "Implement a contractor self-certification program."

At that time, hot mixed asphalt (HMA) acceptance had utilized contractor QC/Acceptance data for nearly 10 years and a recent FHWA Quality Assurance (QA) Stewardship Review indicated that changes were needed to the current QC/Acceptance and Independent Assurance (IA) process associated with this program. The Stewardship review concluded that the SCDOT allowable differences in HMA test data were two to three times the current practice in other states and that the IA tolerances were in a similar need of analyzing and updating.

Because SCDOT inspectors no longer performed extensive routine HMA testing, the limited testing they performed must be used to accept or reject the contractor's test data and, consequently, the material it represents. The SCDOT needed to re-evaluate its current HMA QC/Acceptance and IA programs to ensure proper Department oversight and validation of the contractor's HMA testing data in accordance with Title 23, Code of Federal Regulations, Part 637 (*23 CFR 637*). (1)

A great deal of time and effort was devoted to the development of the SCDOT HMA QA Specification. The initial specification was developed over a five-year period with significant input from a joint SCDOT/Contractor/FHWA specification development committee (2). The HMA QA Specification was subsequently reevaluated (3) to establish how well the specification was working in the field and to uncover any problems that users of the specification had encountered. As part of this evaluation, based on statistical evaluation of project data, some modifications were made to the initial specification limits.

Since the re-analysis was completed, FHWA had issued Technical Advisory T 6120.3 (*T 6120.3*) (4) that provides more detailed and specific "guidance and recommendations for the use and validation of contractor's test results for acceptance, the use of quality measures, and the identification of contractor and department risks." There had also been significant discussion among professionals concerning the risks associated with validation procedures that may not be sufficient for the purposes intended in *23 CFR 637* or *T 6120.3*. See, for example, *Burati et al 2004* (5) and *Burati and Lin 2006* (6).

It was important, therefore, to once again conduct a formal and complete analysis of the SCDOT HMA specification in light of the information that had become available since it was last analyzed.

Objectives

The objectives of this study were:

- To examine the current SCDOT HMA QA specification, which includes QC, Acceptance and IA testing.
- To provide the SCDOT with technical assistance necessary to review and analyze project test data.
- To survey and interview officials in other state transportation departments (STDs) to obtain details of their existing validation and IA procedures.
- To make a detailed comparison of existing HMA QC, Acceptance, and IA specification requirements with recent FHWA technical recommendations on the use of contractor data for materials control and acceptance.
- To review the current allowable differences for HMA test validation and HMA IA test comparisons.
- To re-analyze the details of the current SCDOT HMA PWL analysis procedures along with the corresponding pay factors.
- To determine through analysis whether or not it is necessary to revise the tolerances that are currently used for comparing IA test results for the SCDOT IA program.
- To develop new procedures for validating contractor HMA test data that comply with the regulatory requirements of Title 23 Code of Federal Regulations, Part 637 (23CFR637).
- To develop an implementation plan for any specification changes that are recommended.
- To develop, if recommended by the FHWA QA Stewardship Review Team, guidelines for pilot projects to allow for more in-depth evaluation of proposed specification revisions and increased HMA data collection.

Methodology

The major items that needed to be accomplished to achieve the project objectives are discussed in each of the following sections. These major work tasks include:

- Establish a Research Steering Committee.
- Conduct a review of the existing literature.
- Survey other state departments of transportation (STDs) regarding their procedures.
- If needed, conduct interviews with selected STDs.
- Analyze test result data from SCDOT projects.
- Assist SCDOT, as needed, with revising the existing specification.
- If necessary, recommend implementation procedures for the new specification.

Research Steering Committee. The first step that was taken was to establish a Research Steering Committee (the Committee). Since all parties of the construction process, i.e., SCDOT, FHWA, and the construction industry, would be impacted by changes in the QC, Acceptance, and IA procedures, it was decided that individuals from all three of these groups would serve on the Committee. The Committee was charged to oversee the project on behalf of the SCDOT. The principal investigator (PI) served as the facilitator during meetings at which the Committee guided the PI in establishing the final tasks and timeline to meet the project objectives. These meetings were held in Columbia to minimize travel costs for team members. The members of the Committee are shown in Table 1.1.

Table 1.1. Research Steering Committee Team Members

Name	Position	Organization
Merrill Zwanka (Chair)	State Materials Engineer	SCDOT
Milton Fletcher	Materials and Research Engineer	SCDOT
Chad Hawkins	Quality Assurance Engineer	SCDOT
John McCarter	DCE, District 4	SCDOT
Danny Shealy	Director of Construction	SCDOT
David Law	Pavement and Materials Engineer	FHWA
David Herndon	Executive Director	SCAPA
James Horton	QC Manager	Weaver Constr.
Jim Burati	Principal Investigator	Clemson University

Literature Review. A literature review was conducted to identify reports and publications that address various aspects of the use of contractor tests for acceptance as well as any procedures for validating contractor tests. First, a computer search using the facilities of the Clemson University Cooper Library was conducted. In particular, Transportation Research Records were searched for papers relating to the areas of research. A search of FHWA's website was also conducted. In addition, the FHWA National Highway Specifications website was studied and the HMA specifications were downloaded for all states identified as using contractor tests for acceptance purposes. The results of the literature review were summarized and presented to the Committee.

Survey of STDs. In addition to the literature review, a brief survey instrument was developed and sent by SCDOT to all state materials engineers by means of the Materials Engineer LISTSERVE. The survey instrument was also sent to FHWA's Federal Lands Highways division. This survey briefly explained the purpose for the study, and asked each STD to provide a copy of its current HMA specification as well as how it developed any comparison limits that it uses for validation or IA tests. The survey requested the name and contact information of an individual who could provide further information regarding the development and implementation of the state's verification procedures, and also asked if the STD was willing to participate in an in-person interview with members of the research team. The specifications that were provided were reviewed and summarized and presented to the Committee.

Interviews with Selected STDs. To obtain more in-depth information, it was planned that in-person interviews be conducted with a few selected STDs that use contractor test results in the acceptance decision. After the PI presented the summary of the survey responses, the PI and the Committee were to jointly select STDs to contact to set up in-person interviews. The STDs that agreed to participate were then to be interviewed by one or more members of the research team.

Before the interview, each STD was provided a list of questions that the Committee wanted to have answered. The interviews were then summarized and presented to the Committee.

Analyze Project Test Data. Statistical analyses were conducted on project test results data supplied by the SCDOT. It was planned that the test result data would be supplied in the form of Excel (XLS or XLSX) files or comma separated variables (CSV) files. In fact, much of the data was provided as paper copies of SCDOT test reports. This necessitated that the data be input manually into Excel spreadsheet files that could then be imported for subsequent analyses by Minitab statistical software. This required a significant amount of time for data entry and checking to ensure that data entry errors were eliminated, or at least kept to a very low number.

The variability data from the projects, in terms of standard deviations, were compared with current specification limits to determine if the limits are still appropriate. The risks to both the contractor and the SCDOT could then be evaluated and used in the evaluation of the existing limits.

The project test results were also analyzed with respect to the current SCDOT validation and IA procedures, including the appropriateness of the existing comparison limits. These limits were also compared with those of other STDs that were identified during the survey. Statistical analyses included determination of the power of the existing comparison limits to identify differences between contractor and STD tests for various sample sizes. A risk analysis considered the ability of differing comparison limits to detect actual differences as well as the corresponding likelihoods of incorrectly identifying differences that do not actually exist. The comparison limits studied in the analyses spanned the range identified from the STD specifications that were reviewed for the project.

Revising the Existing Specification. The initial plan was for the Committee, based on all of the information provided, including survey, interview, and statistical and risk analyses results, to determine whether or not revisions to the limits and procedures of the existing HMA QA specification were necessary. If it was the consensus of the Committee that revisions were needed, the research team would provide any necessary information to assist the Committee in determining what revisions to make. The PI was to serve as facilitator for all meetings that were necessary for the Committee to reach a consensus on the required revisions.

The original plan was changed after the project began. Based on the FHWA stewardship review, SCDOT decided that it needed to have a new verification procedure to use on projects to be let in the 2008 construction season. So, the SCDOT developed new validation procedures before any survey, interview, or data analyses results were available. The proposed new procedures were reviewed by the PI. The PI also met with industry representatives to discuss their concerns over the new draft procedures that SCDOT had developed. The new procedures were discussed at a meeting of the Committee on March 11, 2008, and then SCDOT finalized the procedures that were implemented on an interim basis, pending the findings and recommendations of the current research project.

Implementation Procedures. As noted in the previous section, new validation procedures have already been implemented on an interim basis. Therefore, it should be relatively easy for the Committee to decide if, and how, it will implement any of the recommendations that resulted from this research project.

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CHAPTER 2 — LITERATURE REVIEW

Background

The purpose of this literature review is to identify publications that address contractor tests for acceptance as well as any procedures used for validating contractor tests. There has been an evolutionary process in the way asphalt paving projects are constructed and how quality is measured. In many STD programs today, the contractor has the responsibility for process control (quality control or QC) and Acceptance Testing, and the STD does a moderate amount of verification testing. As contractor tests for acceptance are becoming used more in the asphalt paving industry, questions are being raised about their legitimacy.

In the early days of formal highway construction the responsibilities were distributed in such a way that the STD had more control over the work. The STD controlled the production, production rates, and process control of mainline paving. The contractor essentially supplied the financing, the labor, and the equipment needed to complete the project. This scenario, where the product quality is the responsibility of the STD, is the result of the method type specification which was in use at the time. The *TRB Glossary of Highway Quality Assurance Terms* defines method-type specifications as “specifications that require the contractor to use specified materials in definite proportions and specific types of equipment and methods to place the material.” Method type specifications generally force the agency to accept the final product regardless of actual quality (7).

Evolution of Quality Assurance Specifications

QA specifications emerged as the industry recognized the need for contractors to have more control over their own processes. There was a fundamental transition where contractors performed QC testing, and the STD performed the Acceptance Testing. This approach is typical in QA specifications, where the functions of QC and Acceptance are clearly separated. This division is an integral part of QA. QA specifications reflect a mix of specifying both methods and end result testing. They specify methods for processes that do not have good or practical end result tests. For example, the segregation of aggregate is something that is difficult to measure in place. Prescriptive methods are written to help minimize aggregate segregation because there is not a good end result test to measure it. QA specifications also demonstrate a shift towards end result specifications. End result specifications, as defined by the TRB Glossary, are “specifications that require the contractor to take the entire responsibility for supplying a product or an item of construction. The STD’s responsibility is either to accept or reject the final product or to apply a pay adjustment commensurate with the degree of compliance with the specifications” (7). Contractors have the opportunity to use other methods of compaction, scheduling techniques, and new technologies to get the desired result faster and more cost effectively.

This situation where the contractor is responsible for the quality, but the STD performs the Acceptance Testing, is still being used in STDs today. Potential reasons for this are there may not have been a need to reduce agency employment, or the agency does not believe that it is appropriate to give the contractor responsibility for Acceptance Testing. Currently, the majority of STDs are using contractor tests for acceptance (8). During the 1990’s many STDs experienced a decline in resources that meant staff cuts. QC and Acceptance Testing were observed to be an easy and practical area to place more responsibility on the contractor and to reduce work load on STD testing personnel. To do this, a methodology for verification testing is needed to ensure the STD is getting the quality it desires.

STDs that have opted to make this transition to using contractor acceptance tests have developed and integrated verification procedures into their specifications. The process of developing the methodology requires the specification developer to make assumptions to later be verified or refined. For instance, verification plans require sampling and testing procedures that inherently exhibit risks to both the STD and the contractor. These risks may not be fully evaluated before implementation. The need to make assumptions shows that QA specifications are evolutionary in nature.

23 CFR 637 B

FHWA issued *Title 23 Code of Federal Regulations Part 637 Subpart B* (23 CFR 637 B) to mandate certain basic characteristics of a QA plan. It has also created a standard for STDs to meet which subsequently keeps them aligned with other STD's QA programs. *Technical Advisory T 6120.3* (4), issued by FHWA in August of 2004, further explains these points by providing insight and recommendations. Some key topics addressed in these documents include:

- Independent Assurance (IA).
- Split vs. Independent samples.
- Requirements for qualified testing facilities and technicians.
- Dispute Resolution.

Independent Assurance. 23 CFR 637 B requires that a QA program have an IA program to assure the STD that their testing equipment and the contractor's testing equipment are calibrated properly, and that the sampling and testing personnel are performing to standard. The IA program shall evaluate all testing procedures involved in the QA program on a periodic basis. IA complements the QA program by verifying procedure integrity. When assessing the testing equipment and procedures, split samples are used rather than independent samples. This is further discussed in the following section.

Split vs. Independent Samples. 23 CFR 637 B requires that all samples used for QC and verification sampling and testing shall be random independent samples. This means that a contractor cannot take samples, split them, and have the STD run a verification test on one of the split samples. However, this does not mean that split samples can never be used in verification testing. Figure 2.1 shows different scenarios of how samples can be taken and which samples can be used in the verification procedure.

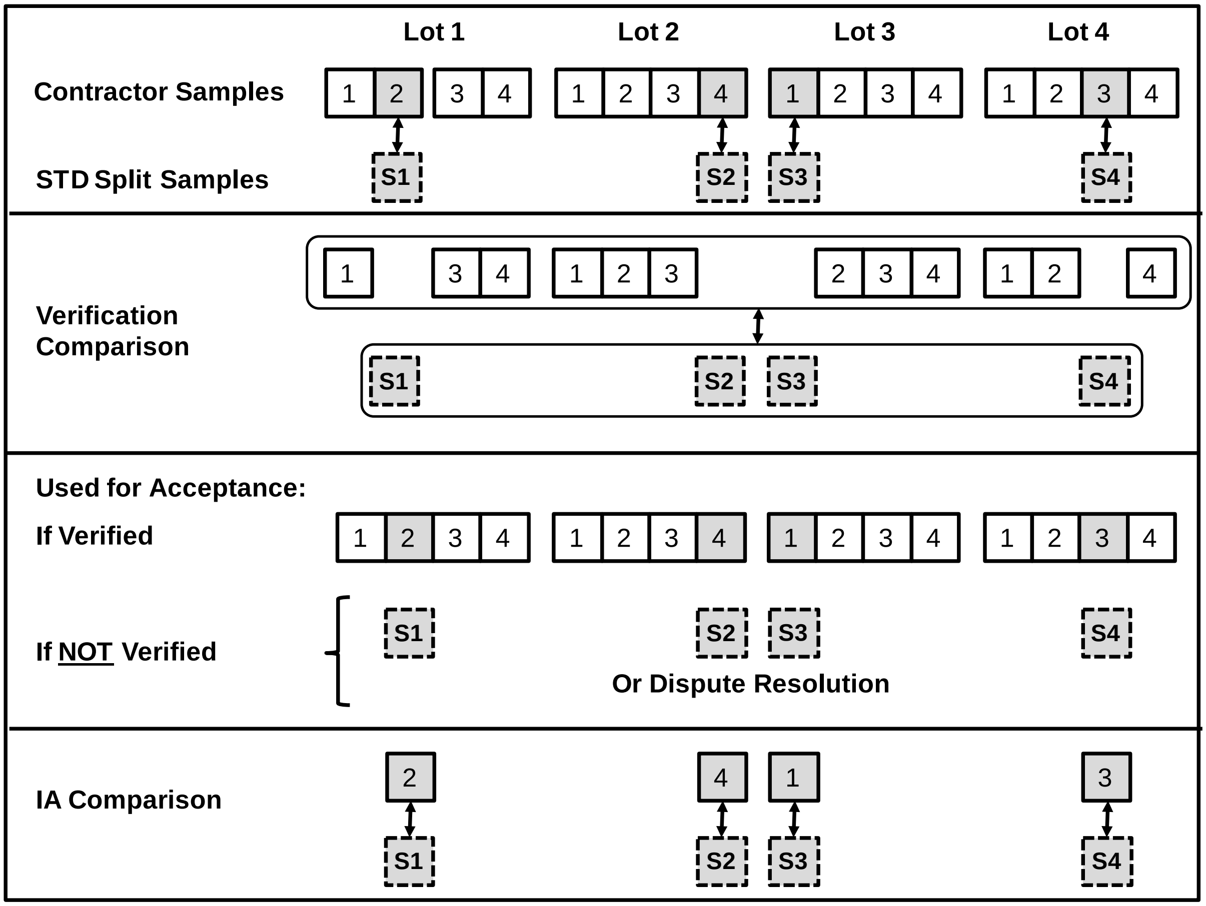

Figure 2.1. Verification and IA Testing Utilizing Split Samples (after 4)

Figure 2.1 demonstrates how IA and verification testing can be done efficiently. It shows that as long as the samples are organized appropriately both IA and verification testing can be accomplished by sharing data. A sample from each lot or sublot is split and an IA test can be performed on one of the split samples. These IA tests can be used as verification tests provided the corresponding split samples are removed from the contractor test results. This assures that the verification tests are independent from the acceptance tests in the verification procedure. If the contractor's acceptance tests are verified, then all of his samples are used for the acceptance decision, where the payment factor is calculated. Otherwise, the STD will use a dispute resolution process to investigate the reason for the verification failure, or use their samples to determine the payment factor.

The STD needs to have samples independent of the contractor's samples to capture the variability of the materials, process, sampling, and testing, all of which must be integrated into the verification limits. If only split samples are used, the STD captures only the contractor's testing variability, which does not fulfill the purpose of verification testing. However, the split samples can be used for the IA program.

Qualified Testing Facilities and Technicians. 23 CFR 637 B requires that all sampling and testing to be used in the acceptance decision or in the IA program shall be executed by qualified sampling and testing personnel, and that testing can occur only in qualified laboratories. It is left up to the STD to determine how to qualify a technician or laboratory. The laboratories must, at a minimum, include provisions for checking test equipment and the laboratory shall keep records of calibration checks. Each STD's central laboratory must be accredited by the AASHTO Accreditation Program or an equivalent accreditation program. (1)

Dispute Resolution. To ensure checks and balances are in place in verification procedures, 23 CFR 637 B mandates that a dispute resolution process be in place for STDs who choose to use results from contractor testing in the acceptance program. "The dispute resolution system shall address the resolution of discrepancies occurring between the verification sampling and testing and the quality control sampling and testing" (1). By formalizing a dispute resolution system it should provide means for minimizing adversarial relationships and claims. Three primary scenarios for dispute resolution should be developed and integrated into a QA plan (9):

- Disputes where contractor and STD test for same property with different procedures.
- Disputes where contractor and STD data do not compare.
- Disputes where no test data are applicable (e.g., segregation, workmanship, and manufactured products defects).

QC vs. Acceptance Testing

23 CFR 637 B states that results of "QC sampling and testing results may be used as part of the acceptance decision…(1)" The fact that an integral part of QA specifications is the separation of QC and Acceptance Testing, as discussed earlier, may seem to contradict this previous statement. 23 CFR 637 B is inconsistent in the terms used in the regulation, as it can be easily misconstrued that QC tests should be used in the acceptance decision. A misconception is that all contractor tests are QC tests and all STD tests are acceptance tests. Contractor tests performed separately and independently from QC, i.e., acceptance tests, are used in the acceptance decision once they are verified by the STD. *Burati and Hughes* believe that QC and acceptance functions should be separated regardless of who performs the acceptance testing (10).

Acceptance tests are typically inappropriate for QC and vice versa. The intent with an acceptance test is to measure the in place quality and make a payment decision based on the result. Conversely, the intent of a QC test is to monitor the production process to ensure that unacceptable material is not integrated into the project. "For an acceptance test to be statistically valid, the sample to be tested must be obtained in a random or stratified manner" (11). If the contractor discovers a suspicious QC test result, it may choose to retest the material. Both tests must be reported, but the second sample cannot be considered random. Again this highlights the importance of separating QC and acceptance testing to ensure a valid verification procedure.

Verification Methods

23 CFR 637 B does not say how data should be verified, but T 6120.3 explains the different methods and makes a recommendation. This recommended validation procedure for comparing contractor and STD data is the use of the statistically based *F*-tests and *t*-tests. Brief descriptions of different verification methods are discussed below:

One-to-One Comparison. The easiest verification method is a one-to-one comparison. This approach determines the results from the contractor test and the STD test done on a split sample, and compares the difference to some allowable limit. The difference two-sigma (D2S) limit is commonly used for comparing two split samples. D2S limits can be found in many AASHTO and ASTM test procedures (12). The limits are established by testing manufactured 'identical' samples by multiple labs. These limits may be too tight for actual conditions, so other ways to establish limits may be used. It is important to remember that if split samples are compared, the only variability under consideration is testing. For example, if the difference in test results is less than the comparison limit, then the testing procedure under consideration is a "pass." This procedure is inherently the least powerful method because the sample size is one, which makes it difficult to detect real differences unless the test results are far apart (12).

Paired *t*-test. The paired *t*-test is a useful procedure for comparing sets of STD and contractor split sample test results. This test can be done on an accumulated amount of one-to-one comparisons of split samples from the contractor and STD. The test checks to see if the differences *within* pairs are significantly different from zero. This method is more powerful than a one-to-one comparison such as using D2S limits because the sample size is greater than one.

***F*-test and *t*-test.** The *F*-test is used to compare the variability and *t*-test is used to compare the means of the verification and acceptance test data. First, the variabilities are tested with the *F*-test (see equation 2.1). If the variabilities are statistically significantly different, then it indicates that the samples are not likely from the same population. Next, the means are tested with the *t*-test. There are two different equations for finding the test statistic for the *t*-test (see equations 2.2 and 2.3). If the variabilities were not significantly different, then the pooled variance (see equation 2.4) is used to find the test statistic for the *t*-test. If the variabilities were significantly different, the two sample variances are used to compute the test statistic (see equation 2.2).

$$F = \frac{s_1^2}{s_2^2} \tag{2.1}$$

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \tag{2.2}$$

$$t = \frac{\overline{X}_1 - \overline{X}_2}{s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad \textbf{(2.3)}$$

$$s_p = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}} \quad \textbf{(2.4)}$$

One reason that the *F*-test and *t*-test approach is more powerful is because not only does it compare the means of two data sets, it also considers the variability. If only one measure is used to compare data sets, the risk of concluding the data are the same when they actually are not is increased. Also, with increased sample sizes associated with *F*-tests and *t*-tests, the risks to both the STD and contractor are reduced. Similarly, when paired *t*-tests are used in IA, there is an increased sample size that reduces the probability of an error. (4, 11)

When using the statistical approach for validating data, a critically important decision about the level of risks to the STD and the contractor must be made before data analysis begins. An alpha value (α), or level of significance, is the probability of making a Type I error, or determining that the data are significantly different when they are not. Typically, alpha values range from 0.01 to 0.10, with 0.05 being the most common. The contractor would like to lower the probability of a Type 1 error so an alpha value of 0.01 would be most beneficial to the contractor. The beta value (β) is the probability of making a Type II error, or accepting that the data are similar when they are not. This can be identified as the STD's risk. Since β is inversely related to the level of significance (α) and directly related to the sample sizes, a balance of acceptable risks needs to be determined by the STD (12).

Industry Acceptance

A common opinion of some STDs and research papers is that contractors should not conduct tests for acceptance because of the apparent conflict of interest. (13, 14, 15, 16) *Mahboub, Hancher and Wang* (13) conducted a survey of all STDs and some large contractors. A frequent comment from STDs was that they have a general lack of trust in the contractor-performed test data.

Exhibit 2.1 shows the questions used in a survey by *Parker and Turochy* (17) and Table 2.1 summarizes the survey responses. The survey was sent to 500 NICET certified asphalt technicians and 21 technicians in a course sponsored by the Florida DOT. The responses to these surveys indicate the perception that contractor acceptance testing is like the "fox guarding the henhouse," or giving the contractor control over its payment. This perception is human nature and should be addressed within the STD. *Killingsworth and Hughes* state that, due to human nature, STD personnel must make a psychological adjustment to accept the fact that contractor test results will be used to establish the pay factor (11).

1. My employer is

□ a state department of transportation
□ a contractor,
□ a consultant, or
□ other

2. I am involved in sampling and testing to control the production and placement of construction materials and/or the acceptance of these materials. Acceptance may be pass/fail or involve adjustments to bid process.

□ Yes – continue
□ No – stop

3. Have you ever felt pressure to produce test results, or to retest, to give more favorable control or acceptance outcomes?

□ Yes – continue
□ No – stop

4. Was the pressure you felt to produce test results that would give more favorable outcomes

□ Self-induced – you just felt you should, or
□ Due to specific reasons/instructions/comments from supervisors?

5. How easy/difficult would it be to manipulate test results to achieve more favorable outcomes?

Easy Difficult
1 2 3 4 5

6. Please rank, from 1 (most effective) to 5 (least effective), the following techniques for preventing manipulation of test results.

a. sampling and testing of split samples for comparison _____

b. sampling and testing of independent samples for comparison _____

c. occasional observation of sampling and testing procedures _____

d. use contractor-performed tests for process control and state DOT-performed tests only for acceptance _____

e. periodic (weekly or monthly) audit and comparison of contractor and state DOT test results by an independent organization _____

Exhibit 2.1. Asphalt Technician Survey Questions (17)

Table 2.1. Summary of Responses to the Asphalt Technician Survey Questions (17)

Question 1 No. (%)		Question 2 Y/N (Y / N %)		Question 3 Y/N (Y / N %)		Question 4*		Question 5 (Average)		Question 6 (Method – Rank)	
FDOT	NICET	FDOT	NICET	FDOT	NICET	FDOT	NICET	FDOT	NICET	FDOT	NICET
Consultants 2 (11%)	Consultants 95 (66%)	1 / 1 50 / 50%	90 / 5 95 / 5%	0 / 1 0 / 100%	61 / 30 67 / 33%	–	A 33 (54%) B 11 (18%) C 8 (13%) D 7 (11%) E 1 (2%) F 1 (2%)	1.00	1.28	a – 1 b – 2 c – 3 d – 5 e – 4	a – 1 b – 2 c – 3 d – 5 e – 4
Contractors 8 (44%)	Contractors 17 (12%)	8 / 0 100 / 0%	15 / 2 88 / 12%	3 / 5 38 /62%	10 / 5 67 / 33%	A 0 (0%) B 3 (100%)	A 6 (60%) B 3 (30%) C 1 (10%)	3.12	1.37	a – 2 b – 1 c – 4 d – 5 e – 3	a – 2 b – 1 c – 4 d – 5 e – 3
FDOT 7 (39%)	DOT 7 (5%)	7 / 0 100 / 0%	6 / 1 86 / 14%	1 / 6 14 / 86%	2 / 4 33 / 67%	A 1 (100%) B 0 (0%)	A 1 (50%) B 1 (50%)	1.50	1.26	a – 2 b – 3 c – 4 d – 1 e – 5	a – 1 b – 5 c – 2 d – 4 e – 3
Other 1 (6%)	Other 24 (17%)	0 / 1 0 / 100%	23 / 1 96 / 4%	–	15 / 8 65 / 35%	–	A 5 (33%) B 3 (20%) C 2 (13%) D 4 (27%) F 1 (7%)	–	1.24	–	a – 1 b – 2 c – 3 d – 5 e – 4
All 18 (100%)	All 143 (100%)	16 / 2 89 / 11%	134 /94 94 / 6%	4 / 12 25 / 75%	88 / 47 65 / 35%	A 1 (25%) B 3 (75%)	A 45 (54%) B 18 (21%) C 11 (12%) D 11 (12%) E 1 (1%) F 2 (2%)	2.33	1.27	a – 1 b – 2 c – 4 d – 3 e – 5	a – 1 b – 2 c – 3 d – 5 e – 4

* A: Supervisor B: Self C: Supervisor and Self D: Contractor E: Clients F: No Response

There are a number of advantages and disadvantages discussed in the literature. By having contractors do their own acceptance testing it encourages a more careful testing process, where more attention is placed on maintaining sample integrity and the testing procedures themselves (11). Contractors certainly should place more attention on their sampling and testing procedures knowing that the test results will be used in the payment decision. If a contractor's test results are not verified and the STD uses its own data to determine payment, the risk of coming to an incorrect decision is increased due to the resulting smaller sample size. This poses a great financial threat to the contractor because it could ultimately be paid for less than the actual quality or even be required to remove and replace. Another advantage is the advanced knowledge the contractor gains by doing its own acceptance tests. A pay factor can be projected assuming the data are verified and the contractor can anticipate the pay factors associated with each lot (11).

A debatable advantage is the reduced inspection staff required at the STD as a result of contractors performing acceptance tests. Depending on the level of risk associated with the number of verification samples the STD tests, there may or may not be a significant reduction in staff by having contractors conduct acceptance tests (11).

The primary disadvantage of using contractor tests for acceptance that was expressed in research papers examining the adequacy of contractor tests is the fact that the contractor and STD data do not consistently compare. Frazier and Turochy (16) found that in six states considered, there was a consistent trend of significant differences in contractor and state data with a 1% level of significance. They also found that the contractor means and variances tended to be more favorable values. These data are compiled with similar data from other papers and discussed in the next section.

Analysis of Contractor Acceptance Test Data

Large data sets for Georgia, North Carolina, Florida, Alabama, Kentucky, Kansas, California, and New Mexico have been compiled and analyzed in various research papers to see if contractor and STD test data are coming from the same populations (13, 14, 15, 16, 17). The data provided in Table 2.2 are a result of compiling all available data for each STD and corresponding contractor tests. Descriptions of the verification procedures and available data for the states analyzed are provided in the following sections.

Florida (FDOT): FDOT conducts verification testing and independent sample verification testing (ISVT) on asphalt content and 9 gradation sieves. The verification testing is performed on split samples, and a one-to-one comparison is used to determine if contractor acceptance tests are used in the pay factor computation. For material density the contractor takes 5 cores per 500-ton sublot and FDOT will test 5 cores in a lot. FDOT then uses one-to-one comparisons to verify the core density. The ISVT results are compared with specification tolerances, and production may be stopped if the ISVT shows that the mix is out of tolerance. For ISVT, 2 tests are done for every 12,000 tons, or 6 lots. A total of 98 projects from the 2003 and 2004 construction season were analyzed.

Georgia (GDOT): *t*-tests are performed on 8 gradation sieves and asphalt content, although only 4 sieves are used for pay adjustment. GDOT randomly takes 2 samples for every 5 contractor samples. GDOT takes 1 split sample for every 10 contractor samples for IA. Data from the 2003 construction season were used for analysis.

Alabama (ALDOT): Acceptance tests included asphalt content, air voids, and density. However, only asphalt content and air voids were analyzed in the study. The acceptance procedure comprised of computing the average absolute deviation from the JMF target and was modified during implementation. Data used for analysis included 80 mix designs from 1990 to 1992 during the implementation of the Alabama Highway Department's QA specifications.

North Carolina (NCDOT): The NCDOT performs 2 types of testing: QA (split samples) and verification (independent samples). Density and the following mix properties are tested: asphalt content, air voids, VMA, %G_{mm} @ N_i, VFA, and 7 gradation sieves. QA testing is done at a rate of 1 NCDOT test per every 10 contractor tests and the results are compared with precision limits. Verification testing is performed at a rate of 5%, or 1 out of every 20 contractor tests. When a QA comparison is not within precision limits the engineer investigates the source of the error and pay adjustments are applied as a last resort. A total of 735 mix designs from the 2004 construction season were analyzed.

California (Caltrans): QA procedures include both density and mix properties, although only mix properties were provided for analysis. The mix properties tested are asphalt content and 6 gradation sieves. Caltrans performs verification testing at a rate of 10% with independent samples. A lot is an entire project's production and a sublot is 500 tons.

Analysis was performed on data from 149 projects between 1996 and 2005.

Kansas (KSDOT): Theoretical MSG, AV, and mat density are analyzed. Asphalt content and gradation tests are performed by the contractor and KSDOT but only for process control. Density is most commonly tested by nuclear gages but cores may also be used. Contractors take 4 verification tests per lot and KSDOT takes 1 test per lot. Means are compared with *t*-tests and if contractor data are verified they are used in the acceptance decision. A lot is 3000 tons and is split up into 4 sublots of 750 tons each. A total of 49 projects from the 2003 construction season were analyzed.

It appears from the summary data in Table 2.2 that there is a tendency for the variabilities between the STD and the contractor data to be significantly different. There is no distinct pattern, although out of the 15 STD and Contractor comparisons, 14 (93%) of the variabilities are significantly different. Only 4 out of the 15 average differences (27%) show evidence of a significant difference.

Table 2.2. Summary of STD and contractor comparisons (after 17, 18)

Source	n	α	Avg. Diff.	Sig. Diff.?	σ	Sig. Diff.?
Asphalt Content						
AL	N/A	0.05	-0.045	no	0.272	**yes**
Contractor	N/A	0.05	-0.036		0.230	
KY	3,082	0.05	-0.007	no	0.210	**yes**
Contractor	3,082	0.05	-0.007		0.152	
GA	2,487	0.01	0.004	no	0.253	**yes**
Contractor	14,061	0.01	0.005		0.200	
FL	526	0.01	0.016	no	0.290	**yes**
Contractor	2,307	0.01	-0.012		0.249	
NC	814	0.01	-0.021	no	0.286	**yes**
Contractor	14,396	0.01	-0.003		0.243	
CA	1,405	0.01	0.036	**yes**	0.295	**yes**
Contractor	9,258	0.01	-0.003		0.205	
Air Voids						
AL	N/A	0.05	-0.357	**yes**	1.025	**yes**
Contractor	N/A	0.05	-0.281		0.863	
KY	1,827	0.05	4.063	no	0.978	**yes**
Contractor	1,818	0.05	4.086		0.853	
FL	469	0.01	-0.285	no	1.144	**yes**
Contractor	2,063	0.01	-0.248		0.841	
NC	817	0.01	-0.161	no	1.039	**yes**
Contractor	14,225	0.01	-0.097		0.751	
KA	393	0.01	0.322	no	0.802	**yes**
Contractor	1,494	0.01	0.262		0.564	
VMA						
KY	422	0.05	1.225	no	1.037	no
Contractor	422	0.05	1.267		0.940	
FL	469	0.01	-0.508	no	1.011	**yes**
Contractor	2,095	0.01	-0.490		0.858	
NC	808	0.01	1.217	**yes**	1.459	**yes**
Contractor	14,225	0.01	1.507		1.343	
Density						
AL	N/A	0.05	-1.245	**yes**	1.470	**yes**
Contractor	N/A	0.05	-0.997		1.175	

Conclusion

From the publications identified in this literature search, it is apparent that there is no industry-wide consensus on the adequacy of using contractor tests for acceptance. The number of STDs with statistical data analysis over a large number of projects found during the literature review is limited to GA, NC, FL, AL, KY, KS, CA, and NM.

These publications look at data from a statewide, multi-project standpoint down to a single project with 6 or more test results for analysis. Consistent results are not typical as there is no distinguishable pattern of data coming from the same or different populations.

There are a number of potential reasons that significant differences arise in contractor and STD performed tests. With knowledge of these potential reasons the STD can make an effort to minimize its chance of affecting the validation procedure. Some of these reasons are provided below in no particular order:

- The number of specimens tested by contractor and state agency technicians.
- The time between sampling and testing of specimens often found between contractors and state agencies (13).
- Differences in procedures.
- Failure to follow prescribed procedures.
- Incorrectly calibrated testing equipment.

CHAPTER 3 — SURVEY RESULTS

Background

This chapter summarizes and discusses the responses to a survey sent out by SCDOT in December of 2007. The survey was developed by SCDOT and then reviewed by the PI. Its purpose was to gain knowledge about whether other states use contractor test results for acceptance as well as to identify other aspects of their acceptance and verification processes. The surveys were sent out to the Materials Engineer of each agency as well as the Federal Lands Highway Divisions. The survey questions are shown in Exhibit 3.1.

1. Does your agency use Contractor test results for acceptance of hot-mix asphalt (HMA)?
2. If your answer to 1 was no, did you consider using Contractor tests results for acceptance? If so, why did you decide against it?

   NOTE: If you don't use Contractor's test results for acceptance you have finished the survey. If you use Contractor's tests results for acceptance, please complete the remaining portion of the survey.
3. Why did you decide to use Contractor test results for acceptance?
4. What HMA properties do the Contractors sample and test for acceptance?
5. Does your agency have a HMA verification program that is separate from your Independent Assurance sampling and testing program?
6. Are the verification tests the same as the acceptance tests?
7. What are your sampling locations and frequencies of acceptance and verification sampling and testing?
8. If you use mix volumetrics for acceptance and verification, do you re-heat the verification samples from ambient room to the proper compaction temperature before testing?
9. What procedure do you use to compare acceptance test results with your verification test results?

Exhibit 3.1 Survey Questions

In addition to the information gained from the survey responses from the State Highway Agencies (SHAs), the technical specifications for the participating SHAs were also assembled. Some of the SHAs responding included an attachment of their specifications to the survey, while others were gathered using the SHA's website. These specifications were used to provide more detailed information on the individual SHA's testing procedures.

Survey Summary

A total of 42 agencies, including 40 states, the FHWA Western Federal Lands Highway Division (WFLHD), and the province of Ontario, Canada (ONT), responded to the survey. This section breaks down the responses on a question-by-question basis. The responding agencies, along with whether or not they use Contractor tests for acceptance, are shown on the map in Figure 3.1.

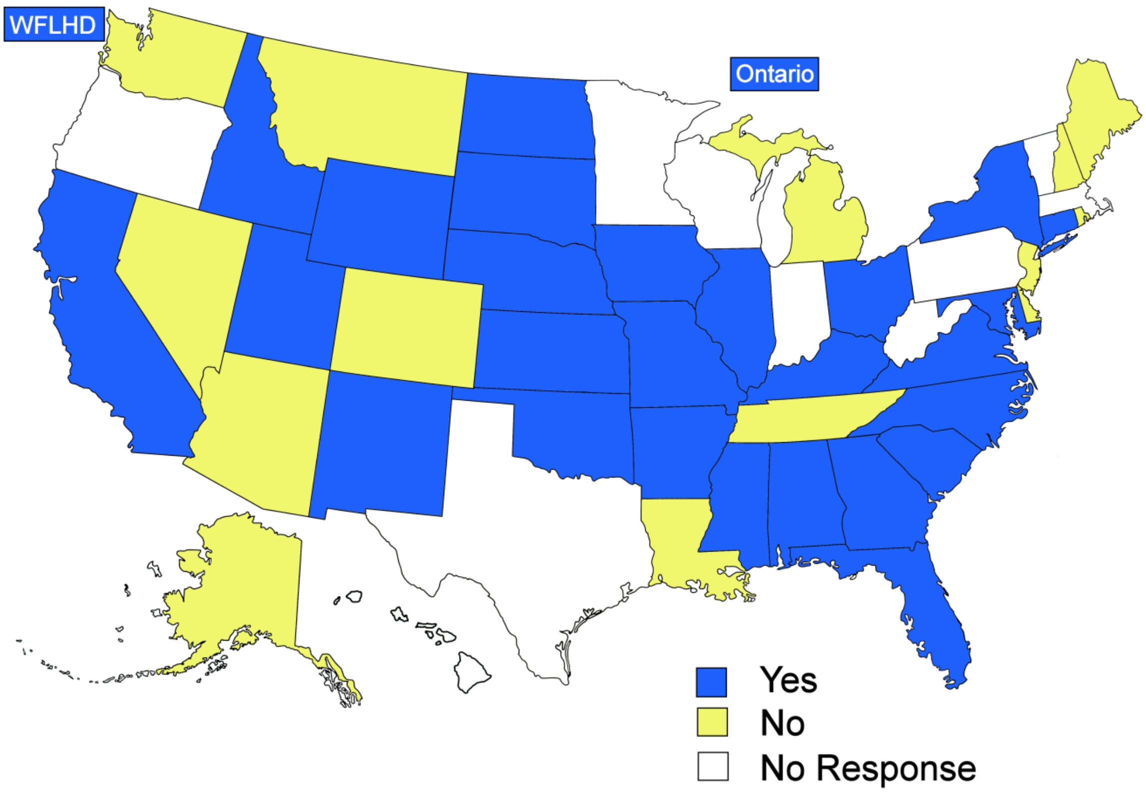

Figure 3.1. Agencies Responding to the Survey and whether They Use Contractor Tests

Question 1. *Does your agency use Contractor test results for acceptance of hot-mix asphalt (HMA)?*

A total of 28 agencies responded that they use contractor tests results for HMA acceptance, while 14 agencies responded that they did not. The responses of the agencies were divided as shown in Table 3.1.

Table 3.1. Responses Regarding Use of Contractor Tests for Acceptance

Use?	No.	Agency
Yes	28	AL, AR, CA, CT, FL, GA, ID, IL, IA, KS, KY, MD, MS, MO, NE, NY, NC, ND, NM, OH, ONT, OK, SC, SD, UT, VA, WFLHD, WY
No	14	AK, AZ, CO, DE, LA, ME, MI, MT, NV, NH, NJ, RI, TN, WA

Question 2. *If your answer to 1 was no, did you consider using Contractor tests results for acceptance? If so, why did you decide against it?*

This question was just for the agencies that indicated that they do not use contractor tests for acceptance. This question was used to determine the reason the agency has chosen not to use contractor test results for acceptance. This question provides insight into some of the perceived problems that can be associated with using contractor tests for acceptance.

The most common answer for this question was that agencies believed that there was a conflict of interest with the contractor doing the acceptance testing. For example, if there is a test that does not meet the specifications then the contractor has a conflict of interest in whether or not to report the correct numbers, which may result in a lower pay factor or the material having to be replaced, or to manipulate the numbers to be in compliance with the specification. This was the reason that AZ, NH, RI, TN, and WA gave for not using contractor tests for acceptance. MI's response said that at one time they used contractor tests for acceptance, but the program was ended as a result of a fraud investigation by the FHWA. CO said they had problems with a pilot program and that was their reason for not using contractor tests for acceptance. ME said there was no advantage of using contractor tests for acceptance with respect to quality or pay factors. LA and MT are considering using contractor tests for acceptance, but do not at this time.

Question 3. *Why did you decide to use Contractor test results for acceptance?*

This question was designed to gather information on why agencies have decided to use contractor test results for acceptance. The most common response was that the contractor takes better care of the testing when their tests are used for acceptance. There were 11 agencies that said this played a role in their decision to use contractor tests for acceptance. The next most common response was that there was a shortage in agency personnel to perform all of the tests themselves. IL's response was that allowing the contractor to perform the acceptance tests allowed for higher testing frequency and quicker turnaround on results as compared to the agency doing the testing themselves. By having quicker turnaround on the results they felt as though the contractor was better able to adjust the mix to stay within the specification limits. NM said that they had achieved improvements in HMA quality by using a statistically based acceptance decision with an incentive/disincentive program. One agency also cited a cost savings as the reason for switching to contractor tests for acceptance.

Question 4. *What HMA properties do the Contractors sample and test for acceptance?*

This question was asked to see which properties each agency requires the contractor to test for acceptance. There are five properties that are used by a large number of agencies, with a larger number of properties that are used by a smaller number of agencies. The five properties that are most commonly used are: laboratory air voids, gradation, roadway density, asphalt cement content, and voids in mineral aggregate (VMA). The less common tests that are used include: dust to asphalt ratio, voids filled with asphalt (VFA), smoothness, G_{mm}, G_{se}, N_{ini}, N_{max}, film thickness, maximum specific gravity, fractured face count, and moisture content. Table 3.2 shows a summary of the number of agencies that use each of these tests. Table 3.3 shows a breakdown of the agencies that use each of the more common tests.

Table 3.2. Characteristics for which Contractor Tests Are Used for Acceptance

Property	Number of Agencies
Laboratory Air Voids	23
Gradation	21
Roadway Density	18
Liquid AC Content	18
VMA	16
Dust/Asphalt Ratio	5
VFA	4
Ride Smoothness	3
G_{mm}, G_{se}, N_{ini}, N_{max}, Film Thickness, Max Spec Gravity, Fractured Face Count, Moisture Content, Hydrated Lime	1

Table 3.3. Characteristics for which Each Agency Uses Contractor Tests for Acceptance

Agency	Laboratory Air Voids	Gradation	Roadway Density	Asphalt Content	VMA
Alabama	X	X	X	X	X
Arkansas	X		X	X	X
California		X		X	
Connecticut	X	X		X	X
Florida	X	X	X	X	
Georgia		X		X	
Idaho	X				X
Illinois	X	X	X	X	X
Iowa	X	X			
Kansas	X		X		
Kentucky	X			X	X
Maryland	X	X	X	X	
Mississippi	X	X		X	X
Missouri	X		X	X	X
Nebraska	X		X		X
New Mexico	X	X	X		X
New York	X				
North Carolina	X	X	X	X	X
North Dakota	X	X	X		
Ohio		X		X	
Ontario	X	X	X	X	X
Oklahoma	X	X	X	X	
South Carolina	X	X	X	X	X
South Dakota	X	X			X
Utah	X	X	X	X	X
Virginia		X	X	X	
WFLHD	X	X	X	X	X
Wyoming		X	X		
TOTAL	**23**	**21**	**18**	**18**	**16**

Question 5. *Does your agency have a HMA verification program that is separate from your Independent Assurance sampling and testing program?*

A total of 29 agencies responded that they have separate programs for verification and independent assurance testing, while there were 13 that responded saying they did not. The responses of the agencies were divided as shown in Table 3.4.

Table 3.4. Responses Regarding Agencies that Use Separate Verification and IA Programs

Use?	No.	Agency
Yes	29	AL, AR, CA, CO, CT, FL, GA, ID, IL, IA, KS, KY, MD, MS, MO, NE, NY, NM, NC, ND, OH, ONT, OK, SC, SD, UT, VA, WFLHD, WY
No	13	AK, AZ, DE, LA, ME, MI, MT, NH, NV, NJ, TN, WA, RI

Question 6. *Are the verification tests the same as the acceptance tests?*

This question was designed to find out if the agencies used the same tests for verification that the contractors perform for acceptance. There were 25 agencies that use the same tests, with 17 not using the same tests. The responses of the agencies were divided as shown in Table 3.5.

Table 3.5. Responses Regarding Agencies that Use the Same Verification and Acceptance Tests

Use?	No.	Agency
Yes	25	AL, AR, CO, CT, FL, GA, ID, IL, IA, KS, KY, MD, NE, NY, NC, ND, OH, ONT, OK, SC, SD, UT, VA, WFLHD, WY
No	17	AK, AZ, CA, DE, LA, ME, MI, MS, MO, MT, NV, NH, NJ, NM, RI, TN, WA

Question 7. *What are your sampling locations and frequencies of acceptance and verification sampling and testing?*

Question 7 was asked to acquire data on how much testing the agencies do, and also how the data are collected. Each agency has its own set of tests it uses for acceptance, and each agency has a different frequency to take their tests. Each responding agency's frequency is shown in Table 3.6.

Table 3.6. Sampling Frequencies and Locations

Agency	Test Frequency
AL	Core every 3000 feet; other tests every 700 tons.
AR	Acceptance every 750 tons, verification every 3000 tons.
CA	Aggregate is sampled from belt or bin. HMA binder content is sampled behind paver.
CO	Location determined by the contractor. Samples were taken from windrow prior to pick-up device. Binder and Density: 1 / 500 tons; Air Voids and VMA: 1 / 1,000 tons.
CT	Samples are taken at the plant at a rate of 1 / 500 tons.
FL	Acceptance tests are done at 1 / 1000 tons, split sample verification samples of 1 in 4 are tested. Independent plant taken at 1 / 4000 tons for binder content, gradation, and air voids.
GA	1 / 1000 or 1 / 500 tons–contractor's choice for acceptance. Verification 1 / 4000 tons.
ID	Acceptance every 750 tons, verification twice per shift.
IL	From the truck at the HMA plant once in the morning and once in the afternoon.
IA	Samples taken from behind the paver at 4 locations, 4 / day. DOT takes 1 random test per day for verification.
KS	Random locations for air voids and density.
KY	Samples taken from truck at the HMA plant, one per 1 / 1000 tons. DOT verifies at 1 / 4000 tons.
MD	1 / 1000 tons, and 5 cores taken for QC, 5 for SHA lab.
MS	Taken from the truck at the plant based on daily tonnage.
MO	1 / 1000 ton sublot.
NE	Sample taken behind paver 1 / 750 tons, every sample split, used for QC, and one random for verification.
NM	1 / 1000 tons for acceptance, 1/3000 tons for verification.
NC	1 / 750 tons, and 10% used for verification.
ND	4 tests to the contractor's first 10, then 10% afterwards.
SC	Acceptance of HMA mixture (Binder, AV, VMA) every 500 tons by contractor – Split samples obtained at a minimum of 10%. Random verification samples taken at least 1 per lot. Roadway cores taken by contractor every 1500 feet for Intermediate and every 2000 feet for Surface.
SD	1 / 5000 tons for verification.
UT	Behind paver 5 / day.
VA	1 / 500 tons for contractor tests and 1 / 2000 tons for verification.
WFLHD	1 / 750 tons behind the paver before compaction.
WY	Aggregate 1 / 1000 tons, cores 1 / 250 tons, volumetrics 1 / 5000 tons.

Question 8. *If you use mix volumetrics for acceptance and verification, do you re-heat the verification samples from ambient room to the proper compaction temperature before testing?*

Question 8 takes into consideration only those agencies that use volumetrics for acceptance and verification testing. This is the reason there are only 28 agencies of the 42 in the survey that have a response to this question. The responses of the agencies were divided as shown in Table 3.7.

Table 3.7. Responses Regarding States that Re-Heat Samples before Testing

Use?	No.	Agency
Yes	24	AR, CA, CO, CT, FL, ID, IL, IA, KS, MD, MS, MO, NE, NM, NY, NC, ND, ONT, OK, SC, UT, VA, WFLHD, WY
No	4	AL, GA, KY, OH, SD

Question 9. *What procedure do you use to compare acceptance test results with your verification test results?*

Verification testing is used to ensure the acceptance tests are accurate. Each agency has its own way of comparing the acceptance test results with its verification tests. There were 9 agencies that used some sort of statistical analysis using *F*-tests and *t*-tests to verify the acceptance tests. These agencies include: CO, ID, KS, MD, NM, SD, UT, VA and WFLHD. Kansas currently uses an Excel spreadsheet to perform its *F*-tests and *t*-tests. They use a significance level (alpha value) of 0.01. However, they are considering changing that to 0.025 or 0.05 at the request of FHWA.

Many agencies use some variety of tolerance tables to compare their verification results to the contractor's test results. FL, GA, MS, NY, NC, VA, ND, WY, AR, NE, and KY all use some version of tolerance tables to verify acceptance tests. Some of these agencies' tolerances are displayed in Table 3.8. MO considers the tests verified if the acceptance tests and the verification tests are within two standard deviations of the lot average for acceptance tests. IL does not have a formal procedure for comparing the tests results, but starts an investigation if the tests do not match. IA does a one-to-one comparison for verification and acceptance tests and multiple sample bias.

The tolerances in the table represent the differences between the contractor and agency tests that would cause a test not to be acceptable or would cause a stoppage of production. Other differences may trigger a pay reduction but still allow the material to remain in place.

Table 3.8. Tolerances Used to Compare Acceptance and Verification Tests

State	Density	Air Voids	AC Content	Gradation 5/8” or 3/8”	Gradation No. 200	VMA	Bulk Specific Gravity	Max. Specific Gravity
AR	2.0%	1.0%	0.30%			1.0%		
FL			0.55%	5.5%	1.5%		0.016	0.022
GA			0.50%	4.0%	2.0%			
MS			0.40%	6.0%	2.0%		0.030	0.020
NE		0.5%	0.50%	5.0%		0.5%		
NY				5.0%			0.200	0.011
NC	2.0%		0.50%	5.0%	2.0%	1.0%	0.030	0.020
ND				7.0%	2.5%		0.040	0.035
VA 1 test 2 tests 3 tests 4 tests 8 tests			 0.60% 0.43% 0.33% 0.30% 0.21%	 8.0% 5.7% 4.4% 4.0% 2.8%	 2.0% 1.4% 1.1% 1.0% 0.7%			

Conclusion

This summary condenses all of the data that were gathered from the survey responses and the specification search. This summary is designed to give an overview of what agencies are doing with regard to using contractor tests for acceptance of asphalt pavements. While each agency has its own procedures, trends can be seen in the responses.

A majority of the responding agencies (28 of 42, or 67%) in some way incorporate contractor test results into the acceptance decision. Only 9 of these 28 agencies use *F*-tests and *t*-tests when comparing contractor acceptance tests with the agency’s verification tests.

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CHAPTER 4 — INTERVIEW RESULTS

Background

This chapter summarizes and discusses the results of in-person interviews that were conducted with STDs. The intent of the interviews was to obtain more in-depth information from STDs that use contractor test results in the acceptance decision. Before each interview, the STD was provided a list of questions that the Committee wanted to have answered.

Interviews

After obtaining approval from the Committee chair, it was decided that the initial interviews would be conducted with the neighboring states of Georgia and North Carolina since many SC contractors also work in these states. This also allowed the researchers to determine the effectiveness of the in-person interviews while keeping travel costs to a minimum. GDOT was interviewed on August 29, 2008 and NC was interviewed on September 15, 2008. Summaries of the results of these interviews are presented in Exhibits 4.1 and 4.2, respectively.

Change to the Interview Process

The researchers experienced difficulties in contacting states that were willing to meet for interviews and in finding mutually agreeable dates for interviews. As a result, based on the initial in-person interviews, and in an effort to make scheduling easier, at the March 12, 2009 meeting of the Committee the researchers proposed that future interviews be conducted as telephone interviews. The Committee agreed to this change in the interview process. The researchers scheduled a telephone interview with the Tennessee DOT (TDOT). The results of this interview are presented in Exhibit 4.3.

Due to the long amount of time that it took to find a time that the three TDOT interviewees could participate in a conference call, and based on the information that had been obtained from the three interviews that were conducted, it was decided that additional "formal" interviews would not be the most efficient method for gathering information. Rather, the graduate research assistant contacted individual STDs on a one-to-one basis to seek additional information and clarifications as needed.

Conclusion

Due to the increasing workloads experienced by STDs, it was very difficult and time consuming to set up formal interviews. The interviews that were conducted did not yield significantly more information than could be obtained from the surveys and from the specifications and procedures manuals of the various STDs. It was therefore concluded that eliminating the formal interviews in favor of telephone calls and emails to solicit additional information on an as needed basis was a better approach than continuing with formal STD interviews.

Summary of Interview Questions: Georgia DOT, August 29, 2008

Why did you decide to use contractor tests for acceptance?

FHWA encouraged it, and it saves staffing requirements for the DOT.

Have there been any complications using the contractor tests for acceptance?

When the DOT people were not present there was a problem with getting lime into some of the mixes. Since lime is not an acceptance material it was not caught in the IA testing.

How did you come up with the allowable differences between the department and contractor acceptance tests?

Was there any research done to come up with these numbers?

They are not sure; they have been trying to figure it out. They are considering a research project to revisit them.

Is there any statistical backing for these numbers?

Not sure.

Have you considered using statistical comparison (*F*- or *t*-tests) for quality assurance?

They are reviewing using *F*- and *t*-tests for quality assurance. The problem is they are not getting enough information for statistical comparison. They have enough information from the contractor side, but only having 2 QA tests per week is not enough for a statistical comparison. This results in about a 1 to 10 ratio of DOT to contractor tests.

Has using contractor tests for acceptance been able to maintain the same level of quality of the pavements?

See above referenced comments about the lime not in mix. It is also hard to tell about the quality since the pavements have yet to make it to their expected design life.

Why did you choose the HMA properties that you have for quality assurance testing?

They feel like gradation and AC Content are the most important aspects to the QA of HMA. These are used for the payment decision. The 3/8” sieve, No.4, and No. 8 sieves are also used for surface courses.

Other tests are used for QC and can shut down the plant, but are not used in the payment decision.

How did you decide on the acceptance characteristics?

Because they have always used these characteristics, i.e., “if it ain’t broke don’t fix it.” They also perform field verifications of the mix design during construction.

Other Information:

They use both ignition oven and extraction for AC content. This has caused problems because there are differences in the results obtained by the two methods, and the individual apparatus.

They have 2 levels: (1) testing twice per week to take samples and (2) “inspectors” that rotate around the state and visit plants and constructions sites.

Exhibit 4.1. Summary of In-Person Interview with Georgia DOT

Summary of Interview Questions: North Carolina DOT, September 15, 2008

Why did you decide to use contractor tests for acceptance?

Began QC/QA in Mid 90's. It was mostly about manpower issues.

Have there been any complications using the contractor tests for acceptance?

They have seen good contractors who take more care in the product, realizing the way to make profit is not by trying to stay on the edge of acceptable limits but by having a better product. The contractors understand more about their product now that they do the testing. They had some fraud issues, which resulted in some technician certifications being revoked.

How did you come up with the allowable differences between the department and contractor acceptance tests?

These were based off recommendations from their consultant (not D2S Limits) and some are tighter than D2S. They are reworking most of these to get them more in line with AASHTO/ASTM D2S limits.

On independent samples they have used the same allowable limits for years. For 2008 they are going to evaluate these limits.

They were doing a minimum of 10% split and 5% independent verification testing and switched after their stewardship review. They now do 10% independent verification testing and 5% split.

They have a referee system with splits for QC, QA, and 1 held by QA for referee check by central lab if needed.

Was there any research done to come up with these numbers?

Not sure.

Is there any statistical backing for these numbers?

Not that they are aware of.

Have you considered using statistical comparison (*F*- or *t*-tests) for quality assurance?

Yes, but they have limitations on capturing enough data for *F*- and *t*-tests. They do not have a way to separate QC/QA data from data input into the system to be used for *F*- and *t*-tests. They are thinking about adding a new part to the in-house developed software to separate out data and allow for *F*- and *t*-tests.

Has using contractor tests for acceptance been able to maintain the same level of quality of the pavements?

When letting volume was higher and greater amounts of outside help were hired it was down some because of how fast paced things were going. Overall, it is about the same, but the last few years it seems as though some of the attention to detail has been lost. Starting in 2005 they started to evaluate individual technicians as well.

(*continued*)

Exhibit 4.2. Summary of In-Person Interview with North Carolina DOT

Have there been any problems with allowing contractors to use cores or nuclear density tests for density? Was there any discussion on the accuracy difference between using cores versus using nuclear density gauges?

Nuclear density is correlated to a percentage of control strip density, on which cores have been taken and tested. Core jobs use 5 random tests per lot as does nuclear testing, but nuclear testing takes 2 readings per spot to reduce some of the variability. East of Raleigh mostly utilizes nuclear control. West of Raleigh does not want to use nuclear control.

Other Information:

Use 250 ton lots sampled from truck at plant.

AC content (ignition oven) and Gradation (#8 and #200) are used for payment.

They use bulk specific gravity, Rice gravity, and check volumetrics as a percentage of MTD. Run recommended Superpave gyrations going toward Table 9-9 levels.

Verification Samples (independent samples taken randomly by DOT forces): they are based on what they call Retest Limits. If the verification sample and the most recent QC sample from the same lot are outside of the Retest Limits, an investigation is initiated.

Pay Factors: These are based on a straight-line drop from 100% down to 50%. Anything < 50% is Remove and Replace.

Exhibit 4.2. Summary of In-Person Interview with North Carolina DOT (*continued*)

Summary of Interview Questions: Tennessee DOT

Why did you decide against using contractor tests for acceptance?

They have always had a strong asphalt interest. They have been fortunate to have their own people be able to do the testing.

Are there any drawbacks to the department having to do all of the testing itself?

Personnel is now a tremendous problem.

Have you considered the possible cost savings by being able to reduce in house testing?

They would rather do what they can themselves than to use contractor tests for acceptance. Nobody really wants to switch. They now use certified producers for Liquid AC and it has cut down on their testing. They still pull assurance tests though.

What HMA properties do you test for acceptance, and why did you choose those properties?

Pay factor sieves: 3/8”, #4, #8, #16, #30, #50, #100, #200. Pay tables single or double test. Use absolute average deviation (keep contractor from compensating up or down). The majority of tests are taken from the truck. For AC content the majority use vacuum method, but ignition oven is also accepted. Their tests are done in the contractors’ labs so it depends on which equipment the contractor has. Sublots 1< 500 tons, 2: 500–1000 tons, 3: 1500–3000 tons, 4: 3000–4500 tons.

For Density they use Nuclear Gauges for time purposes. This allows for instant feedback (contractor can keep rolling). Density tested 1 test/sublot.

Is the contractor required to do any Quality Control testing? If so, what QC tests are required and what are the frequencies of these tests?

They recommend tests for QC. They usually recommend the same frequencies that TDOT uses. Contractor Quality plans are submitted in the pre-construction meeting.

Exhibit 4.3. Summary of Telephone Interview with Tennessee DOT

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CHAPTER 5 — ANALYSIS OF ACCEPTANCE TEST RESULTS

Background

This chapter discusses the analyses that were conducted to determine appropriate standard deviation values to represent the variability of each of the acceptance characteristics used by SCDOT. These include asphalt content, air voids, and VMA of plant samples, as well as core densities from the in-place pavement. These variabilities are necessary to evaluate the appropriateness of the existing specification limits. They can also be used when evaluating the risks of various comparison and verification procedures.

Data Obtained for Analysis

Test result data from SCDOT projects were obtained from SCDOT. The data were divided into two categories:

- ♦ Density acceptance test results.
- ♦ Plant acceptance test results, including AC, AV, and VMA.

All of the density acceptance test data that were provided are included in Appendix A. A total of 1,260 density test results were provided. In all, density data were provided from 22 different projects, with some projects having multiple HMA mixes involved.

All of the plant acceptance test data that were provided are included in Appendix A. A total of 1,775 asphalt content tests were provided from 30 different projects, with some projects having multiple HMA mixes involved. Since no voids testing was done on Base course mixes, open graded friction course (OGFC) mixes, or Surface E mixes, there were only 1,343 air voids and VMA tests provided.

Each project is identified with a unique number, ranging from P01 to P36. Each of these numbered projects corresponds with a unique SCDOT project file number. Each job mix formula (JMF) is identified with a unique number, ranging from J01 to J83.

Data Analyses

A number of different analyses were conducted on the test result data that were obtained from SCDOT. Some of the analyses conducted included analysis of variance (ANOVA) to determine if differences in means existed among the various subsets of the data. These subsets included comparing individual lots within a project, individual projects within a mix type, individual mix types within a course, and courses against one another. *F*-tests, Bartlett's tests, and Levene's tests were conducted to make similar comparisons among the variances.

The analyses were conducted separately on the density and plant test data. The density data also had to be divided into two different subsets. This was due to the fact that that there is no formal target value for density, and that there are different specification limits for Interstate and multi-lift paving (Interstate) than for all other paving (Other). Since there was no target value there was no common reference point to which to compare the density results. So, the density analyses were conducted treating the Interstate and Other as different populations.

Unlike density, the plant test data had specific target values. It was not possible to compare directly the actual test results since each project and each mix design had its own set of target values. It was possible, however, to normalize the data by considering the asphalt content (AC), air voids (AV), and VMA values as differences from their target values. This made it possible to make comparisons among the various lots, mix designs, projects, mix types, and courses that could not be done on the actual test values.

Since they were treated differently, the results of the analyses on the density and plant tests are presented in separate chapters. One of the most important goals of the analyses was to determine appropriate standard deviation values to represent the variability for density, AC, AV, and VMA. Before presenting the results of the data analyses it is important to present some general principles associated with selecting these typical project variabilities.

Selecting a “Typical” Variability

The first question to be answered in the analyses was “What variability will be used for the typical variability on which to base the specification limits?”

Determining the Project Variability. The first, and perhaps most important, issue is to develop a value for project variability that is consistent with the way in which a lot is defined under the acceptance plan. Since the SCDOT specification is based on lot-by-lot acceptance, the variability that is used to evaluate the specification limits must be that which is appropriate for a typical lot. To determine this, the individual standard deviation values for each lot must be calculated and then these lot standard deviations are “averaged” in some way to get a typical “within-lot” standard deviation for the process.

This within-lot population standard deviation can be estimated by a function of the *average* sample standard deviation. This is obtained by averaging the individual standard deviations calculated from each of the lots on the project, with each lot having some size, *n*. There is, unfortunately, a slight problem involved when working with the usual estimator of σ.

If σ^2 is the unknown variance of a probability distribution, then the *sample* variance is an unbiased estimator of σ^2 (see equation 5.1).

$$s^2 = \frac{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2}{n-1} \qquad \textbf{(5.1)}$$

Where
s^2 = the sample variance,
X_i = the individual data values in the sample,
$\bar{X}$ = the sample mean,
n = the number of data values in each sample.

However, *s*, the sample standard deviation which is the square root of the variance, is *not* an unbiased estimator of σ. If the underlying distribution is normal, then *s* actually estimates $c_4\ \sigma$, where c_4 is a constant that depends on the sample size *n*. This constant is tabulated in many text books on statistical quality control and may be calculated using equation 5.2.

$$c_4 = \sqrt{\frac{2}{n-1}}\frac{\left(\frac{n}{2}-1\right)!}{\left(\frac{n-1}{2}-1\right)!} \quad \textbf{(5.2)}$$

To compute this we need a *non-integer factorial*, which is defined for $n/2$ as shown in equation 5.3.

$$\left(\frac{n}{2}\right)! = \left(\frac{n}{2}\right)\left(\frac{n}{2}-1\right)\left(\frac{n}{2}-2\right)\cdots\left(\frac{1}{2}\right)\sqrt{\pi} \quad \textbf{(5.3)}$$

Since it depends only on n, values of c_4 are readily available in tables. Table 5.1 shows c_4 values for various values of n.

So the *mean* or expected value of the sample standard deviation is $\bar{s} = c_4\sigma$. In other words, the population standard deviation, σ, is estimated by $\bar{s}/c_4$. For equal sample sizes, equation 5.4 is used to calculate $\bar{s}$. In the equation, k = the number of sample standard deviations used (i.e., the number of lots) to calculate $\bar{s}$.

$$\bar{s} = \frac{s_1 + s_2 + \cdots + s_k}{k}. \quad \textbf{(5.4)}$$

The estimated population standard deviation, $\hat{\sigma}$, is then calculated using equation 5.5 with the single c_4 value for the equal sample size.

$$\hat{\sigma} = \frac{\bar{s}}{c_4} \quad \textbf{(5.5)}$$

If the sample sizes are not equal, then compute $\hat{\sigma}$ with equation 5.6 using the c_4 values for the appropriate sample sizes. In the equation, k = the number of sample standard deviations used (i.e., the number of lots) to calculate $\bar{s}$.

$$\hat{\sigma} = \frac{\frac{s_1}{c_{4_1}} + \frac{s_2}{c_{4_2}} + \cdots + \frac{s_k}{c_{4_k}}}{k} \quad \textbf{(5.6)}$$

Table 5.1. c_4 Factors for Various Sample Sizes, n

Sample Size, n	c_4
2	0.7979
3	0.8862
4	0.9213
5	0.9400
6	0.9515
7	0.9594
8	0.9650
9	0.9693
10	0.9727
11	0.9754
12	0.9776
13	0.9794
14	0.9810
15	0.9823
16	0.9835
17	0.9845
18	0.9854
19	0.9862
20	0.9869
21	0.9876
22	0.9882
23	0.9887
24	0.9892
25	0.9896
Over 25	*

* $(4n-4)/(4n-3)$

Target Miss. The typical standard deviation value that is selected serves as a measure of variability within the process for a typical contractor on a typical project. This standard deviation will be used to help decide upon specification limits for the acceptance plan. Another factor that needs to be considered in addition to this within–process variability is the capability of contractors to center their processes on the target value. This may be an even more difficult task than deciding on a typical within–process standard deviation.

AC, AV, and VMA all have target values about which two–sided specification limits are established. The typical process standard deviation can be used to establish these specification limits. The STD, however, must decide whether or not a typical contractor can be expected to always be able to center its process exactly on the target value. If the STD believes this to be possible, then the typical process standard deviation that was developed from the individual project values can be used when setting the specification limits. If, on the other hand, the STD believes that a typical contractor's process mean may vary somewhat about the target value, then it will be necessary to consider this fact when developing specification limits.

What is being considered here is not the case where a contractor, for whatever reason, chooses to intentionally center its process at some point other than the target value. If a contractor chooses to do this, then the contractor must bear any potential acceptance risks associated with its decision. On the other hand, failure to consider that current technology may not be adequate to allow the contractor to always hit the target with all of its processes places a risk on the contractor.

The ideal way to address the issue of "target miss," is to determine how variable the actual process means are about the target value. This variability regarding where the process will be centered, call it "process center variability," can then be combined with the previously determined typical within–process variability to obtain the correct standard deviation value for use in establishing specification limits.

The "process center variability" and the "within–process variability" can be combined simply by adding their associated variances, NOT their standard deviations. This assumes that the amount of process variability is independent of where the process is centered; an assumption that seems reasonable, particularly as long as the target miss is not very large. Note that it is NOT correct to add the two standard deviations. The two variances must be added to get a combined variance. The square root of this combined variance can then be used as an estimate of the standard deviation value.

It is difficult to answer this "target miss" question from project data because the STD never knows with certainty where the contractor intended to center its process. A contractor with particularly low variability could, for a number of reasons, choose to center its process at a point other than the target value and still plan to meet the specification requirements based on its low variability. It will also not be possible to determine from project data whether or not the contractor's process mean was constant throughout the project or whether for any of a number of reasons it was changed during the course of the project. Any "target miss" analysis will therefore require some assumptions.

If the agency assumes that there is a constant process throughout a project, then the mean value of all of the individual lot means on the project can be used as an estimate of where the process was centered for the project. The agency could then obtain a large number of project "target misses" and analyze these to determine the variability associated with missing the target value. One potential problem with this approach is that the project data that were obtained do not have a large number of lots for many of the projects. This, therefore, makes it difficult to obtain a good estimate of where the process was centered.

If the STD does not believe that the contractor's process is constant throughout the life of a project, as would typically be the case when the agency has decided to use lot–by–lot acceptance, then there is no way to know how much of the lot–to–lot variation in sample means is from the natural variation of the sampling process and how much is due to misses, changes, or adjustments in the contractor's target mean during the project.

One possibility might be to calculate a standard deviation based on combining all of the project data into one data set. While this is not recommended as the best way to establish a typical within–process standard deviation to use with lot–by–lot acceptance, this approach will provide a larger standard deviation value that includes the lot–to–lot variation among the individual lot means. A decision to use this approach assumes that any “target miss” variation within the project will be accounted for when all the test results are combined. The various project standard deviations could then be used to arrive at a typical process standard deviation that attempts to include both the “within–process” and the possible “target miss” variability.

Determining the Typical Process Variability. Once the project variability data are available, a decision must be made regarding what variability to use as the “typical” process variability. This typical variability can then be used to establish specification limits. There is no single “correct” way to decide upon the typical variability to use.

Suppose that an STD has collected data from a number of past projects that it considered acceptable. The STD could decide to select the smallest project standard deviation as the “typical” process standard deviation value (measure of process variability) since this value is “capable” of being achieved. On the other hand, the STD could select the largest value since this value was obtained on a project that the STD had apparently considered acceptable. It is probably not appropriate to select either the best (smallest) variability or the worst (largest) variability as the “typical” variability. An STD cannot reduce variability by simply specifying it, particularly if it has been shown that contractors, in general, have not been able consistently to meet that variability value. It is probably also not a good practice to base acceptance plan decisions on the worst contractor results.

Therefore, the STD would probably wish to select the typical process variability value based on consideration of all the past project data rather than just a single best or worst project. The STD might order the standard deviation values from smallest to largest and then subjectively decide what value to select as the typical process variability. This decision might be based on selecting a value that was attained on two–thirds, or three–fourths of the projects. This is a judgment decision, and many defensible subjective choices are possible.

CHAPTER 6 — RESULTS OF DENSITY ACCEPTANCE TEST ANALYSES

Background

This chapter summarizes and discusses the results of analyses to determine appropriate standard deviation values to represent the variability for density. This variability is necessary to evaluate the appropriateness of the existing specification limits. It can also be used when evaluating the risks of various comparison and verification procedures.

Data Obtained for Analysis

All of the density acceptance test data that were provided are included in Appendix A. A total of 1,260 density test results were provided. In all, density data were provided from 22 different projects, with some projects having multiple HMA mixes involved. The numbers of density tests for the various projects and JMF mix designs are presented in Tables 6.1-6.4.

In the tables, each project is identified with a unique number, ranging from P01 to P36. Each of these numbered projects corresponds with a unique SCDOT project file number. Each job mix formula (JMF) is identified with a unique number, ranging from J01 to J83.

The density data had to be divided into two different subsets. This was due to the facts that that there is no formal target value for density and that there were different specification limits for multi-lane and Interstate highways (Interstate) than for non-multi-lane and non-Interstate highways (Other). Since there was no target value there was no common reference point to which to compare the density results. So, the density analyses were conducted treating Interstate projects and Other projects as different populations.

Table 6.1. Summary of Density Data for Intermediate Course on Other Projects

Mix Type	Project	JMF	Lots in JMF	Tests in JMF	Lots on Project	Tests on Project
Intermediate B	P01	J23	2	8	2	8
	P03	J04	5	30	5	30
	P36	J09	5	21	5	21
Total			**12**	**59**	**12**	**59**

Table 6.2. Summary of Density Data for Surface Course on Other Projects

Mix Type	Project	JMF	Lots in JMF	Tests in JMF	Lots on Project	Tests on Project
Surface 1	P06	J26	1	14	1	14
Surface 1D	P06	J24	5	25	5	25
Surface 1R	P04	J14	5	36	5	36
	P08	J11	1	8	1	8
Surface B	P27	J55	4	24	11	57
		J70	7	33		
	P30	J65	2	8	2	8
	P31	J71	2	8	2	8
Surface C	P13	J03	1	9	1	9
	P14	J16	6	38	6	38
	P15	J44	5	18	5	18
	P16	J20	3	12	3	12
	P18	J48	3	18	3	18
	P20	J50	7	67	7	67
	P24	J56	7	56	7	56
	P26	J59	8	55	8	55
	P28	J39	4	28	4	28
Total			**71**	**457**	**71**	**457**

Table 6.3. Summary of Density Data for Intermediate Course on Interstate Projects

Mix Type	Project	JMF	Lots in JMF	Tests in JMF	Lots on Project	Tests on Project
Binder 1	P01	J02	4	22	4	22
Intermediate B	P01	J10	7	30	7	30
	P23	J33	4	16	4	16
	P32	J76	13	105	13	105
	P33	J73	8	56	8	56
Total			**36**	**229**	**36**	**229**

Table 6.4. Summary of Density Data for Surface Course on Interstate Projects

Mix Type	Project	JMF	Lots in JMF	Tests in JMF	Lots on Project	Tests on Project
Surface 1C	P01	J07	4	22	4	22
Surface A	P26	J62	9	42	25	123
		J69	16	81		
	P32	J74	1	6	26	172
		J79	25	166		
	P33	J77	6	40	6	40
	P34	J62	4	25	4	25
Surface B	P01	J07	5	20	5	20
	P03	J15	5	25	5	25
	P23	J63	6	18	6	18
	P32	J72	8	70	8	70
Total			**89**	**515**	**89**	**515**

Density Test Data Analyses

As noted above, the density tests were divided into two different subsets since the Interstate and Other projects had different specification limits. The Interstate projects had lower and upper specification limits of 92.2 and 96.0, respectively. Other projects had the same upper limit, but had a lower limit of 91.2. The specifications listed target values of 94.0 for Interstate and 93.0 for Other paving.

However, since these "target" values are not in the centers of their respective specification limits, there is no real benefit to the contractor to attempt to hit these targets with its process. The contractor maximizes it chances of meeting the PWL requirement by aiming for the center of the specification limits. This allows for the largest standard deviation that can be obtained while still meeting the specification requirements for full payment. So, even though the specification lists "target" values, in reality the "real" target values become the midpoint between the lower and upper specification limits. Therefore, these target values were not considered when performing analyses on the density test results.

Interstate vs. Other Paving. To determine if the difference in specification limits led to differences in the densities achieved on projects, the mean and variance of the Interstate projects were compared statistically with those for the Other projects. These comparisons were made separately for Intermediate and Surface mixes. Table 6.5 presents the results of these comparisons.

Table 6.5. Summary of Density Comparisons between Interstate and Other Paving for Intermediate and Surface Mixes

Course	Paving Type	No. of Projects	No. of Tests	Mean	P-value*	St Dev	P-value*
Intermediate	Other	3	59	93.39	0.195	1.420	0.094
	Interstate	4	229	93.15		1.204	
Surface	Other	15	457	92.02	**0.000**	1.695	**0.000**
	Interstate	7	515	92.97		1.131	

***** Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

The results in Table 6.5 show that the density Surface course results definitely had a higher mean and lower standard deviation for Interstate paving than for Other paving. For Intermediate course, the differences were not significant at the 0.05 level.

Table 6.6 shows the same mean and standard deviation values as in Table 6.5, but compares differences between Intermediate and Surface courses within Interstate paving and Other paving. For both Interstate and Other paving, the Intermediate course had higher mean values than the Surface course. However, the standard deviations were not significantly different at the 0.05 level for either type of paving.

Table 6.6. Summary of Density Comparisons between Intermediate and Surface Mixes for Interstate and Other Paving Projects

Paving Type	Course	No. of Projects	No. of Tests	Mean	P-value*	St Dev	P-value*
Interstate	**Intermediate**	4	229	93.15	**0.043**	1.204	0.256
	Surface	7	515	92.97		1.131	
Other	**Intermediate**	3	59	93.39	**0.000**	1.420	0.096
	Surface	15	457	92.02		1.695	

***** Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

Comparing Mix Types within Course. Table 6.6 shows that it was not possible to declare a difference in variability between Intermediate and Surface course mixes. This supports an argument that there is not a need to have wider or narrower specification tolerances for the two courses. The next question to consider is whether it is appropriate to use the same specification tolerances for all Intermediate course mixes and for all Surface course mixes. When establishing the allowable tolerances it is the standard deviation that is most important. There were only two types of Intermediate course, Binder 1 and Intermediate B, for which data were provided. Since 266 out of 288 data values were Intermediate B, no comparison was made for Intermediate course.

Table 6.7 shows the results of comparisons among the density variabilities for the different types of Surface course mixes. The results show that the standard deviation values are definitely not the same for all Surface mix types. However, there are so few projects and total tests available for some of the mix types that it is difficult to consider these results conclusive.

Caveat. None of the standard deviation values shown in Tables 6.5-6.7 are the appropriate standard deviation to use to represent the process standard deviation for density. These calculations were done simply for exploratory purposes. Aggregating the data as in these tables is not appropriate for establishing specification limits since the specification limits are based on lot-by-lot acceptance, or at least on acceptance of a project.

Typical Variability Values for Density. As noted above, since the SCDOT specification is based on lot-by-lot acceptance, the variability that is used to evaluate the specification limits must be that which is appropriate for a typical lot. To determine this, the individual standard deviation values for each lot were calculated and then these lot standard deviations were averaged to get the "within-lot" standard deviation for each project. This was done by using the square root of equation 6.1 to calculate the standard deviation for each lot and then using equation 6.6 to calculate the unbiased estimate for the lot population standard deviation. This calculation process is illustrated in Exhibit 6.1 for one of the projects for which data were obtained.

Table 6.7. Summary of Density Variability Comparisons among Surface Mixes

Mix Type	No. of Projects	No. of Tests	St Dev	P-value*
Surface 1	1	14	1.159	
Surface 1C	1	22	0.792	
Surface 1D	1	25	1.733	
Surface 1R	2	44	1.339	**0000**
Surface A	4	360	1.222	
Surface B	7	206	1.029	
Surface C	9	301	1.438	

***** Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

Lot No.	Lot Size	Lot Mean	Lot St Dev*	c_4**	Unbiased Lot St Dev***
1	5	92.71	0.546	0.9400	0.581
3	6	91.83	0.863	0.9515	0.907
4	7	92.50	0.504	0.9594	0.525
5	6	92.15	0.489	0.9515	0.514
	Average	**92.3**	**0.601**		**0.632**

***** calculated from $s = \sqrt{\dfrac{\sum_{i=1}^{n}\left(X_i - \overline{X}\right)^2}{n-1}}$

****** obtained from Table 5.10 for the sample size, *n*

******* calculated as $\dfrac{s}{c_4}$

******** calculated as $\dfrac{\dfrac{s_1}{c_{4_1}} + \dfrac{s_3}{c_{4_3}} + \dfrac{s_4}{c_{4_4}} + \dfrac{s_5}{c_{4_5}}}{4}$

Exhibit 6.1. Example of Calculating Unbiased Std Dev for Project P27, JMF J55

The data in Exhibit 6.1 are for Surface B using JMF J55 on project P27. There were 4 lots with differing sample sizes of 5, 6, and 7. The mean and standard deviation (calculated using equation 6.1) are shown for each lot. Then, each lot standard deviation is divided by the c_4 factor corresponding to the lot sample size to get the unbiased estimate. Finally, the four unbiased lot standard deviations are averaged to arrive at the within-lot standard deviation for the project. As noted above, this within-lot standard deviation does not take into consideration any target miss variability that may be present.

To provide the option to consider using the total project as the payment lot, the total project standard deviation was also calculated for each project. This was done by using the square root of equation 6.1 to calculate a single standard deviation that combines all of the test results on the project. As noted above, this “project” standard deviation could also be used as one way of trying to incorporate any target miss variability that might be present in the contractor’s process.

Appendix B includes calculations similar to those in Exhibit 6.1 for each project for which density data were obtained. These calculations were used to arrive at the project standard deviations that were used to establish the typical process variability for density.

Projects with Multiple JMFs. Before compiling all of the within-lot and project variabilities, a decision had to be made regarding how to deal with projects on which more than one JMF was used for the same mix type and course. Should each JMF be treated as a separate project, or should the multiple JMF results be combined together as one project? To help make this decision, the projects with multiple JMFs were examined. Table 6.8 shows the projects (extracted from Tables 6.1-6.4) that had multiple JMFs for the same mix type.

Table 6.8. Projects with More than One JMF for the Same Mix Type

Mix Type	Project	JMF	Lots in JMF	Tests in JMF	Lots on Project	Tests on Project
Surface A	P26	J62	9	42	25	123
		J69	16	81		
	P32	J74	1	6	26	172
		J79	25	166		
Surface B	P27	J55	4	24	11	57
		J70	7	33		

For each of the projects in Table 6.8 comparisons were made between the means and variances of the two JMFs on the project. The results of these comparisons are shown in Table 6.9.

Table 6.9. Summary of Density Comparisons for Projects with Multiple JMFs

Project	JMF	No. of Lots	No. of Tests	Mean	P-value*	St Dev	P-value*
P26	**J62**	9	42	92.85	**0.026**	1.358	0.362
	J69	16	81	93.39		1.206	
P32	**J74**	1	6	93.20	0.275	1.348	0.149
	J79	25	166	92.77		0.838	
P27	**J55**	4	24	92.29	**0.009**	0.667	**0.034**
	J70	7	33	92.95		1.028	

***** Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

Since the primary goal was to determine the within-lot standard deviation, the fact that the means are different for two of the projects is not a particular issue. For project P27, however, the different standard deviation values will lead to an averaged result that may not represent either value. Also, in the project data a new lot was established in nearly every case that the JMF changed. This would argue in favor of treating the JMFs as separate projects when determining the within-lot standard deviations.

However, if a total project is being used as the payment lot, then the data from the two JMFs would be combined when calculating the standard deviation to use for payment determination. This would argue in favor of combining the separate JMFs into a single project. For consistency in presentation and in comparing results, it was decided to treat the separate JMFs as separate projects when calculating standard deviations and when presenting the results.

Determining the Typical Process Variability for Density

Table 6.10 shows the standard deviation results for density for all projects for which data were obtained. The projects are sorted by mix type. The “Lot” standard deviation is the average of the unbiased standard deviation estimates for each lot on the project. The “Project” standard deviation is the standard deviation of all the individual test results for the total project. The table also shows the total number of lots and tests for each project, the mean for all tests on the project, and the mean of the individual project lot means.

Intermediate vs. Surface Course. One thing to consider from the results in Table 6.10 was whether to treat the Intermediate course results separate from the Surface course results or to combine them. By observation, the standard deviation values for the Intermediate course projects are in the same range as those for the Surface course projects. Also, the Two-Sample Mann-Whitney hypothesis test was used to compare the medians of the Means of Lot Means results for the Intermediate and Surface results. The same test was used to compare the medians of the Lot Standard Deviations. The Mann-Whitney test does not require the data to come from normally distributed populations. It assumes that the populations of interest have the same shape and that the populations are independent. In both cases the Intermediate and Surface results were not significantly different at the 0.05 level of significance. It was therefore decided to combine the two sets of data for further evaluations.

Interstate vs. Other Paving Projects. Another thing to consider was whether the Interstate and Other projects should be treated separately or combined when deciding upon the process standard deviation. To investigate this, Table 6.11 shows the same standard deviation results from Table 6.10, but sorted into Interstate and Other projects. By observation, the average Lot mean appears to be higher and the average Lot standard deviation appears to be smaller for the Interstate paving projects. It would appear that there is better compaction control on Interstate paving projects than on Other paving projects. The fact that the means are different does not affect the selection of the process standard deviation.

Table 6.10. Summary of Density Test Results for Each Project

Number		Total Number of		Mean of *		Std Deviation**		Mix
Project	JMF	Lots	Tests	All Tests	Lot Means	Project	Lot	Type
P01	J02	4	22	93.94	93.56	0.908	0.848	Binder 1
P01	J10	7	30	92.90	92.85	0.599	0.515	Inter B
P23	J33	4	16	91.64	91.63	1.374	1.649	Inter B
P32	J76	13	105	93.27	93.27	1.072	1.059	Inter B
P33	J73	8	56	93.18	93.17	1.377	1.459	Inter B
P01	J23	2	8	93.75	93.77	1.160	1.403	Interm B
P03	J04	5	30	93.73	93.59	1.388	1.053	Interm B
P36	J09	5	21	92.76	92.83	1.439	1.524	Interm B
Total/Average		**48**	**288**	**93.15**	**93.08**	**1.164**	**1.189**	
P01	J07	4	22	93.26	93.24	0.801	0.543	Surf 1C
P06	J26	1	14	90.05	90.05	1.181	1.181	Surf 1C
P06	J24	5	25	91.47	91.69	1.751	0.995	Surf 1D
P04	J14	5	36	89.77	89.80	1.312	1.262	Surf 1R
P08	J11	1	8	88.65	88.65	1.203	1.203	Surf 1R
P26	J62	9	42	92.85	92.84	1.366	1.052	Surf A
P26	J69	16	81	93.39	93.40	1.210	1.126	Surf A
P32	J79	24	166	92.77	92.77	0.943	0.868	Surf A
P32	J74	1	6	93.20	93.20	1.417	1.417	Surf A
P33	J77	6	40	92.67	92.72	1.486	1.161	Surf A
P34	J62	4	25	92.74	93.01	1.820	1.500	Surf A
P01	J07	5	20	92.73	92.77	0.591	0.546	Surf B
P03	J15	5	25	93.23	93.41	1.272	0.957	Surf B
P23	J63	6	18	93.11	93.11	0.584	0.607	Surf B
P27	J55	4	24	92.29	92.30	0.674	0.632	Surf B
P27	J70	7	33	92.95	92.92	1.036	1.091	Surf B
P30	J65	2	8	93.74	93.80	2.486	1.989	Surf B
P31	J71	2	8	94.12	94.15	0.517	0.616	Surf B
P32	J72	8	70	93.07	93.06	0.861	0.854	Surf B
P13	J03	1	9	92.01	92.01	1.567	1.567	Surf C
P14	J16	6	38	92.46	92.55	1.313	1.179	Surf C
P15	J44	5	18	92.68	92.68	1.465	1.584	Surf C
P16	J20	3	12	91.58	91.58	1.087	1.063	Surf C
P18	J48	3	18	91.55	91.65	1.824	2.042	Surf C
P20	J50	7	67	92.38	92.42	0.938	0.945	Surf C
P24	J56	7	56	93.12	93.20	1.078	1.001	Surf C
P26	J59	7	55	91.03	91.22	1.343	1.170	Surf C
P28	J39	4	28	93.26	93.28	1.298	1.242	Surf C
Total/Average		**158**	**972**	**92.36**	**92.41**	**1.229**	**1.121**	

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

To further investigate the potential difference in standard deviations, the Two-Sample Mann-Whitney hypothesis test was used to compare the medians of the Lot Standard Deviations results for the Interstate and Other projects. The results were not significantly different at the 0.10 level of significance. The SCDOT will need to decide whether this is sufficient evidence to warrant using different process standard deviations for Interstate and Other projects. For this report, both cases were considered.

The case of combining the Interstate and Other projects was considered first. Table 6.12 shows the same standard deviation results from Table 6.10, but with the projects combined and sorted from the smallest to largest Lot (i.e., within-lot) standard deviations. The projects are listed in increasing order of the Lot standard deviation to facilitate selecting a typical process standard deviation. The table also shows the total number of lots and tests for all density projects, the averages for both the Project standard deviation values and for the Lot standard deviation values, and percentiles based on ranked order for both the Project and Lot standard deviation values.

SCDOT can use Table 6.12 to assist in selecting the “typical” variability to use to establish specification limits. As noted in the discussion above, there is no single “correct” way to establish this value. A subjective decision must be made regarding the standard deviation to select. The percentile values shown in the table should assist in making the decision. To get a “picture” of the results in Table 6.12, Figure 6.1 shows the empirical cumulative distribution function (CDF) for the Lot standard deviation values.

As the reference lines show, there appears to be a natural break point at around a standard deviation of 1.26, which corresponds to approximately the 72^{nd} percentile. This would seem to be a logical choice for the process standard deviation if only one will be selected for both Interstate and Other paving projects.

The case of treating the Interstate and Other paving projects separately can now be considered. Table 6.13 shows the standard deviation results from Table 6.10 that are for the Interstate paving projects. The projects are sorted from the smallest to largest Lot (i.e., within-lot) standard deviations. The table also shows the total number of lots and tests for all density projects, the averages for both the Project standard deviation values and for the Lot standard deviation values, and percentiles based on ranked order for both the Project and Lot standard deviation values. Figure 6.2 shows the empirical CDF for the Lot standard deviation values.

As the reference lines show, there appears to be a natural break point at around a standard deviation of 1.16, which corresponds to approximately the 75^{th} percentile. This would seem to be a logical choice for the process standard deviation for Interstate paving projects if they are treated separately from Other paving projects.

Table 6.11. Summary of Density Test Results for Each Project Sorted by Paving Type

Number		Total Number of		Mean of *		Std Deviation*		Paving
Project	JMF	Lots	Tests	All Tests	Lot Means	Project	Lot	Type
P01	J02	4	22	93.94	93.56	0.908	0.848	Interstate
P01	J07	4	22	93.26	93.24	0.801	0.543	Interstate
P01	J07	5	20	92.73	92.77	0.591	0.546	Interstate
P01	J10	7	30	92.90	92.85	0.599	0.515	Interstate
P03	J15	5	25	93.23	93.41	1.272	0.957	Interstate
P23	J33	4	16	91.64	91.63	1.374	1.649	Interstate
P23	J63	6	18	93.11	93.11	0.584	0.607	Interstate
P26	J62	9	42	92.85	92.84	1.366	1.052	Interstate
P26	J69	16	81	93.39	93.40	1.210	1.126	Interstate
P32	J72	8	70	93.07	93.06	0.861	0.854	Interstate
P32	J74	1	6	93.20	93.20	1.417	1.417	Interstate
P32	J76	13	105	93.27	93.27	1.072	1.059	Interstate
P32	J79	24	166	92.77	92.77	0.943	0.868	Interstate
P33	J73	8	56	93.18	93.17	1.377	1.459	Interstate
P33	J77	6	40	92.67	92.72	1.486	1.161	Interstate
P34	J62	4	25	92.74	93.01	1.820	1.500	Interstate
Total / Average		**124**	**744**	**93.00**	**93.00**	**1.105**	**1.010**	**Interstate**
P01	J23	2	8	93.75	93.77	1.160	1.403	Other
P03	J04	5	30	93.73	93.59	1.388	1.053	Other
P04	J14	5	36	89.77	89.80	1.312	1.262	Other
P06	J24	5	25	91.47	91.69	1.751	0.995	Other
P06	J26	1	14	90.05	90.05	1.181	1.181	Other
P08	J11	1	8	88.65	88.65	1.203	1.203	Other
P13	J03	1	9	92.01	92.01	1.567	1.567	Other
P14	J16	6	38	92.46	92.55	1.313	1.179	Other
P15	J44	5	18	92.68	92.68	1.465	1.584	Other
P16	J20	3	12	91.58	91.58	1.087	1.063	Other
P18	J48	3	18	91.55	91.65	1.824	2.042	Other
P20	J50	7	67	92.38	92.42	0.938	0.945	Other
P24	J56	7	56	93.12	93.20	1.078	1.001	Other
P26	J59	7	55	91.03	91.22	1.343	1.170	Other
P27	J55	4	24	92.29	92.30	0.674	0.632	Other
P27	J70	7	33	92.95	92.92	1.036	1.091	Other
P28	J39	4	28	93.26	93.28	1.298	1.242	Other
P30	J65	2	8	93.74	93.80	2.486	1.989	Other
P31	J71	2	8	94.12	94.15	0.517	0.616	Other
P36	J09	5	21	92.76	92.83	1.439	1.524	Other
Total / Average		**82**	**516**	**92.17**	**92.21**	**1.303**	**1.237**	**Other**

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

Table 6.12. Summary of Density Test Results for Each Project

Number		Total Number of		Mean of *		Std Deviation*		Mix
Project	JMF	Lots	Tests	All Tests	Lot Means	Project	Lot	Type
P01	J10	7	30	92.90	92.85	0.599	0.515	Inter B
P01	J07	4	22	93.26	93.24	0.801	0.543	Surf 1C
P01	J07	5	20	92.73	92.77	0.591	0.546	Surf B
P23	J63	6	18	93.11	93.11	0.584	0.607	Surf B
P31	J71	2	8	94.12	94.15	0.517	0.616	Surf B
P27	J55	4	24	92.29	92.30	0.674	0.632	Surf B
P01	J02	4	22	93.94	93.56	0.908	0.848	Binder 1
P32	J72	8	70	93.07	93.06	0.861	0.854	Surf B
P32	J79	24	166	92.77	92.77	0.943	0.868	Surf A
P20	J50	7	67	92.38	92.42	0.938	0.945	Surf C
P03	J15	5	25	93.23	93.41	1.272	0.957	Surf B
P06	J24	5	25	91.47	91.69	1.751	0.995	Surf 1D
P24	J56	7	56	93.12	93.20	1.078	1.001	Surf C
P26	J62	9	42	92.85	92.84	1.366	1.052	Surf A
P03	J04	5	30	93.73	93.59	1.388	1.053	Interm B
P32	J76	13	105	93.27	93.27	1.072	1.059	Inter B
P16	J20	3	12	91.58	91.58	1.087	1.063	Surf C
P27	J70	7	33	92.95	92.92	1.036	1.091	Surf B
P26	J69	16	81	93.39	93.40	1.210	1.126	Surf A
P33	J77	6	40	92.67	92.72	1.486	1.161	Surf A
P26	J59	7	55	91.03	91.22	1.343	1.170	Surf C
P14	J16	6	38	92.46	92.55	1.313	1.179	Surf C
P06	J26	1	14	90.05	90.05	1.181	1.181	Surf 1C
P08	J11	1	8	88.65	88.65	1.203	1.203	Surf 1R
P28	J39	4	28	93.26	93.28	1.298	1.242	Surf C
P04	J14	5	36	89.77	89.80	1.312	1.262	Surf 1R
P01	J23	2	8	93.75	93.77	1.160	1.403	Interm B
P32	J74	1	6	93.20	93.20	1.417	1.417	Surf A
P33	J73	8	56	93.18	93.17	1.377	1.459	Inter B
P34	J62	4	25	92.74	93.01	1.820	1.500	Surf A
P36	J09	5	21	92.76	92.83	1.439	1.524	Interm B
P13	J03	1	9	92.01	92.01	1.567	1.567	Surf C
P15	J44	5	18	92.68	92.68	1.465	1.584	Surf C
P23	J33	4	16	91.64	91.63	1.374	1.649	Inter B
P30	J65	2	8	93.74	93.80	2.486	1.989	Surf B
P18	J48	3	18	91.55	91.65	1.824	2.042	Surf C
Total/Mean		**206**	**1260**	**92.54**	**92.56**	**1.215**	**1.136**	
					50%	**1.241**	**1.109**	
					60%	**1.313**	**1.179**	
					70%	**1.375**	**1.252**	
					80%	**1.439**	**1.459**	
					90%	**1.659**	**1.576**	

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

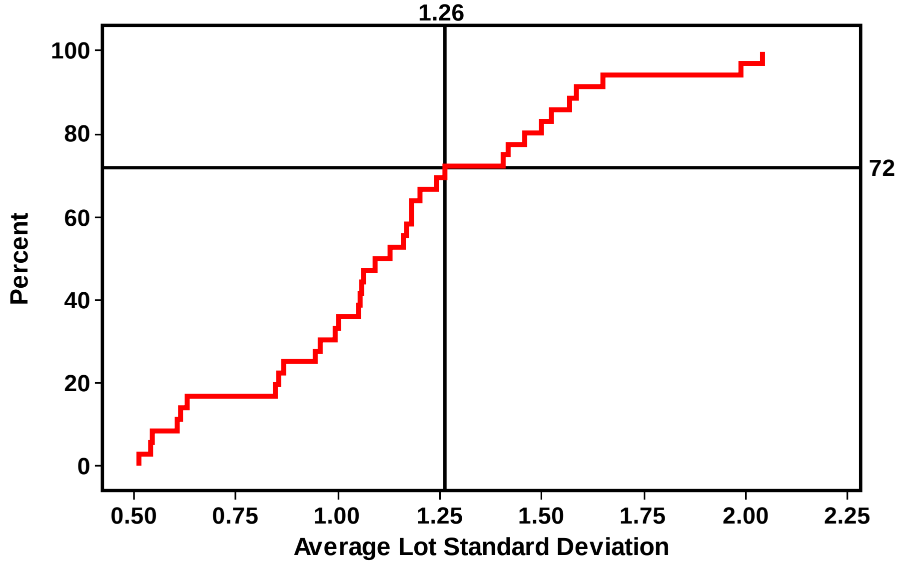

Figure 6.1. Empirical CDF for the Lot Standard Deviations for All Projects

Table 6.13. Summary of Density Test Results for Interstate Paving Projects

Number		Total Number of		Mean of *		Std Deviation*	
Project	**JMF**	**Lots**	**Tests**	**All Tests**	**Lot Means**	**Project**	**Lot**
P01	J10	7	30	92.9	92.85	0.599	0.515
P01	J07	4	22	93.26	93.24	0.801	0.543
P01	J07	5	20	92.73	92.77	0.591	0.546
P23	J63	6	18	93.11	93.11	0.584	0.607
P01	J02	4	22	93.94	93.56	0.908	0.848
P32	J72	8	70	93.07	93.06	0.861	0.854
P32	J79	24	166	92.77	92.77	0.943	0.868
P03	J15	5	25	93.23	93.41	1.272	0.957
P26	J62	9	42	92.85	92.84	1.366	1.052
P32	J76	13	105	93.27	93.27	1.072	1.059
P26	J69	16	81	93.39	93.40	1.210	1.126
P33	J77	6	40	92.67	92.72	1.486	1.161
P32	J74	1	6	93.20	93.20	1.417	1.417
P33	J73	8	56	93.18	93.17	1.377	1.459
P34	J62	4	25	92.74	93.01	1.820	1.500
P23	J33	4	16	91.64	91.63	1.374	1.649
Total / Average		**124**	**744**	**93.00**	**93.00**	**1.105**	**1.010**
					50%	**1.141**	**1.005**
					60%	**1.272**	**1.059**
					70%	**1.370**	**1.144**
					80%	**1.377**	**1.417**
					90%	**1.452**	**1.480**

***** see Table 6.10 for explanations for these terms.

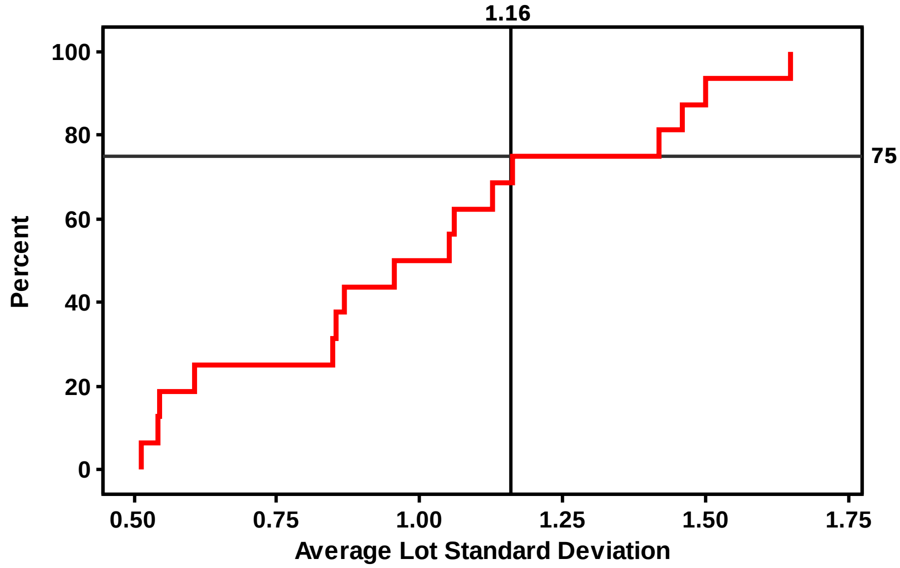

Figure 6.2. Empirical CDF for the Lot Standard Deviations for Interstate Projects

Table 6.14 shows the standard deviation results from Table 6.10 that are for the Other paving projects. Figure 6.3 shows the empirical CDF for the Lot standard deviation values.

As the reference lines show, there may be a natural break point at around a standard deviation of 1.20, which corresponds to approximately the 75th percentile. Although, the 80th percentile, with a standard deviation of 1.26, is another possible choice. Therefore, somewhere in the range 1.20 to 1.26 would seem to be a logical choice for the process standard deviation for Interstate paving projects if they are treated separately from Other paving projects.

The results from Figures 6.1-6.3 show that possible choices for within-lot process standard deviation are 1.16 for Interstate paving projects, 1.20 to 1.26 for Other paving projects, and 1.25 if Interstate and Other projects are combined and treated as one data set. SCDOT will need to reach its own decision regarding whether or not to separate Interstate and Other paving projects, and then decide what typical standard deviation or deviations to use. For the remaining calculations in this report, a value of 1.20 will be used as the standard deviation to represent both Interstate and Other paving projects.

This value, as well as some of the various standard deviation values in Table 6.12, may seem high if compared with values that may have been calculated on some past projects. This is at least partially due to the fact that the values in the table have been adjusted for bias, whereas the lot standard deviation values do not need to be adjusted for bias when calculating PWL. The average lot standard deviation that would be expected in the field would depend upon the sample size and can be calculated using equation 6.5. For example, if the typical lot size were n = 5, which corresponds to a c_4 value of 0.9400 (see Table 5.1), then the selected Lot standard deviation of 1.20 would correspond to an average sample standard deviation of

1.20 × 0.9400 = 1.128. Different corresponding values would be expected for different sample sizes.

Table 6.14. Summary of Density Test Results for Other Paving Projects

Number		Total Number of		Mean of *		Std Deviation*	
Project	**JMF**	**Lots**	**Tests**	**All Tests**	**Lot Means**	**Project**	**Lot**
P31	J71	2	8	94.12	94.15	0.517	0.616
P27	J55	4	24	92.29	92.30	0.674	0.632
P20	J50	7	67	92.38	92.42	0.938	0.945
P06	J24	5	25	91.47	91.69	1.751	0.995
P24	J56	7	56	93.12	93.20	1.078	1.001
P03	J04	5	30	93.73	93.59	1.388	1.053
P16	J20	3	12	91.58	91.58	1.087	1.063
P27	J70	7	33	92.95	92.92	1.036	1.091
P26	J59	7	55	91.03	91.22	1.343	1.170
P14	J16	6	38	92.46	92.55	1.313	1.179
P06	J26	1	14	90.05	90.05	1.181	1.181
P08	J11	1	8	88.65	88.65	1.203	1.203
P28	J39	4	28	93.26	93.28	1.298	1.242
P04	J14	5	36	89.77	89.80	1.312	1.262
P01	J23	2	8	93.75	93.77	1.160	1.403
P36	J09	5	21	92.76	92.83	1.439	1.524
P13	J03	1	9	92.01	92.01	1.567	1.567
P15	J44	5	18	92.68	92.68	1.465	1.584
P30	J65	2	8	93.74	93.80	2.486	1.989
P18	J48	3	18	91.55	91.65	1.824	2.042
Total / Average		**82**	**516**	**92.17**	**92.21**	**1.303**	**1.237**
					50%	**1.305**	**1.090**
					60%	**1.325**	**1.174**
					70%	**1.403**	**1.188**
					80%	**1.485**	**1.290**
					90%	**1.758**	**1.569**

***** see Table 6.10 for explanations for these terms.

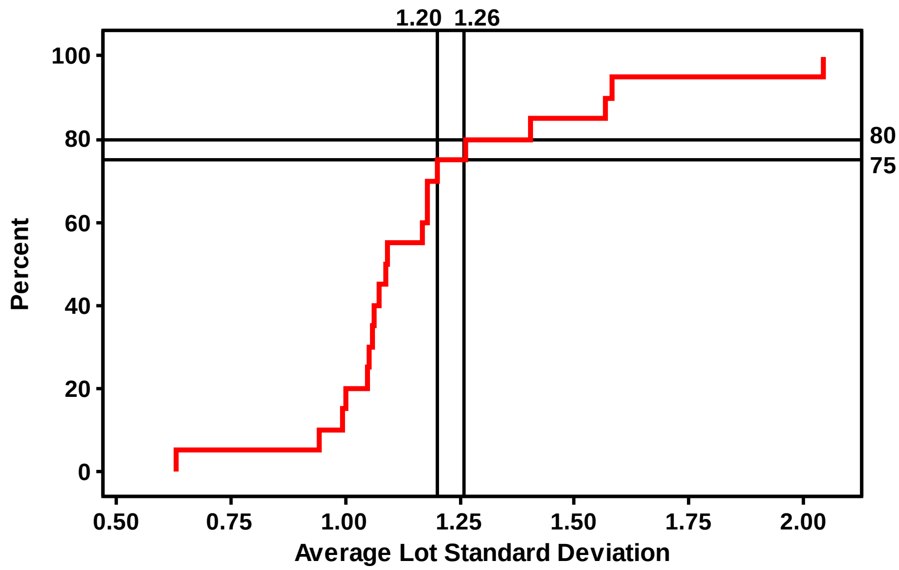

Figure 6.3. Empirical CDF for the Lot Standard Deviations for Other Projects

PWL Values for the Density Projects. One potential point of concern with the values in Table 6.12 was the relatively low value for the average densities on the various projects. These individual project average values ranged from a low of 88.65 to a high of 94.12, and the average for all projects was around 92.4. The specification “target” values for density were 94.0 for Interstate paving and 93.0 for Other paving. To further investigate how well the projects for which data were obtained met the specification requirements, lot PWL values were calculated. For each project, the PWL value for each lot was calculated and the average PWL for all lots on the project was also calculated. The average PWL values for each project are shown in Table 6.15 for Interstate paving projects and Table 6.16 for Other paving projects. Appendix C includes the PWL values for each individual lot on each project.

As shown in Table 6.15, the average lot PWL estimates for the Interstate paving projects vary from 37.76 to 99.52. Of concern is the fact that 11 of the 16 projects had average PWL values less than 90, which is the minimum value to receive 100 percent payment. The average PWL values in Table 6.16 for Other paving projects vary from 0.16 to 100, and 12 of the 20 projects had PWL values less than 90. Furthermore, 3 of the projects had PWL values less than 20, which is the value that triggers the remove and replace provision.

Table 6.15. Summary of Density Lot PWL Values for Each Interstate Paving Project

Project Number	JMF Number	No. of Lots	Average Lot Mean	Average Lot StDev	Avg Lot PWL	Mix Type
P01	J02	4	93.56	0.810	98.50	Binder 1
P01	J10	7	92.85	0.478	96.42	Interm B
P23	J33	4	91.63	1.502	37.76	Interm B
P32	J76	13	93.27	1.009	83.58	Interm B
P33	J73	8	93.17	1.394	72.47	Interm B
Total / Average		**36**	**93.01**	**1.030**	**77.75**	**Interm**
P01	J07	4	93.24	0.515	96.47	Surf 1C
P26	J62	9	92.84	0.987	73.49	Surf A
P26	J69	16	93.40	1.057	83.86	Surf A
P32	J74	1	93.20	1.348	76.06	Surf A
P32	J79	24	92.77	0.826	75.01	Surf A
P33	J77	6	92.72	1.109	66.63	Surf A
P34	J62	4	93.01	1.426	70.43	Surf A
P01	J07	5	92.77	0.4942	90.83	Surf B
P03	J15	5	93.41	0.892	85.06	Surf B
P23	J63	6	93.11	0.538	99.52	Surf B
P32	J72	8	93.06	0.821	83.05	Surf B
Total / Average		**88**	**93.01**	**0.888**	**81.06**	**Surface**
Total / Average		**124**	**93.01**	**0.928**	**80.57**	**All**

Summary

Analyses were conducted on project test results for Density. The primary goal of these analyses was to determine a value to use to represent the typical variability for Density. This is a subjective decision that ultimately must be made by SCDOT. Some potential values were identified during the analyses, and these are used as examples for additional evaluations in subsequent chapters.

The range of values that SCDOT might consider for the typical Density standard used to evaluate existing specification limits includes 1.16% to 1.26%.

Important Note of Caution: As noted in Chapter 5, a STD may choose to establish the typical standard deviation value to use based on "data from a number of past projects that it considered acceptable." Considering that nearly two-thirds of the projects from which density data were obtained had average project PWL values less than the AQL of 90 PWL, SCDOT must decide whether or not it wishes to establish the typical project standard deviation based on these data.

If SCDOT believes that these projects represent the state-of-the-art regarding the process capability of a typical contractor, then SCDOT will need to re-evaluate their target density value and their density specification limits. If SCDOT believes that these projects do not represent what a typical contractor is capable of providing, then additional data from other representative projects will need to be obtained for analysis.

CHAPTER 7 — ANALYSIS OF PLANT ACCEPTANCE TEST RESULTS

Background

This chapter summarizes and discusses the results of analyses to determine appropriate standard deviation values to represent the variability of each of the plant acceptance characteristics used by SCDOT. These include asphalt content, air voids, and VMA. These variabilities are necessary to evaluate the appropriateness of the existing specification limits.

Data Obtained for Analysis

All of the plant acceptance test data that were provided are included in Appendix A. A total of 1,775 asphalt content tests were provided from 30 different projects, with some projects having multiple HMA mixes involved. Since no voids testing was done on Base course mixes, open graded friction course (OGFC) mixes, or Surface E mixes, there were only 1,341 air voids and VMA tests provided. The numbers of tests for the various projects and JMF mix designs are presented in Tables 7.1-7.5.

In the tables, each project is identified with a unique number, ranging from P01 to P36. Each of these numbered projects corresponds with a unique SCDOT project file number. Each job mix formula (JMF) is identified with a unique number, ranging from J01 to J83.

Table 7.1. Summary of Asphalt Content Data for Base Course

Mix Type	Project	JMF	Lots in JMF	Tests in JMF	Lots on Project	Tests on Project
AABC 1	P01	J01	8	22	11	31
		J06	3	9		
Base A	P01	J18	33	82	46	109
		J21	15	27		
	P02	J17	6	17	19	47
		J28	13	30		
	P26	J45	4	12	4	12
	P27	J66	11	11	11	11
Base B	P28	J47	10	14	10	14
Base C	P24	J57	6	12	6	12
Total			**109**	**236**	**107**	**236**

Table 7.2. Summary of Asphalt Content Data for Intermediate Course

Mix Type	Project	JMF	Lots in JMF	Tests in JMF	Lots on Project	Tests on Project
Binder 1	P01	J02	4	12	4	12
	P04	J08	11	21	11	21
Intermediate B	P01	J10	18	39	24	51
		J23	6	12		
	P02	J04	14	30	32	64
		J09	18	34		
	P27	J60	15	15	15	15
	P32	J76	12	43	12	43
	P33	J73	8	25	8	25
Intermediate C	P05	J27	8	15	8	15
	P10	J31	41	77	61	114
		J37	12	22		
		J82	8	15		
	P17	J22	6	11	6	11
	P21	J34	3	8	3	8
	P24	J51	15	23	15	23
	P25	J29	7	12	7	12
	P27	J53	16	19	16	19
	P28	J42	13	15	13	15
Total			**235**	**448**	**235**	**448**

Table 7.3. Summary of Asphalt Content Data for Surface Course

Mix Type	Project	JMF	Lots in JMF	Tests in JMF	Lots on Project	Tests on Project
OGFC	P26	J68	4	13	4	13
	P33	J78	4	13	4	13
Surface 1C	P01	J07	5	16	5	16
Surface 1D	P06	J24	5	15	5	15
Surface 1R	P04	J14	5	17	5	17
Surface 3	P07	J30	19	40	19	40
Surface 4	P10	J12	13	19	13	19
Surface A	P26	J62	9	31	27	84
		J69	18	53		
	P32	J79	24	96	24	96
	P33	J77	6	22	6	22
	P34	J62	7	28	7	28
Surface B	P01	J07	4	14	4	14
	P02	J15	6	18	6	18
	P27	J55	5	15	14	42
		J71	9	27		
	P30	J65	4	8	4	8
	P32	J72	8	34	8	34
Surface C	P01	J19	14	18	14	18
	P02	J05	6	8	20	26
		J13	14	18		
	P11	J41	4	10	4	10
	P12	J38	6	14	6	14
	P13	J03	8	16	16	35
		J43	8	19		
	P14	J16	13	32	13	32
	P16	J20	3	9	3	9
	P18	J48	7	12	7	12
	P20	J50	17	46	17	46
	P21	J39	6	15	6	15
	P24	J56	18	40	24	50
		J67	6	10		
	P26	J58	12	13	12	13
	P28	J39	9	24	9	24
	P29	J59	9	26	9	26
	P34	J81	7	13	7	13
	P35	J32	6	14	22	50
		J38	16	36		
Surface CM	P09	J35	3	9	6	17
		J83	3	8		
	P27	J61	9	9	9	9
Surface D	P05	J25	8	8	8	8
	P19	J49	7	20	7	20
	P22	J54	3	12	3	12
	P24	J64	7	13	7	13
	P25	J36	6	10	6	10
Surface E	P05	J40	5	9	5	9
	P26	J52	30	58	30	58
	P32	J46	31	41	31	41
	P33	J75	10	10	10	10
	P34	J80	6	12	6	12
Total			**472**	**1091**	**472**	**1091**

Table 7.4. Summary of Air Voids and VMA Data for Intermediate Course

Mix Type	Project	JMF	Lots in JMF	Tests in JMF	Lots on Project	Tests on Project
Binder 1	P01	J02	4	8	4	8
	P04	J08	5	10	5	10
Intermediate B	P01	J10	18	39	24	51
		J23	6	12		
	P02	J04	14	30	32	64
		J09	18	34		
	P27	J60	15	15	15	15
	P32	J76	12	43	12	43
	P33	J73	8	25	8	25
Intermediate C	P05	J27	8	15	8	15
	P10	J31	41	77	61	114
		J37	12	22		
		J82	8	15		
	P17	J22	6	11	6	11
	P21	J34	3	8	3	8
	P25	J29	7	12	7	12
	P27	J53	14	15	14	15
	P28	J42	13	15	13	15
Total			**212**	**406**	**212**	**406**

Table 7.5. Summary of Air Voids and VMA Data for Surface Course

Mix Type	Project	JMF	Lots in JMF	Tests in JMF	Lots on Project	Tests on Project
Surface 1C	P01	J07	5	16	5	16
Surface 1D	P06	J24	5	15	5	15
Surface 1R	P04	J14	5	17	5	17
Surface 3	P07	J30	19	40	19	40
Surface 4	P10	J12	13	19	13	19
Surface A	P26	J62	9	31	27	84
		J69	18	53		
	P32	J79	24	96	24	96
	P33	J77	6	22	6	22
	P34	J62	7	28	7	28
Surface B	P01	J07	4	14	4	14
	P02	J15	6	18	6	18
	P27	J55	5	15	14	42
		J71	9	27		
	P30	J65	4	8	4	8
	P32	J72	8	34	8	34
Surface C	P01	J19	14	18	14	18
	P02	J05	6	8	20	26
		J13	14	18		
	P11	J41	4	10	4	10
	P12	J38	6	14	6	14
	P13	J03	8	16	16	35
		J43	8	19		
	P14	J16	13	32	13	32
	P16	J20	3	9	3	9
	P18	J48	7	12	7	12
	P20	J50	17	46	17	46
	P21	J39	6	15	6	15
	P24	J56	18	40	24	50
		J67	6	10		
	P26	J58	12	13	12	13
	P28	J39	9	24	9	24
	P29	J59	9	26	9	26
	P34	J81	7	13	7	13
	P35	J32	6	14	24	50
		J38	16	36		
Surface CM	P09	J35	3	9	6	17
		J83	3	8		
	P27	J61	9	9	9	9
Surface D	P05	J25	8	8	8	8
	P19	J49	7	20	7	20
	P22	J54	3	12	3	12
	P24	J64	7	13	7	13
	P25	J36	6	10	6	10
Total			**382**	**935**	**384**	**935**

Plant Test Data Analyses

Unlike density, the plant test data had specific target values. It was not possible to compare directly the actual test results since each project and each mix design had its own set of target values. It was possible, however, to normalize the data by considering the asphalt content (AC), air voids (AV), and VMA values as differences from their target values. This made it possible to make comparisons among the various lots, mix designs, projects, mix types, and courses that could not be done on the actual test values.

Asphalt Content

Comparing Courses. The specifications for AC had one set of allowable tolerances for "mainline paving." Unlike density, the AC tolerances did not differ between Interstate and Other paving projects. There were, however, different tolerances for Base, Intermediate, and Surface courses. These tolerances were 0.36 for Surface course, 0.43 for Intermediate course, and 0.50 for Base course. To evaluate whether or not different tolerances were warranted for different courses, the variances of the three courses were compared statistically using Bartlett's test and Levene's test. Bartlett's test assumes that the data are from normal distributions, whereas Levene's test applies for any continuous distribution. Table 7.6 shows the results of the comparisons.

Table 7.6. Summary of AC Comparisons among Courses

Course	No. of Tests	St Dev	P-value* Bartlett's	P-value* Levene's
Base	236	0.2500	**0.011**	**0.000**
Intermediate	448	0.2372		
Surface	1091	0.1960		

* Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

The results in Table 7.6 show that, with a P-value of 0.011 for Bartlett's test and 0.000 for Levene's test, there is essentially no chance that the variabilities are the same for the three courses. To further investigate the variabilities, Figure 7.1 shows the standard deviation along with its 95% confidence interval for each course. Since the confidence interval for Surface course does not overlap at all with those for Base and Intermediate courses, it is apparent that the AC for Surface course has less variability than for Intermediate and Base courses. While the standard deviation for Intermediate Course is less than that for Base course, due to the overlap of the confidence intervals, it cannot be concluded that the Base course standard deviation is larger than the standard deviation for Intermediate course.

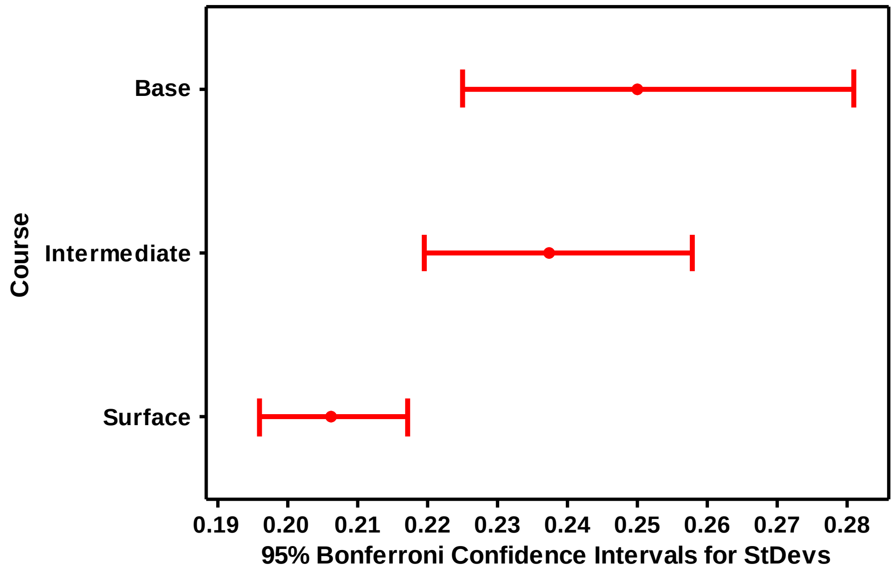

Figure 7.1. Comparison of AC Standard Deviations for Each Course

Comparing Mix Types within Course. The next question to consider is whether it is appropriate to use the same specification tolerances for all mix types within a given course. When establishing the allowable tolerances it is the standard deviation that is most important.

Base Course Mixes. Table 7.7 shows the results of comparisons among the AC variabilities for the different types of Base course mixes. The results are mixed, with Bartlett's test, with a P-value of 0.013, showing the variances different, and Levene's test showing them not different at the 0.10 significance level.

Table 7.7. Summary of AC Comparisons of Base Course Mix Types

Mix Type	No. of Tests	St Dev	P-value* Bartlett's	P-value* Levene's
AABC 1	31	0.2206	**0.013**	0.100
Base A	179	0.2602		
Base B	14	0.2361		
Base C	12	0.1085		

* Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

From Table 7.7, it is apparent that if the variabilities are different it is most likely due to the low value for the Base C mix. All of the other values are more than twice as large as the Base C value.

To further investigate the variabilities, Figure 7.2 shows the standard deviation along with its 95% confidence interval for each Base course mix type. The large sample size for the Base A mix is apparent in its narrow confidence interval. The small Base C standard deviation is apparent, but due to the small sample size its confidence interval overlaps two of the other confidence intervals.

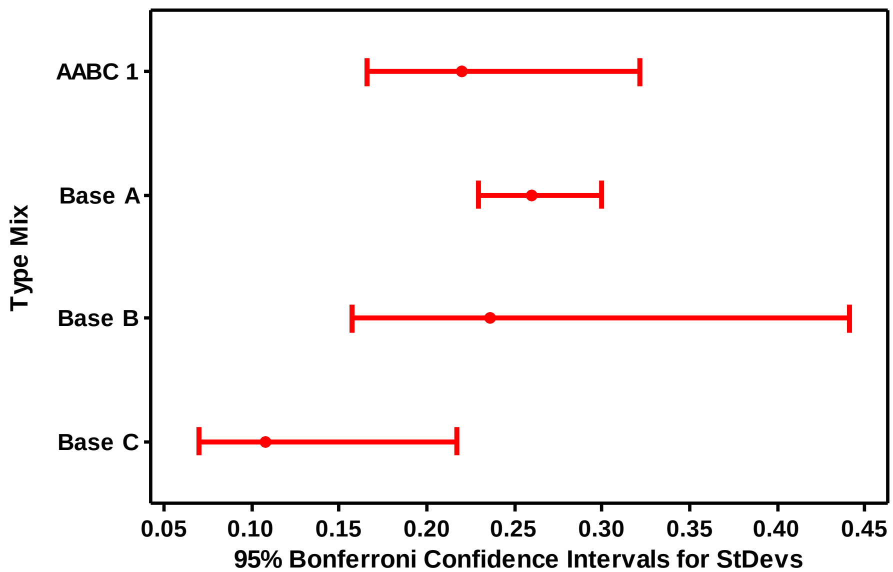

Figure 7.2. Comparison of AC Standard Deviations for Each Base Course Mix Type

To investigate further, Base C was eliminated and the variabilities of the other three mixes were compared. The results are shown in Table 7.8. Without Base C, there is strong evidence to consider the standard deviations to be the same for Base course mixes.

Table 7.8. Summary of AC Comparisons of Base Course Mix Types without Base C Mix

Mix Type	No. of Tests	St Dev	P-value* Bartlett's	P-value* Levene's
AABC 1	31	0.2206	0.495	0.699
Base A	179	0.2602		
Base B	14	0.2361		

***** Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

Intermediate Course Mixes. Table 7.9 shows the results of comparisons among the AC variabilities for the different types of Intermediate course mixes. The results, with Bartlett's test having a P-value of 0.425 and Levene's test having a P-value of 0.582, show no evidence that the standard deviations are different for the different mix types. Figure 7.3 shows the standard deviation along with its 95% confidence interval for each Intermediate course mix type.

Table 7.9. Summary of AC Comparisons of Intermediate Course Mix Types

Mix Type	No. of Tests	St Dev	P-value* Bartlett's	P-value* Levene's
Binder 1	33	0.2598	0.425	0.582
Intermediate B	198	0.2337		
Intermediate C	217	0.2216		

* Values in bold are statistically significantly different at the α = 0.05 level.

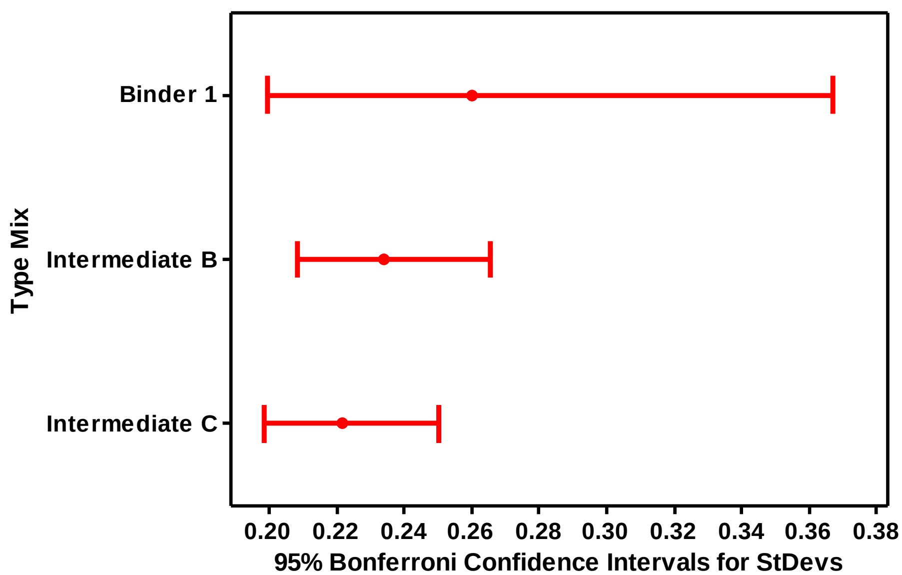

Figure 7.3 Comparison of AC Standard Deviations for Each Intermediate Course Mix Type

Surface Course Mixes. Table 7.10 shows the results of comparisons among the AC variabilities for the different types of Surface course mixes. The results show clearly that the standard deviations are not equal for all 12 mix types. Figure 7.4 shows the standard deviation along with its 95% confidence interval for each Surface course mix type. It is apparent that the OGFC mix is markedly larger than any of the other mixes. The Surface 4 mix also seems to be above the range of the other values. If these two projects are eliminated the Bartlett's P-value is still 0.000, but Levene's P-value rises to 0.111.

Table 7.10. Summary of AC Comparisons of Surface Course Mix Types

Mix Type	No. of Tests	St Dev	P-value* Bartlett's	P-value* Levene's
OGFC	26	0.3872	**0.000**	**0.000**
Surface 1C	16	0.1773		
Surface 1D	15	0.1701		
Surface 1R	17	0.1907		
Surface 3	40	0.1454		
Surface 4	19	0.2743		
Surface A	230	0.1925		
Surface B	116	0.1758		
Surface C	393	0.2182		
Surface CM	26	0.1482		
Surface D	63	0.2027		
Surface E	130	0.1586		

* Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

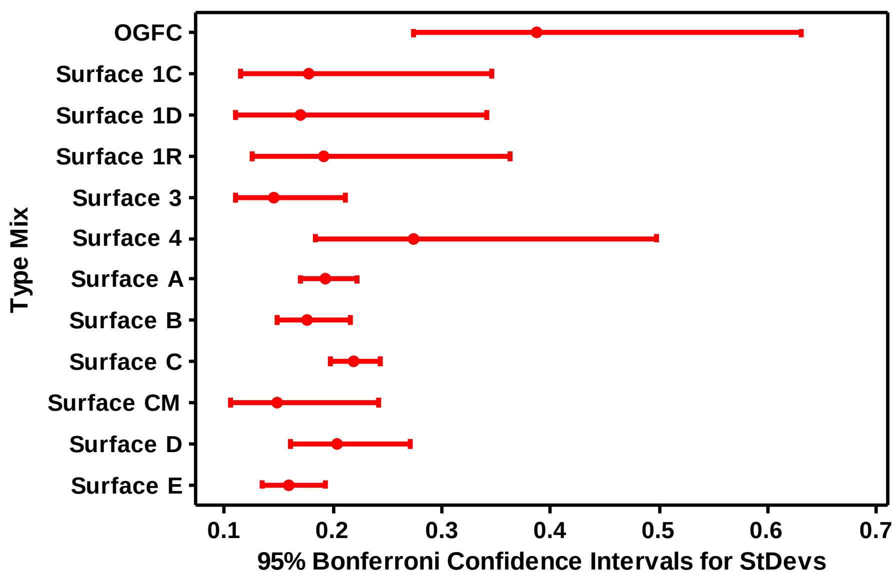

Figure 7.4 Comparison of AC Standard Deviations for Each Surface Course Mix Type

Caveat. None of the standard deviation values shown in Tables 7.6-7.10 are the appropriate standard deviation to use to represent the process standard deviation for AC. These calculations were done simply for exploratory purposes. Aggregating the data as is done in these tables is not appropriate for establishing specification limits since the specification limits are based on lot-by-lot acceptance, or at least on acceptance of a project.

Typical Variability Values for AC. As noted above, since the SCDOT specification is based on lot-by-lot acceptance, the AC variability that is used to evaluate the specification limits must be that which is appropriate for a typical lot. To determine this, the individual standard deviation values for each lot were calculated and then these lot standard deviations were averaged to get the "within-lot" standard deviation for each project. This was done using the procedure that is described for density in Chapter 6. As noted in Chapter 6, this within-lot standard deviation does not take into consideration any target miss variability that may be present.

To provide the option to consider using the total project as the payment lot, the total project AC standard deviation was also calculated for each project. As noted above, this "project" standard deviation could also be used as one way of trying to incorporate any target miss variability that might be present in the contractor's process.

Appendix B includes the necessary calculations for each project for which AC data were obtained. These calculations were used to arrive at the project standard deviations that were used to establish the typical process variability for AC.

Projects with Multiple JMFs. Before compiling all of the within-lot and project variabilities, a decision had to be made regarding how to deal with projects on which more than one JMF was used for the same mix type and course. Should each JMF be treated as a separate project, or should the multiple JMF results be combined together as one project? To help make this decision, the projects with multiple JMFs were examined. Table 7.11 shows the projects (extracted from Tables 7.1-7.5) that had multiple JMFs for the same mix type.

None of the multi-mix design projects showed a difference in variability for the Base course and Intermediate course. Two of the seven Surface course projects showed significantly different variabilities. So, in a total of 11 out of 13 projects no difference was detected between the multiple mix designs on the project. Also, in the project data a new lot was established in nearly every case that the JMF changed. This would argue in favor of treating the JMFs as separate projects when determining the within-lot standard deviations.

However, if a total project is being used as the payment lot, then the data from the multiple JMFs would be combined when calculating the standard deviation to use for payment determination. This would argue in favor of combining the separate JMFs into a single project. For consistency in presentation and in comparing results, it was decided to treat the separate JMFs as separate projects when calculating standard deviations and when presenting the results.

Table 7.11. Projects with More than One JMF for the Same Mix Type for AC

Project	JMF	No. of Lots	No. of Tests	St Dev	F-Test P-value*
Base Course					
P01	J01	8	22	0.229	0.840
	J06	3	9	0.210	
P01	J18	33	82	0.243	0.919
	J21	15	27	0.255	
P02	J17	6	17	0.294	0.389
	J28	13	30	0.245	
Intermediate Course					
P01	J10	18	39	0.200	0.056
	J23	6	12	0.304	
P02	J04	14	30	0.224	0.614
	J09	18	34	0.246	
P10	J31	41	77	0.257	0.238**
	J37	12	22	0.204	
	J82	8	15	0.193	
Surface Course					
P26	J62	9	31	0.178	0.610
	J69	18	53	0.194	
P27	J55	5	15	0.191	0.427
	J71	9	27	0.161	
P02	J05	6	8	0.145	0.070
	J13	14	18	0.291	
P13	J03	8	16	0.269	**0.025**
	J43	8	19	0.153	
P24	J56	18	40	0.249	**0.000**
	J67	6	10	0.595	
P35	J32	6	14	0.148	0.387
	J38	16	36	0.124	
P09	J35	3	9	0.144	0.473
	J83	3	8	0.189	

* Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

** Bartlett's Test

Determining the Typical Process Variability for AC. Table 7.12 shows the standard deviation results for AC for all projects for which data were obtained. The projects are sorted by mix type. The "Lot" standard deviation is the average of the unbiased standard deviation estimates for each lot on the project. The "Project" standard deviation is the standard deviation of all the individual test results for the total project. The table also shows the total number of lots and tests for each project, the mean for all tests on the project, and the mean of the individual project lot means. Note that some projects do not have an average Lot standard deviation. This is due to the fact that there was only one AC test for each lot on the project. With only one test it is not possible to calculate a standard deviation for the lot.

One thing to consider from the results in Table 7.12 is whether to treat the Base course results, the Intermediate course results, and the Surface course results as separate from one another or to combine them. By observation, the standard deviation values for the three courses are in the same general range. Also, the Two-Sample Mann-Whitney hypothesis test was used to make all pair-wise comparisons of the medians of the Means of Lot Means results for each course. The same test was used to make pair-wise comparisons of the medians of the Lot Standard Deviations. The Mann-Whitney test does not require the data to come from normally distributed populations. It assumes that the populations of interest have the same shape and that the populations are independent. The results of the Mann-Whitney tests are shown in Table 7.13.

The medians of the Lot Means for Intermediate and Surface courses are different at the 0.041 significance level. The medians of the Lot Std Devs show more evidence of differing between courses, with the Base and Surface courses different at the 0.015 level and the Intermediate and Surface courses different at the 0.056 level. The results support the use of different AC specification limits for different courses.

Table 7.12. Summary of AC Test Results for Each Project

Number		Total Number of		Mean of *		Std Deviation**	
Project	JMF	Lots	Tests	All Tests	Lot Means	Project	Lot
Base Course							
P01	J01	8	22	0.0673	0.0398	0.2318	0.1933
P01	J06	3	9	0.0978	0.0942	0.2163	0.2512
P01	J18	33	82	-0.0480	-0.0564	0.2435	0.2237
P01	J21	15	27	0.1085	0.1324	0.2574	0.3360
P02	J17	6	17	-0.0147	0.0022	0.2983	0.3225
P02	J28	13	30	0.0383	0.0404	0.2475	0.1832
P24	J57	6	12	0.1375	0.1375	0.1110	0.0517
P26	J45	4	12	0.0620	0.0423	0.3723	0.3406
P27	J66	11	11	0.0455	0.0455	0.2035	—
P28	J47	10	14	-0.0250	-0.0385	0.2407	0.2193
Total/Average		**109**	**236**	**0.0469**	**0.0439**	**0.2422**	**0.2357**
Intermediate Course							
P01	J02	4	12	0.1217	0.1150	0.1734	0.1915
P01	J10	18	39	0.0036	0.0162	0.2016	0.1559
P01	J23	6	12	0.1050	0.0936	0.3111	0.4165
P02	J04	14	30	0.1290	0.1815	0.2260	0.2131
P02	J09	18	34	0.0218	0.1190	0.2479	0.2058
P04	J08	11	21	0.1800	0.1959	0.3053	0.2916
P05	J27	8	15	-0.1187	-0.1200	0.1290	0.1494
P10	J31	41	77	0.0129	0.0222	0.2583	0.2984
P10	J37	12	22	0.0250	0.0396	0.2067	0.1764
P10	J82	8	15	-0.0313	-0.0238	0.1963	0.1291
P17	J22	6	11	0.0036	-0.0175	0.2648	0.2322
P21	J34	3	8	0.1025	0.0467	0.1861	0.1294
P24	J51	15	23	0.0287	0.0457	0.1627	0.1806
P25	J29	7	12	-0.1567	-0.1614	0.2091	0.2127
P27	J53	16	19	-0.0000	0.0134	0.2079	0.1566
P27	J60	15	15	0.2613	0.2613	0.2445	—
P28	J42	13	15	0.0847	0.0877	0.1950	0.1241
P32	J76	12	43	0.0935	0.0920	0.2078	0.1813
P33	J73	8	25	0.0520	0.0783	0.2283	0.2585
Total/Average		**235**	**448**	**0.0483**	**0.0571**	**0.2190**	**0.2057**
Continued							

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

Table 7.12. Summary of AC Test Results for Each Project (*continued*)

Number		Total Number of		Mean of *		Std Deviation**	
Project	JMF	Lots	Tests	All Tests	Lot Means	Project	Lot
Surface Course							
P01	J07	9	30	-0.0243	-0.0212	0.1808	0.1811
P01	J19	14	18	0.0828	0.1007	0.1435	0.1462
P02	J05	6	8	-0.0050	-0.0117	0.1506	0.0798
P02	J13	14	18	-0.0572	-0.0318	0.2949	0.1130
P02	J15	6	18	-0.0122	0.0501	0.2058	0.1750
P04	J14	5	17	0.0618	0.0575	0.1937	0.2051
P05	J25	8	8	-0.1313	-0.1313	0.1884	—
P05	J40	5	9	-0.1344	-0.1180	0.1756	0.1726
P06	J24	5	15	0.0647	0.0647	0.1732	0.1438
P07	J30	19	40	-0.0940	-0.0971	0.1463	0.1034
P09	J35	3	9	-0.0178	-0.0178	0.1492	0.1349
P09	J83	3	8	-0.0413	-0.0333	0.1954	0.1891
P10	J12	13	19	-0.0374	-0.0373	0.2781	0.2083
P11	J41	4	10	0.0710	0.0721	0.1731	0.1190
P12	J38	6	14	0.0536	0.0676	0.1820	0.1592
P13	J03	8	16	-0.0100	-0.0458	0.2735	0.3268
P13	J43	8	19	-0.0011	-0.0020	0.1554	0.1305
P14	J16	13	32	-0.1769	-0.1827	0.2113	0.1937
P16	J20	3	9	-0.1811	-0.1811	0.2351	0.2103
P18	J48	7	12	0.1117	0.1164	0.2138	0.1701
P19	J49	7	20	-0.0775	-0.0788	0.2602	0.2105
P20	J50	17	46	0.0202	0.0484	0.1923	0.1648
P21	J39	6	15	0.0007	-0.0026	0.1283	0.1078
P22	J54	3	12	0.0467	0.0647	0.0845	0.0609
P24	J56	18	40	0.0000	0.0759	0.2507	0.2161
P24	J64	7	13	0.1431	0.1443	0.0574	0.0473
P24	J67	6	10	0.0590	0.1667	0.6117	0.0682
P25	J36	6	10	0.0570	0.0458	0.2081	0.2906
P26	J52	30	58	-0.0621	-0.0525	0.1452	0.1211
P26	J58	12	13	-0.0031	0.0050	0.1707	0.2481
P26	J62	9	31	0.0145	0.0082	0.1791	0.1741
P26	J68	4	13	-0.0970	-0.0879	0.4339	0.4153
P26	J69	18	53	0.0029	-0.0201	0.1949	0.1531
P27	J55	5	15	0.1287	0.1287	0.1947	0.2122
P27	J61	9	9	-0.0589	-0.0589	0.1290	—
P27	J71	9	27	0.0559	0.0597	0.1621	0.1882
P28	J39	9	24	0.0429	0.0149	0.1542	0.1486
P29	J59	9	26	-0.0458	-0.0494	0.1427	0.1296
P30	J65	4	8	-0.0100	0.0000	0.0905	0.1000
P32	J46	31	41	-0.0220	-0.0157	0.1792	0.1736
P32	J72	8	34	0.0706	0.0773	0.1740	0.1819
P32	J79	24	96	0.1139	0.1106	0.1622	0.1253
P33	J75	10	10	-0.0150	-0.0150	0.1885	—

Continued

Table 7.12. Summary of AC Test Results for Each Project (*continued*)

Number		Total Number of		Mean of *		Std Deviation**	
Project	JMF	Lots	Tests	All Tests	Lot Means	Project	Lot
P33	J77	6	22	0.0973	0.0988	0.2472	0.2295
P33	J78	4	13	0.0492	0.0419	0.3541	0.3556
P34	J62	7	28	-0.0232	-0.0225	0.2043	0.1496
P34	J80	7	12	-0.0058	-0.0286	0.1030	0.0806
P34	J81	7	13	0.0923	0.0971	0.2117	0.2600
P35	J32	6	14	-0.0507	-0.0294	0.1513	0.1347
P35	J38	16	36	0.0536	0.0495	0.1249	0.1171
Total/Average		**472**	**1091**	**0.0020**	**0.0079**	**0.1962**	**0.1708**

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

Table 7.13. Results of Mann-Whitney Tests on the AC Lot Means and Lot Std Devs

Course	No. of Lots	Median of Lot Means	P-Value*	No. of Lots	Median of Lot Std Devs	P-Value*
Base	10	0.0413	0.697	9	0.2237	0.143
Intermediate	19	0.0467		18	0.1864	
Base	10	0.0413	0.317	9	0.2237	0.015
Surface	50	-0.0010		47	0.1648	
Intermediate	19	0.0467	0.041	18	0.1864	0.056
Surface	50	-0.0010		47	0.1648	

* Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

Base Course. Table 7.14 shows Lot standard deviation results for Base course (from Table 7.12), but with the projects sorted from the smallest to largest Lot (i.e., within-lot) standard deviations. The projects are listed in increasing order of the Lot standard deviation to facilitate selecting a typical process standard deviation. The table also shows the total number of lots and tests for all AC projects, the averages for both the Project standard deviation values and for the Lot standard deviation values, and percentiles based on ranked order for both the Project and Lot standard deviation values.

SCDOT can use Table 7.14 to assist in selecting the "typical" variability to use to establish specification limits. As noted in the discussion above, there is no single "correct" way to establish this value. A subjective decision must be made regarding the standard deviation to select. The percentile values shown in the table should assist in making the decision. To get a "picture" of the results in Table 7.14, Figure 7.5 shows the empirical cumulative distribution function (CDF) for the Lot standard deviation values.

As the reference lines show, there appears to be a natural break point at around a standard deviation of 0.25, which corresponds to approximately the 67th percentile on the CDF plot. This would seem to be a logical choice for the process standard deviation. However, note that due to the large gap between values, the 70th percentile (see Table 7.14), at 0.294, is quite a bit larger than 0.25. This difference is due to the relatively small number of projects and the relatively large gap between standard deviation values of 0.2512 and 0.3225. Somewhere in the range 0.25 to 0.295 would seem to be a logical choice for the process standard deviation.

Table 7.14. Summary of AC Test Results for Each Base Course Project

Number		Total Number of		Mean of *		Std Deviation*	
Project	JMF	Lots	Tests	All Tests	Lot Means	Project	Lot
P27	J66	11	11	0.0455	0.0455	0.2035	—
P24	J57	6	12	0.1375	0.1375	0.1110	0.0517
P02	J28	13	30	0.0383	0.0404	0.2475	0.1832
P01	J01	8	22	0.0673	0.0398	0.2318	0.1933
P28	J47	10	14	-0.0250	-0.0385	0.2407	0.2193
P01	J18	33	82	-0.0480	-0.0564	0.2435	0.2237
P01	J06	3	9	0.0978	0.0942	0.2163	0.2512
P02	J17	6	17	-0.0147	0.0022	0.2983	0.3225
P01	J21	15	27	0.1085	0.1324	0.2574	0.3360
P26	J45	4	12	0.0620	0.0423	0.3723	0.3406
Total/Average		**109**	**236**	**0.0469**	**0.0439**	**0.2422**	**0.2357**
					50%	**0.2421**	**0.2237**
					60%	**0.2451**	**0.2457**
					70%	**0.2505**	**0.2940**
					80%	**0.2656**	**0.3279**
					90%	**0.3057**	**0.3369**

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

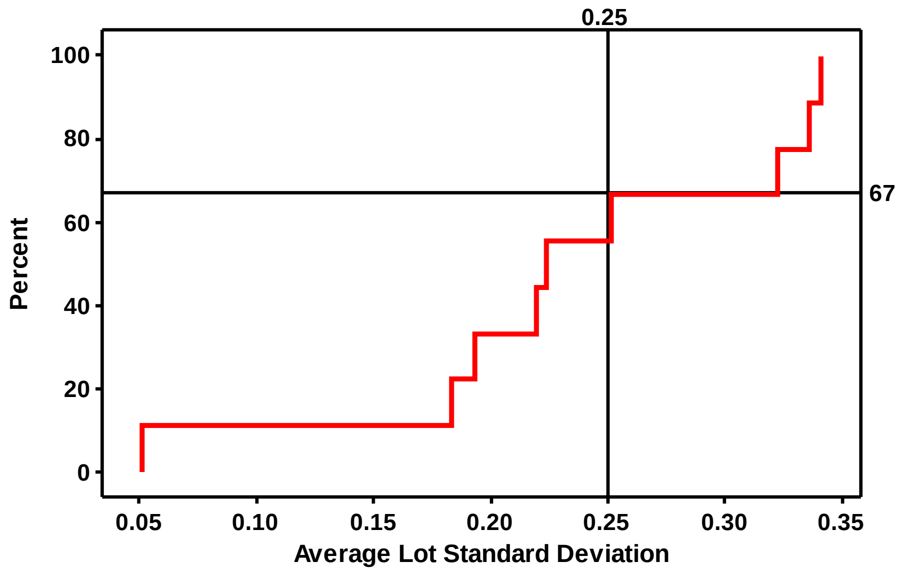

Figure 7.5. CDF for the Lot Standard Deviations for AC for Base Course Projects

Intermediate Course. Table 7.15 shows Lot standard deviation results for Intermediate course (from Table 7.12), but with the projects sorted from the smallest to largest Lot (i.e., within-lot) standard deviations. The projects are listed in increasing order of the Lot standard deviation to facilitate selecting a typical process standard deviation. The table also shows the total number of lots and tests for all AC projects, the averages for both the Project standard deviation values and for the Lot standard deviation values, and percentiles based on ranked order for both the Project and Lot standard deviation values.

SCDOT can use Table 7.15 to assist in selecting the “typical” variability to use to establish specification limits. As noted in the discussion above, there is no single “correct” way to establish this value. A subjective decision must be made regarding the standard deviation to select. The percentile values shown in the table should assist in making the decision. To get a “picture” of the results in Table 7.15, Figure 7.6 shows the empirical cumulative distribution function (CDF) for the Lot standard deviation values.

There is not as obvious a natural break point as in Figure 7.5, but the reference lines shown represent the 70^{th}, 75^{th}, and 80^{th} percentiles and the corresponding standard deviations between 0.21 and 0.26. Given the CDF, somewhere in this range would seem to be a logical choice for the process standard deviation.

Table 7.15. Summary of AC Test Results for Each Intermediate Course Project

Number		Total Number of		Mean of *		Std Deviation*	
Project	**JMF**	**Lots**	**Tests**	**All Tests**	**Lot Means**	**Project**	**Lot**
P27	J60	15	15	0.2613	0.2613	0.2445	—
P28	J42	13	15	0.0847	0.0877	0.1950	0.1241
P10	J82	8	15	-0.0313	-0.0238	0.1963	0.1291
P21	J34	3	8	0.1025	0.0467	0.1861	0.1294
P05	J27	8	15	-0.1187	-0.1200	0.1290	0.1494
P01	J10	18	39	0.0036	0.0162	0.2016	0.1559
P27	J53	16	19	-0.0000	0.0134	0.2079	0.1566
P10	J37	12	22	0.0250	0.0396	0.2067	0.1764
P24	J51	15	23	0.0287	0.0457	0.1627	0.1806
P32	J76	12	43	0.0935	0.0920	0.2078	0.1813
P01	J02	4	12	0.1217	0.1150	0.1734	0.1915
P02	J09	18	34	0.0218	0.1190	0.2479	0.2058
P25	J29	7	12	-0.1567	-0.1614	0.2091	0.2127
P02	J04	14	30	0.1290	0.1815	0.2260	0.2131
P17	J22	6	11	0.0036	-0.0175	0.2648	0.2322
P33	J73	8	25	0.0520	0.0783	0.2283	0.2585
P04	J08	11	21	0.1800	0.1959	0.3053	0.2916
P10	J31	41	77	0.0129	0.0222	0.2583	0.2984
P01	J23	6	12	0.1050	0.0936	0.3111	0.4165
Total/Average		**235**	**448**	**0.0483**	**0.0571**	**0.2190**	**0.2057**
					50%	**0.2079**	**0.1864**
					60%	**0.2226**	**0.2072**
					70%	**0.2380**	**0.2131**
					80%	**0.2521**	**0.2480**
					90%	**0.2729**	**0.2936**

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

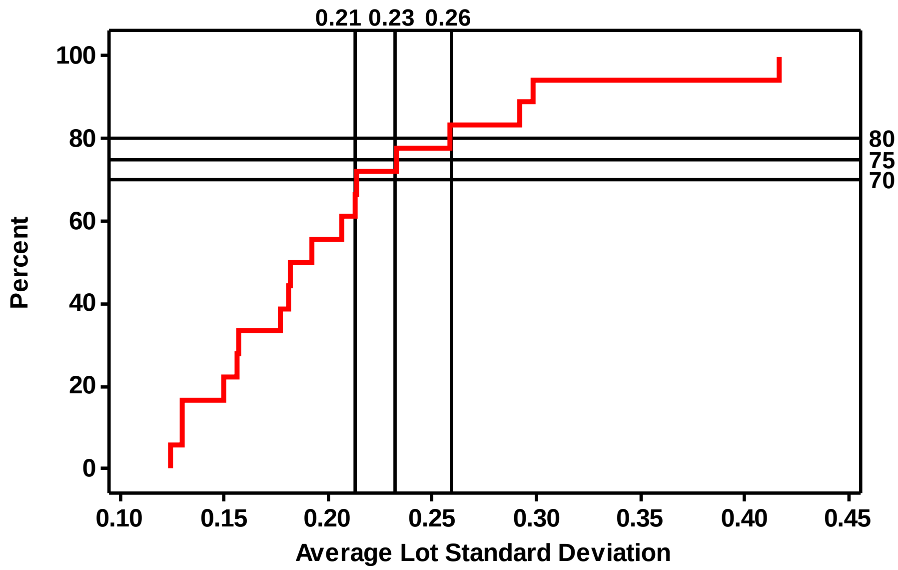

Figure 7.6. CDF for the Lot Standard Deviations for AC for Intermediate Course Projects

Surface Course. Table 7.16 shows Lot standard deviation results for Surface course (from Table 7.12), but with the projects sorted from the smallest to largest Lot (i.e., within-lot) standard deviations. The projects are listed in increasing order of the Lot standard deviation to facilitate selecting a typical process standard deviation. The table also shows the total number of lots and tests for all AC projects, the averages for both the Project standard deviation values and for the Lot standard deviation values, and percentiles based on ranked order for both the Project and Lot standard deviation values.

SCDOT can use Table 7.16 to assist in selecting the "typical" variability to use to establish specification limits. As noted in the discussion above, there is no single "correct" way to establish this value. A subjective decision must be made regarding the standard deviation to select. The percentile values shown in the table should assist in making the decision. To get a "picture" of the results in Table 7.16, Figure 7.7 shows the empirical cumulative distribution function (CDF) for the Lot standard deviation values.

There is more than one potential break point in Figure 7.7. The reference lines shown represent approximately the 72^{nd} and 85^{th} percentiles and the corresponding standard deviations of 0.194 and 0.216, respectively. From Table 7.16, the 80^{th} percentile with a standard deviation of 0.21 would be another possibility. SCDOT will need to make a subjective decision regarding the typical standard deviation to use to represent Surface course paving. Given the CDF, somewhere between 0.195 and 0.215 would seem to be a logical choice for the process standard deviation.

Table 7.16. Summary of AC Test Results for Each Surface Course Project

Number		Total Number of		Mean of *		Std Deviation*	
Project	JMF	Lots	Tests	All Tests	Lot Means	Project	Lot
P05	J25	8	8	-0.1313	-0.1313	0.1884	—
P27	J61	9	9	-0.0589	-0.0589	0.1290	—
P33	J75	10	10	-0.0150	-0.0150	0.1885	—
P24	J64	7	13	0.1431	0.1443	0.0574	0.0473
P22	J54	3	12	0.0467	0.0647	0.0845	0.0609
P24	J67	6	10	0.0590	0.1667	0.6117	0.0682
P02	J05	6	8	-0.0050	-0.0117	0.1506	0.0798
P34	J80	7	12	-0.0058	-0.0286	0.1030	0.0806
P30	J65	4	8	-0.0100	0.0000	0.0905	0.1000
P07	J30	19	40	-0.0940	-0.0971	0.1463	0.1034
P21	J39	6	15	0.0007	-0.0026	0.1283	0.1078
P02	J13	14	18	-0.0572	-0.0318	0.2949	0.1130
P35	J38	16	36	0.0536	0.0495	0.1249	0.1171
P11	J41	4	10	0.0710	0.0721	0.1731	0.1190
P26	J52	30	58	-0.0621	-0.0525	0.1452	0.1211
P32	J79	24	96	0.1139	0.1106	0.1622	0.1253
P29	J59	9	26	-0.0458	-0.0494	0.1427	0.1296
P13	J43	8	19	-0.0011	-0.0020	0.1554	0.1305
P35	J32	6	14	-0.0507	-0.0294	0.1513	0.1347
P09	J35	3	9	-0.0178	-0.0178	0.1492	0.1349
P06	J24	5	15	0.0647	0.0647	0.1732	0.1438
P01	J19	14	18	0.0828	0.1007	0.1435	0.1462
P28	J39	9	24	0.0429	0.0149	0.1542	0.1486
P34	J62	7	28	-0.0232	-0.0225	0.2043	0.1496
P26	J69	18	53	0.0029	-0.0201	0.1949	0.1531
P12	J38	6	14	0.0536	0.0676	0.1820	0.1592
P20	J50	17	46	0.0202	0.0484	0.1923	0.1648
P18	J48	7	12	0.1117	0.1164	0.2138	0.1701
P05	J40	5	9	-0.1344	-0.1180	0.1756	0.1726
P32	J46	31	41	-0.0220	-0.0157	0.1792	0.1736
P26	J62	9	31	0.0145	0.0082	0.1791	0.1741
P02	J15	6	18	-0.0122	0.0501	0.2058	0.1750
P01	J07	9	30	-0.0243	-0.0212	0.1808	0.1811
P32	J72	8	34	0.0706	0.0773	0.1740	0.1819
P27	J71	9	27	0.0559	0.0597	0.1621	0.1882
P09	J83	3	8	-0.0413	-0.0333	0.1954	0.1891
P14	J16	13	32	-0.1769	-0.1827	0.2113	0.1937
P04	J14	5	17	0.0618	0.0575	0.1937	0.2051
P10	J12	13	19	-0.0374	-0.0373	0.2781	0.2083
P16	J20	3	9	-0.1811	-0.1811	0.2351	0.2103
P19	J49	7	20	-0.0775	-0.0788	0.2602	0.2105
P27	J55	5	15	0.1287	0.1287	0.1947	0.2122

Continued

Table 7.16. Summary of AC Test Results for Each Surface Course Project (*continued*)

Number		Total Number of		Mean of *		Std Deviation*	
Project	JMF	Lots	Tests	All Tests	Lot Means	Project	Lot
P24	J56	18	40	0.0000	0.0759	0.2507	0.2161
P33	J77	6	22	0.0973	0.0988	0.2472	0.2295
P26	J58	12	13	-0.0031	0.0050	0.1707	0.2481
P34	J81	7	13	0.0923	0.0971	0.2117	0.2600
P25	J36	6	10	0.0570	0.0458	0.2081	0.2906
P13	J03	8	16	-0.0100	-0.0458	0.2735	0.3268
P33	J78	4	13	0.0492	0.0419	0.3541	0.3556
P26	J68	4	13	-0.0970	-0.0879	0.4339	0.4153
Total/Average		**472**	**1091**	**0.0020**	**0.0079**	**0.1962**	**0.1708**
					50%	**0.1800**	**0.1648**
					60%	**0.1929**	**0.1746**
					70%	**0.2048**	**0.1900**
					80%	**0.2181**	**0.2105**
					90%	**0.2740**	**0.2529**

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

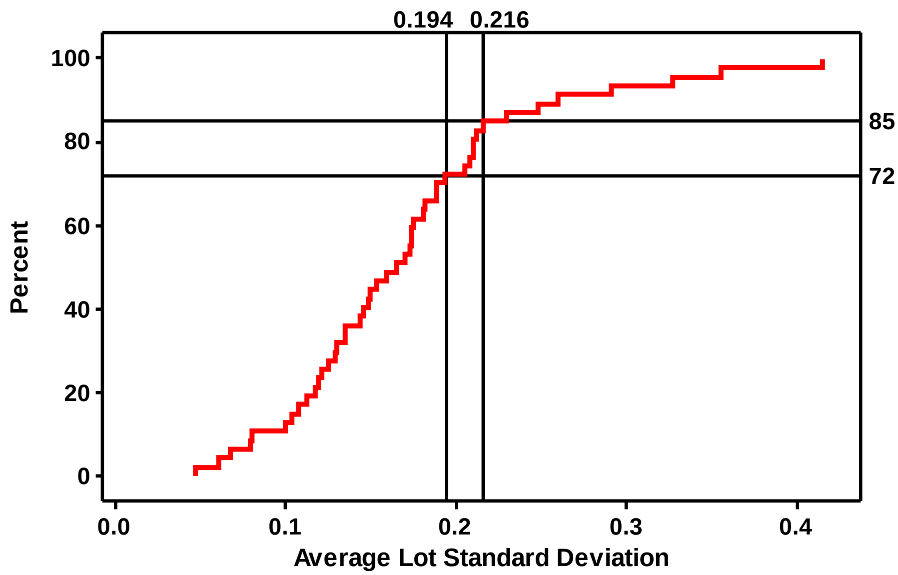

Figure 7.7. CDF for the Lot Standard Deviations for AC for Surface Course Projects

PWL Values for the AC Projects. The AC projects did not exhibit the same concern that was found with the Density projects where many of the projects had relatively low average PWL values. A different problem with the AC projects was that many of the projects did not have sufficient sample sizes to calculate a PWL value for the lots. There must be at least 3 test results for a lot to be able to estimate the PWL value for the lot. Rather than to combine lots, which is what would have been done in the field to determine the PWL to use for determining the payment factor, lots that had at least 3 tests were evaluated to determine their estimated PWL values.

For Base course, only 6 of 42 lots had PWL values less than the 90 that was required for full payment. For Intermediate course, only 8 of 42 lots had PWL values less than the 90. The Surface course requirements were a little more difficult to meet, with 39 of 207 lots having PWL values less than 90. For Base course, 1 of 7 projects had average PWL values less than 90. For Intermediate course, 2 of 8 projects had average PWL values less than 90. For Surface course, 10 of 37 projects had average PWL values less than 90, which was required for full payment. Therefore, no additional PWL analyses were conducted for the AC test results.

Air Voids

Comparing Courses. The specifications for AV had one set of allowable tolerances, 1.15%, for Intermediate, and Surface courses. AV values were not determined for Base course mixes. To evaluate whether or not different tolerances might be warranted for Intermediate and Surface courses, the variances of the two courses were compared statistically using the *F*-test and Levene's test. The *F*-test assumes that the data are from normal distributions, whereas Levene's test applies for any continuous distribution. Table 7.17 shows the results of the comparison.

Table 7.17. Summary of AV Comparisons among Courses

Course	No. of Tests	St Dev	P-value* *F*-test	P-value* Levene's
Intermediate	406	0.5907	**0.035**	0.141
Surface	935	0.6464		

***** Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

The results in Table 7.17 show that the *F*-test, with a P-value of 0.035, concludes that the variabilities for Intermediate and Surface courses are likely not the same. Levene's test, with a P-value of 0.141, would not conclude that the variabilities should be considered different. To further investigate the variabilities, Figure 7.8 shows the standard deviation along with its 95% confidence interval for each course. While the standard deviation result for Surface course is outside the upper confidence limit for the Intermediate course standard deviation, there is still quite a bit of overlap between the two confidence intervals. Therefore, there is some evidence to conclude that the AV variability is less for Intermediate course than it is for Surface course. There is also contradictory evidence to support using the same variability to represent both courses. While the decision must be made by SCDOT, for this report, it has been assumed that it is reasonable to treat the two courses as having similar variabilities.

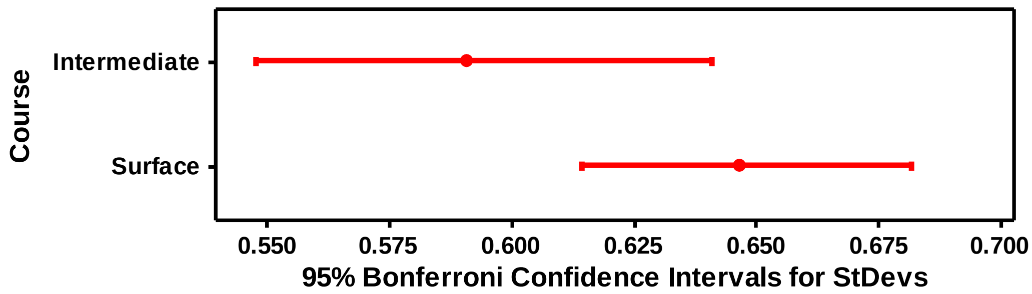

Figure 7.8. Comparison of AV Standard Deviations for Intermediate and Surface Courses

Comparing Mix Types within Course. The next question to consider is whether it is appropriate to use the same specification tolerances for all mix types within a given course. When establishing the allowable tolerances it is the standard deviation that is most important.

Intermediate Course Mixes. Table 7.18 shows the results of comparisons among the AV variabilities for the different types of Intermediate course mixes. The results, with Bartlett's test having a P-value of 0.693 and Levene's test having a P-value of 0.554, show no evidence that the standard deviations are different for the different mix types. Figure 7.9 shows the standard deviation along with its 95% confidence interval for each Intermediate course mix type.

Table 7.18. Summary of AV Comparisons of Intermediate Course Mix Types

Mix Type	No. of Tests	St Dev	P-value* Bartlett's	P-value* Levene's
Binder 1	18	0.5291	0.693	0.554
Intermediate B	198	0.5344		
Intermediate C	190	0.5673		

* Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

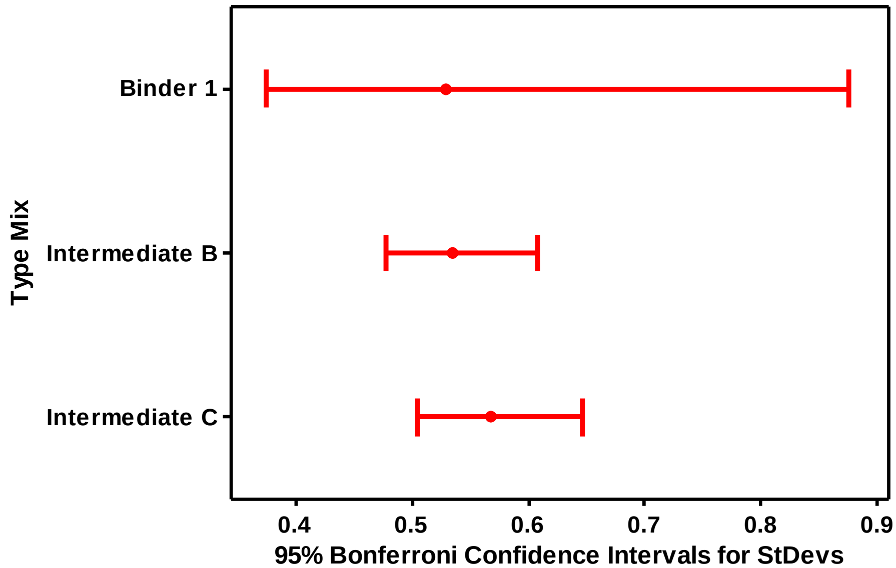

Figure 7.9 Comparison of AC Standard Deviations for Each Intermediate Course Mix Type

Surface Course Mixes. Table 7.19 shows the results of comparisons among the AV variabilities for the different types of Surface course mixes. The results show clearly that the standard deviations are not equal for all 10 mix types. Figure 7.10 shows the standard deviation along with its 95% confidence interval for each Surface course mix type.

Table 7.19. Summary of AV Comparisons of Surface Course Mix Types

Mix Type	No. of Tests	St Dev	P-value* Bartlett's	P-value* Levene's
Surface 1C	16	0.5805	**0.011**	**0.012**
Surface 1D	15	0.4212		
Surface 1R	17	0.5145		
Surface 3	40	0.5004		
Surface 4	19	0.6232		
Surface A	230	0.6231		
Surface B	116	0.5145		
Surface C	393	0.6720		
Surface CM	26	0.5952		
Surface D	63	0.6986		

* Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

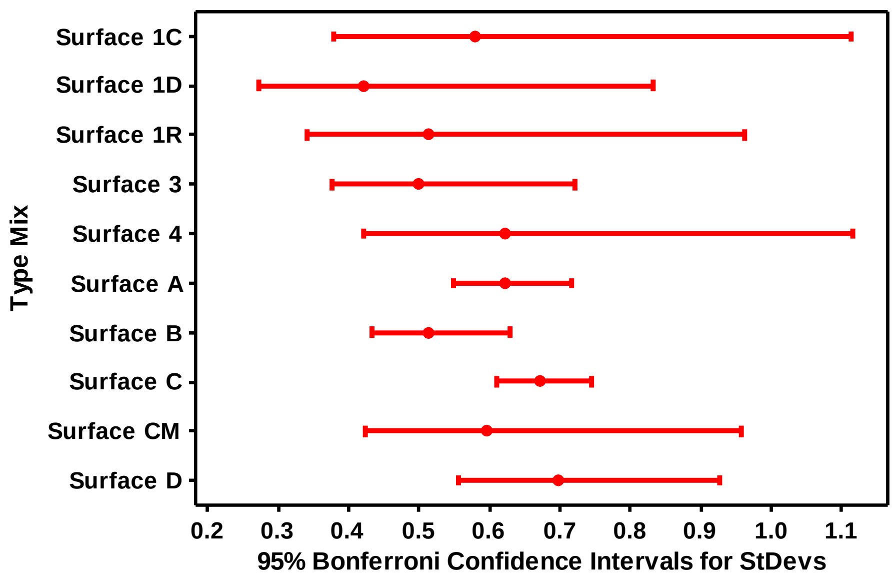

Figure 7.10 Comparison of AC Standard Deviations for Each Surface Course Mix Type

It must be noted that the above analysis can be thought of as a quick simplification. For example, many of the mix types with the smaller standard deviations also had the smallest number of data points. With a limited number of projects there is likely to be less variability when the data are combined than there would be when many projects were combined. In fact, the Surface 1C, 1D, 1R, 3, and 4 mixes each appeared on only one project. The effect of combining several projects in the other Surface mix types will be addressed when the individual average Lot standard deviation and average project standard deviations are analyzed.

Caveat. None of the standard deviation values shown in Tables 7.17-7.19 are the appropriate standard deviation to use to represent the process standard deviation for AV. These calculations were done simply for exploratory purposes. Aggregating the data as in these tables is not appropriate for establishing specification limits since the specification limits are based on lot-by-lot acceptance, or at least on acceptance of a project.

Typical Variability Values for AV. As noted above, since the SCDOT specification is based on lot-by-lot acceptance, the AV variability that is used to evaluate the specification limits must be that which is appropriate for a typical lot. To determine this, the individual standard deviation values for each lot were calculated and then these lot standard deviations were averaged to get the "within-lot" standard deviation for each project. This was done using the procedure that is described for density in Chapter 6. As noted in Chapter 6, this within-lot standard deviation does not take into consideration any target miss variability that may be present.

To provide the option to consider using the total project as the payment lot, the total project AV standard deviation was also calculated for each project. As noted above, this "project" standard deviation could also be used as one way of trying to incorporate any target miss variability that might be present in the contractor's process.

Appendix B includes the necessary calculations for each project for which AV data were obtained. These calculations were used to arrive at the project standard deviations that were used to establish the typical process variability for AV.

Projects with Multiple JMFs. Before compiling all of the within-lot and project variabilities, a decision had to be made regarding how to deal with projects on which more than one JMF was used for the same mix type and course. Should each JMF be treated as a separate project, or should the multiple JMF results be combined together as one project? To help make this decision, the projects with multiple JMFs were examined. Table 7.20 shows the projects (extracted from Tables 7.1-7.5) that had multiple JMFs for the same mix type.

Only 1 out of 10 multi-mix design projects showed a difference in variability. Also, in the project data a new lot was established in nearly every case that the JMF changed. This would argue in favor of treating the JMFs as separate projects when determining the within-lot standard deviations.

However, if a total project is being used as the payment lot, then the data from the multiple JMFs would be combined when calculating the standard deviation to use for payment determination. This would argue in favor of combining the separate JMFs into a single project. For consistency in presentation and in comparing results, it was decided to treat the separate JMFs as separate projects when calculating standard deviations and when presenting the results.

Table 7.20. Projects with More than One JMF for the Same Mix Type for AV

Project	JMF	No. of Lots	No. of Tests	St Dev	*F*-Test P-value*
Intermediate Course					
P01	J10	18	39	0.4843	0.237
	J23	6	12	0.3473	
P02	J04	14	30	0.5750	0.471
	J09	18	34	0.5053	
P10	J31	41	77	0.5658	**0.005****
	J37	12	22	0.3924	
	J82	8	15	0.2876	
Surface Course					
P26	J62	9	31	0.5947	0.944
	J69	18	53	0.6044	
P27	J55	5	15	0.4386	0.612
	J71	9	27	0.5013	
P02	J05	6	8	0.4277	0.611
	J13	14	18	0.5225	
P13	J03	8	16	0.7029	0.486
	J43	8	19	0.8416	
P24	J56	18	40	0.8204	0.664
	J67	6	10	0.7071	
P35	J32	6	14	0.5270	0.129
	J38	16	36	0.3817	
P09	J35	3	9	0.4907	0.627
	J83	3	8	0.5858	

* Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

** Bartlett's Test

Determining the Typical Process Variability for AV. Table 7.21 shows the standard deviation results for AV for all projects for which data were obtained. The projects are sorted by mix type. The "Lot" standard deviation is the average of the unbiased standard deviation estimates for each lot on the project. The "Project" standard deviation is the standard deviation of all the individual test results for the total project. The table also shows the total number of lots and tests for each project, the mean for all tests on the project, and the mean of the individual project lot means. Note that some projects do not have an average Lot standard deviation. This is due to the fact that there was only one AV test for each lot on the project. With only one test it is not possible to calculate a standard deviation for the lot.

One thing to consider from the results in Table 7.21 is whether to treat the Intermediate course results and the Surface course results as separate from one another or to combine them. By observation, the standard deviation values for the two courses are in the same general range. The Two-Sample Mann-Whitney hypothesis test was used to compare the medians of the Means of Lot Means results for each course. The same test was used to compare the medians of the Lot Standard Deviations. The Mann-Whitney test does not require the data to come from normally distributed populations. It assumes that the populations of interest have the same shape and that the populations are independent. The results of the Mann-Whitney tests are shown in Table 7.22.

The medians of the Lot Means for Intermediate and Surface courses, with a P-value of 0.7339, are not different from one another. Similarly, with a P-value of 0.1827, the medians of the Lot Std Devs, cannot be declared significantly different. This supports the use of one set of tolerances for both Intermediate and Surface course mixes.

Table 7.23 shows Lot standard deviation results for the combined Intermediate and Surface course projects (from Table 7.21), but with the projects sorted from the smallest to largest Lot (i.e., within-lot) standard deviations. The projects are listed in increasing order of the Lot standard deviation to facilitate selecting a typical process standard deviation. The table also shows the total number of lots and tests for all AV projects, the averages for both the Project standard deviation values and for the Lot standard deviation values, and percentiles based on ranked order for both the Project and Lot standard deviation values.

SCDOT can use Table 7.23 to assist in selecting the “typical” variability to use to establish specification limits. As noted in the discussion above, there is no single “correct” way to establish this value. A subjective decision must be made regarding the standard deviation to select. The percentile values shown in the table should assist in making the decision. To get a “picture” of the results in Table 7.23, Figure 7.11 shows the empirical cumulative distribution function (CDF) for the combined Lot standard deviation values.

As the reference lines show, there appears to be a natural break point at around a standard deviation of 0.525, which corresponds to approximately the 75th percentile on the CDF plot. This would seem to be a logical choice for the process standard deviation. However, note that the slope of the CDF begins to flatten noticeably around the 89th percentile, which corresponds to a standard deviation of about 0.59. Somewhere within the range of these two values would be a reasonable choice for the typical process standard deviation for AV.

Table 7.21. Summary of AV Test Results for Each Project

Number		Total Number of		Mean of *		Std Deviation**	
Project	JMF	Lots	Tests	All Tests	Lot Means	Project	Lot
Intermediate Course							
P01	J02	4	8	-0.301	-0.2750	0.5772	0.4763
P01	J10	18	39	-0.3559	-0.4066	0.4875	0.3224
P01	J23	6	12	-0.328	-0.3075	0.3550	0.3523
P02	J04	14	30	-0.1630	-0.0838	0.5799	0.2696
P02	J09	18	34	-0.0912	-0.0825	0.5091	0.4415
P04	J08	5	10	0.1330	0.1330	0.4534	0.5619
P05	J27	8	15	0.2327	0.2256	0.3932	0.2823
P10	J31	41	77	0.1560	0.1524	0.5677	0.4411
P10	J37	12	22	0.5327	0.5371	0.3971	0.2207
P10	J82	8	15	0.7847	0.7869	0.2928	0.2216
P17	J22	6	11	-0.4240	-0.3875	0.5813	0.6717
P21	J34	3	8	-0.0100	0.0833	0.3834	0.3477
P25	J29	7	12	0.6360	0.5929	0.5074	0.2375
P27	J53	14	15	-0.1810	-0.1811	0.4510	0.0443
P27	J60	15	15	0.0080	0.0080	0.6414	—
P28	J42	13	15	-0.0290	-0.0092	0.4540	0.5938
P32	J76	12	43	-0.6007	-0.5974	0.3272	0.3108
P33	J73	8	25	0.1260	0.0860	0.5295	0.4808
Total/Average		**212**	**406**	**0.0070**	**0.0153**	**0.4716**	**0.3692**
Surface Course							
P01	J07	9	30	0.3303	0.3323	0.5090	0.3991
P01	J19	14	18	-0.4180	-0.3925	0.5957	0.5251
P02	J05	6	8	0.331	0.3942	0.4435	0.3944
P02	J13	14	18	0.457	0.3721	0.5307	0.2880
P02	J15	6	18	0.532	0.2926	0.5602	0.3942
P04	J14	5	17	0.244	0.2433	0.5231	0.3691
P05	J25	8	8	0.011	0.0113	0.5534	—
P06	J24	5	15	-0.391	-0.3907	0.4286	0.4613
P07	J30	19	40	0.0193	0.0884	0.5036	0.5144
P09	J35	3	9	0.293	0.2933	0.5066	0.3475
P09	J83	3	8	-0.310	-0.3633	0.6073	0.4908
P10	J12	13	19	0.415	0.3935	0.6317	0.5627
P11	J41	4	10	0.106	0.0977	0.4256	0.3034
P12	J38	6	14	-0.643	-0.7899	0.7625	0.5774
P13	J03	8	16	-0.212	-0.0487	0.7148	0.5782
P13	J43	8	19	0.067	0.1515	0.8538	0.7440
P14	J16	13	32	-0.447	-0.3851	0.7389	0.5168
P16	J20	3	9	0.164	0.1644	0.7841	0.7990
P18	J48	7	12	-0.442	-0.4002	0.8357	0.2787
P19	J49	7	20	-0.514	-0.4204	0.5826	0.5758
Continued							

Table 7.21. Summary of AV Test Results for Each Project (*continued*)

Number		Total Number of		Mean of *		Std Deviation**	
Project	JMF	Lots	Tests	All Tests	Lot Means	Project	Lot
Surface Course (*cont*)							
P20	J50	17	46	-0.2567	-0.3337	0.5495	0.4515
P21	J39	6	15	-0.8340	-0.7936	0.1504	0.1451
P22	J54	3	12	0.112	0.2432	0.8910	0.8222
P24	J56	18	40	-0.263	-0.1499	0.8253	0.6368
P24	J64	7	13	-0.6423	-0.5964	0.2932	0.1935
P24	J67	6	10	-0.192	-0.1569	0.7268	0.5045
P25	J36	6	10	0.375	0.4125	0.6240	0.6116
P26	J58	12	13	0.281	0.1821	0.6810	0.2038
P26	J62	9	31	0.335	0.3689	0.6000	0.4910
P26	J69	18	53	0.1649	0.2549	0.6703	0.4460
P27	J55	5	15	0.133	0.1333	0.4469	0.4258
P27	J61	9	9	-0.364	-0.3644	0.5365	—
P27	J71	9	27	0.2059	0.2039	0.5061	0.5727
P28	J39	9	24	-0.5963	-0.5436	0.2858	0.2291
P29	J59	9	26	-0.0069	-0.0072	0.2840	0.2487
P30	J65	4	8	0.5100	0.4867	0.2434	0.2316
P32	J72	8	34	-0.0374	-0.0719	0.5010	0.2384
P32	J79	24	96	-0.2536	-0.2436	0.4877	0.4356
P33	J77	6	22	0.462	0.4626	0.6375	0.4186
P34	J62	7	28	0.152	0.1174	0.6853	0.5621
P34	J81	7	13	0.075	0.0907	0.5851	0.3057
P35	J32	6	14	0.399	0.3861	0.5372	0.4463
P35	J38	16	36	0.0358	0.0815	0.3844	0.2381
Total/Average		**382**	**935**	**-0.0143**	**-0.0045**	**0.5633**	**0.4385**

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

Table 7.22. Results of Mann-Whitney Tests on the AV Lot Means and Lot Std Devs

Course	No. of Lots	Median of Lot Means	P-Value*	Median of Lot Std Devs	P-Value*
Intermediate	18	-0.0006	0.7339	0.3477	0.1827
Surface	43	0.0907		0.4460	

* Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

Table 7.23. Summary of AV Test Results for Combined Intermediate and Surface Projects

Number		Total Number of		Mean of *		Std Deviation*		
Project	JMF	Lots	Tests	All Tests	Lot Means	Project	Lot	Course
P27	J60	15	15	0.0080	0.0080	0.6414	—	Interm
P05	J25	8	8	0.011	0.0113	0.5534	—	Surface
P27	J61	9	9	-0.364	-0.3644	0.5365	—	Surface
P27	J53	14	15	-0.1810	-0.1811	0.4510	0.0443	Interm
P21	J39	6	15	-0.8340	-0.7936	0.1504	0.1451	Surface
P24	J64	7	13	-0.6423	-0.5964	0.2932	0.1935	Surface
P26	J58	12	13	0.281	0.1821	0.6810	0.2038	Surface
P10	J37	12	22	0.5327	0.5371	0.3971	0.2207	Interm
P10	J82	8	15	0.7847	0.7869	0.2928	0.2216	Interm
P28	J39	9	24	-0.5963	-0.5436	0.2858	0.2291	Surface
P30	J65	4	8	0.5100	0.4867	0.2434	0.2316	Surface
P25	J29	7	12	0.6360	0.5929	0.5074	0.2375	Interm
P35	J38	16	36	0.0358	0.0815	0.3844	0.2381	Surface
P32	J72	8	34	-0.0374	-0.0719	0.5010	0.2384	Surface
P29	J59	9	26	-0.0069	-0.0072	0.2840	0.2487	Surface
P02	J04	14	30	-0.1630	-0.0838	0.5799	0.2696	Interm
P18	J48	7	12	-0.442	-0.4002	0.8357	0.2787	Surface
P05	J27	8	15	0.2327	0.2256	0.3932	0.2823	Interm
P02	J13	14	18	0.457	0.3721	0.5307	0.2880	Surface
P11	J41	4	10	0.106	0.0977	0.4256	0.3034	Surface
P34	J81	7	13	0.075	0.0907	0.5851	0.3057	Surface
P32	J76	12	43	-0.6007	-0.5974	0.3272	0.3108	Interm
P01	J10	18	39	-0.3559	-0.4066	0.4875	0.3224	Interm
P09	J35	3	9	0.293	0.2933	0.5066	0.3475	Surface
P21	J34	3	8	-0.0100	0.0833	0.3834	0.3477	Interm
P01	J23	6	12	-0.328	-0.3075	0.3550	0.3523	Interm
P04	J14	5	17	0.244	0.2433	0.5231	0.3691	Surface
P02	J15	6	18	0.532	0.2926	0.5602	0.3942	Surface
P02	J05	6	8	0.331	0.3942	0.4435	0.3944	Surface
P01	J07	9	30	0.3303	0.3323	0.5090	0.3991	Surface
P33	J77	6	22	0.462	0.4626	0.6375	0.4186	Surface
P27	J55	5	15	0.133	0.1333	0.4469	0.4258	Surface
P32	J79	24	96	-0.2536	-0.2436	0.4877	0.4356	Surface
P10	J31	41	77	0.1560	0.1524	0.5677	0.4411	Interm
P02	J09	18	34	-0.0912	-0.0825	0.5091	0.4415	Interm
P26	J69	18	53	0.1649	0.2549	0.6703	0.4460	Surface
P35	J32	6	14	0.399	0.3861	0.5372	0.4463	Surface
P20	J50	17	46	-0.2567	-0.3337	0.5495	0.4515	Surface
P06	J24	5	15	-0.391	-0.3907	0.4286	0.4613	Surface
P01	J02	4	8	-0.301	-0.2750	0.5772	0.4763	Interm
P33	J73	8	25	0.1260	0.0860	0.5295	0.4808	Interm

Continued

Table 7.23. Summary of AV Test Results for Combined Intermediate and Surface Projects (*continued*)

Number		Total Number of		Mean of *		Std Deviation*		
Project	**JMF**	**Lots**	**Tests**	**All Tests**	**Lot Means**	**Project**	**Lot**	**Course**
P09	J83	3	8	-0.310	-0.3633	0.6073	0.4908	Surface
P26	J62	9	31	0.335	0.3689	0.6000	0.4910	Surface
P24	J67	6	10	-0.192	-0.1569	0.7268	0.5045	Surface
P07	J30	19	40	0.0193	0.0884	0.5036	0.5144	Surface
P14	J16	13	32	-0.447	-0.3851	0.7389	0.5168	Surface
P01	J19	14	18	-0.4180	-0.3925	0.5957	0.5251	Surface
P04	J08	5	10	0.1330	0.1330	0.4534	0.5619	Interm
P34	J62	7	28	0.152	0.1174	0.6853	0.5621	Surface
P10	J12	13	19	0.415	0.3935	0.6317	0.5627	Surface
P27	J71	9	27	0.2059	0.2039	0.5061	0.5727	Surface
P19	J49	7	20	-0.514	-0.4204	0.5826	0.5758	Surface
P12	J38	6	14	-0.643	-0.7899	0.7625	0.5774	Surface
P13	J03	8	16	-0.212	-0.0487	0.7148	0.5782	Surface
P28	J42	13	15	-0.0290	-0.0092	0.4540	0.5938	Interm
P25	J36	6	10	0.375	0.4125	0.6240	0.6116	Surface
P24	J56	18	40	-0.263	-0.1499	0.8253	0.6368	Surface
P17	J22	6	11	-0.4240	-0.3875	0.5813	0.6717	Interm
P13	J43	8	19	0.067	0.1515	0.8538	0.7440	Surface
P16	J20	3	9	0.164	0.1644	0.7841	0.7990	Surface
P22	J54	3	12	0.112	0.2432	0.8910	0.8222	Surface
Total/Average		**594**	**1341**	**-0.008**	**0.0013**	**0.5363**	**0.4182**	
					50%	0.5307	0.43070	
					60%	0.5677	0.45346	
					70%	0.5957	0.50315	
					80%	0.6414	0.56246	
					90%	0.7389	0.59914	

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

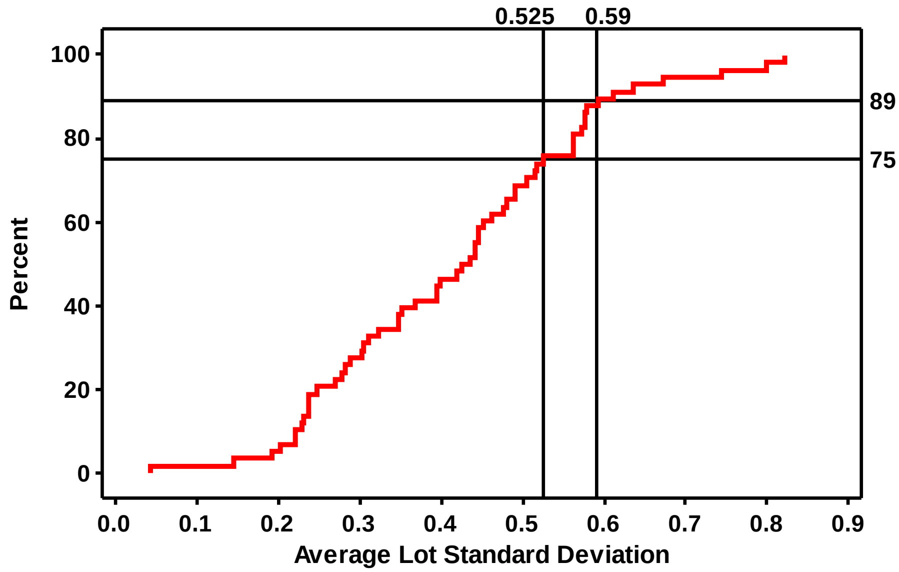

Figure 7.11. CDF for AV for Lot Standard Deviations for Intermediate and Surface Projects

PWL Values for the AV Projects. The AV projects did not exhibit the same concern that was found with the Density projects where many of the projects had relatively low average PWL values. A different problem with the AV projects was that many of the projects did not have sufficient sample sizes to calculate a PWL value for the lots. There must be at least 3 test results for a lot to be able to estimate the PWL value for the lot. Rather than to combine lots, which is what would have been done in the field to determine the PWL to use for determining the payment factor, lots that had at least 3 tests were evaluated to determine their estimated PWL values. This resulted in PWL calculations for 207 lots.

Of the 207 lots, 32 had PWL values less than 90, which would result in some form of price reduction. Only 6 of the projects had average lot PWL values less than 90, and 2 of those had average lot PWL values greater than 89.5.

VMA

Comparing Courses. The specifications for VMA had one set of allowable tolerances, 1.15%, for Intermediate and Surface courses. VMA values were not determined for Base course mixes. To evaluate whether or not different tolerances might be warranted for Intermediate and Surface courses, the variances of the two courses were compared statistically using the *F*-test and Levene’s test. The *F*-test assumes that the data are from normal distributions, whereas Levene’s test applies for any continuous distribution. Table 7.24 shows the results of the comparison.

Table 7.24. Summary of VMA Comparisons among Courses

Course	No. of Tests	St Dev	P-value* *F*-test	P-value* Levene's
Intermediate	406	0.5974	0.183	0.248
Surface	935	0.5654		

* Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

The results in Table 7.24 show that neither the *F*-test, with a P-value of 0.035, nor Levene's test, with a P-value of 0.141, would conclude that the variabilities should be considered different. To further investigate the variabilities, Figure 7.12 shows the standard deviation along with its 95% confidence interval for each course. There is quite a bit of overlap between the two confidence intervals. Therefore, it is reasonable to conclude that the two courses can be treated having similar variabilities.

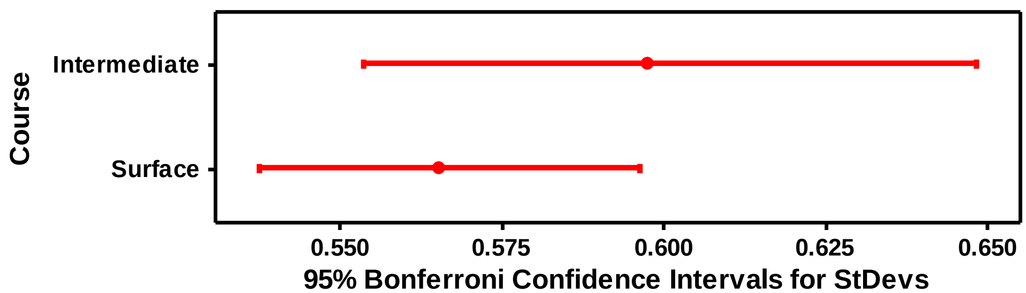

Figure 7.12. Comparison of VMA Standard Deviations for Intermediate and Surface Courses

Comparing Mix Types within Course. The next question to consider is whether it is appropriate to use the same specification tolerances for all mix types within a given course. When establishing the allowable tolerances it is the standard deviation that is most important.

Intermediate Course Mixes. Table 7.25 shows the results of comparisons among the VMA variabilities for the different types of Intermediate course mixes. The results, with Bartlett's test having a P-value of 0.216 and Levene's test having a P-value of 0.153, show no evidence that the standard deviations are different for the different mix types. Figure 7.13 shows the standard deviation along with its 95% confidence interval for each Intermediate course mix type.

Table 7.25. Summary of VMA Comparisons of Intermediate Course Mix Types

Mix Type	No. of Tests	St Dev	P-value* Bartlett's	P-value* Levene's
Binder 1	18	0.7076	0.216	0.153
Intermediate B	198	0.5565		
Intermediate C	190	0.6123		

* Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

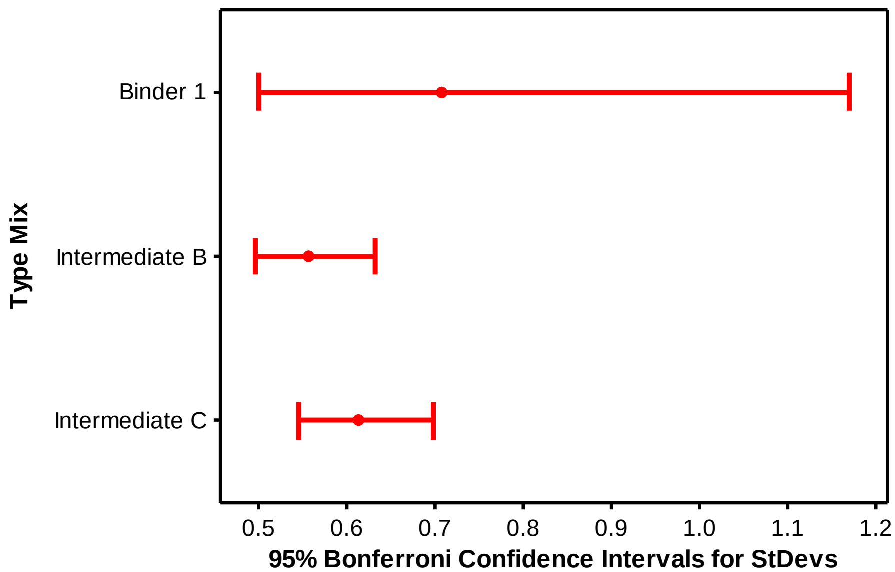

Figure 7.13. Comparison of VMA Standard Deviations for Each Intermediate Mix Type

Surface Course Mixes. Table 7.26 shows the results of comparisons among the VMA variabilities for the different types of Surface course mixes. The results show clearly that the standard deviations are not equal for all 10 mix types. Figure 7.14 shows the standard deviation along with its 95% confidence interval for each Surface course mix type.

Table 7.26. Summary of VMA Comparisons of Surface Course Mix Types

Mix Type	No. of Tests	St Dev	P-value* Bartlett's	P-value* Levene's
Surface 1C	16	0.4013	**0.000**	**0.002**
Surface 1D	15	0.5012		
Surface 1R	17	0.5099		
Surface 3	40	0.4565		
Surface 4	19	0.6871		
Surface A	230	0.5162		
Surface B	116	0.4550		
Surface C	393	0.5482		
Surface CM	26	0.5549		
Surface D	63	0.7526		

* Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

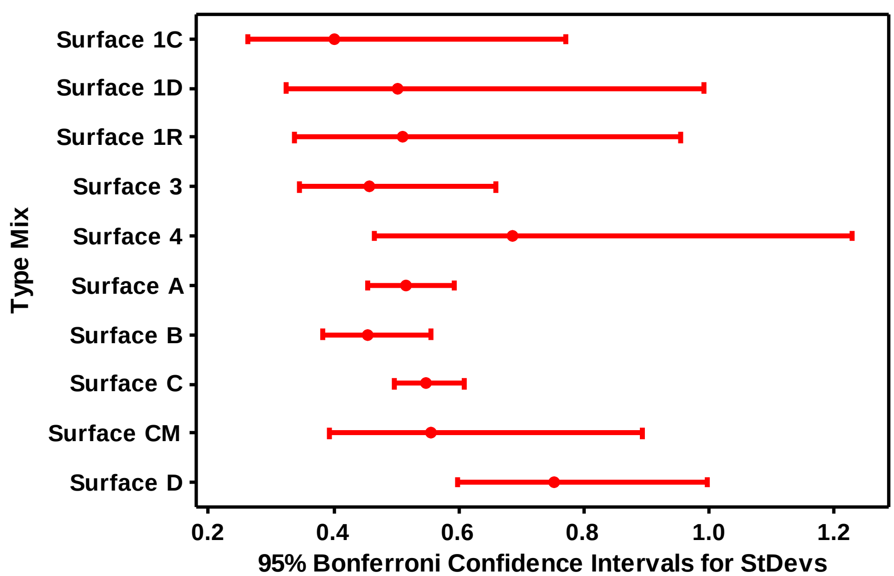

Figure 7.14 Comparison of VMA Standard Deviations for Each Surface Course Mix Type

It must be noted that the above analysis can be thought of as a quick simplification. The effect of combining several projects in the varioius Surface mix types will be addressed when the individual average Lot standard deviation and average project standard deviations are analyzed.

Caveat. None of the standard deviation values shown in Tables 7.24-7.26 are the appropriate standard deviation to use to represent the process standard deviation for VMA. These calculations were done simply for exploratory purposes. Aggregating the data as in these tables is not appropriate for establishing specification limits since the specification limits are based on lot-by-lot acceptance, or at least on acceptance of a project.

Typical Variability Values for VMA. As noted above, since the SCDOT specification is based on lot-by-lot acceptance, the VMA variability that is used to evaluate the specification limits must be that which is appropriate for a typical lot. To determine this, the individual standard deviation values for each lot were calculated and then these lot standard deviations were averaged to get the "within-lot" standard deviation for each project. This was done using the procedure that is described for density in Chapter 6. As noted in Chapter 6, this within-lot standard deviation does not take into consideration any target miss variability that may be present.

To provide the option to consider using the total project as the payment lot, the total project VMA standard deviation was also calculated for each project. As noted above, this "project" standard deviation could also be used as one way of trying to incorporate any target miss variability that might be present in the contractor's process.

Appendix B includes the necessary calculations for each project for which VMA data were obtained. These calculations were used to arrive at the project standard deviations that were used to establish the typical process variability for VMA.

Projects with Multiple JMFs. Before compiling all of the within-lot and project variabilities, a decision had to me made regarding how to deal with projects on which more than one JMF was used for the same mix type and course. Should each JMF be treated as a separate project, or should the multiple JMF results be combined together as one project? To help make this decision, the projects with multiple JMFs were examined. Table 7.27 shows the projects (extracted from Tables 7.4-7.5) that had multiple JMFs for the same mix type.

None of the multi-mix design projects showed a difference in variability. Also, in the project data a new lot was established in nearly every case that the JMF changed. This would argue in favor of treating the JMFs as separate projects when determining the within-lot standard deviations.

However, if a total project is being used as the payment lot, then the data from the multiple JMFs would be combined when calculating the standard deviation to use for payment determination. This would argue in favor of combining the separate JMFs into a single project. For consistency in presentation and in comparing results, it was decided to treat the separate JMFs as separate projects when calculating standard deviations and when presenting the results.

Determining the Typical Process Variability for VMA. Table 7.28 shows the standard deviation results for VMA for all projects for which data were obtained. The projects are sorted by mix type. The "Lot" standard deviation is the average of the unbiased standard deviation estimates for each lot on the project. The "Project" standard deviation is the standard deviation of all the individual test results for the total project. The table also shows the total number of lots and tests for each project, the mean for all tests on the project, and the mean of the individual project lot means. Note that some projects do not have an average Lot standard deviation. This is due to the fact that there was only one VMA test for each lot on the project. With only one test it is not possible to calculate a standard deviation for the lot.

Table 7.27. Projects with More than One JMF for the Same Mix Type for VMA

Project	JMF	No. of Lots	No. of Tests	St Dev	*F*-Test P-value*
Intermediate Course					
P01	J10	18	39	0.4694	0.858
	J23	6	12	0.4798	
P02	J04	14	30	0.5831	0.644
	J09	18	34	0.6351	
P10	J31	41	77	0.6384	0.696**
	J37	12	22	0.7139	
	J82	8	15	0.5838	
Surface Course					
P26	J62	9	31	0.4305	0.713
	J69	18	53	0.4596	
P27	J55	5	15	0.3453	0.491
	J71	9	27	0.4127	
P02	J05	6	8	0.3108	0.077
	J13	14	18	0.6103	
P13	J03	8	16	0.4195	0.219
	J43	8	19	0.5765	
P24	J56	18	40	0.5181	0.632
	J67	6	10	0.4409	
P35	J32	6	14	0.4541	0.118
	J38	16	36	0.3257	
P09	J35	3	9	0.4315	0.483
	J83	3	8	0.5592	

***** Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

****** Bartlett's Test

One thing to consider from the results in Table 7.28 is whether to treat the Intermediate course results and the Surface course results as separate from one another or to combine them. By observation, the standard deviation values for the two courses are in the same general range. The Two-Sample Mann-Whitney hypothesis test was used to compare the medians of the Means of Lot Means results for each course. The same test was used to compare the medians of the Lot Standard Deviations. The Mann-Whitney test does not require the data to come from normally distributed populations. It assumes that the populations of interest have the same shape and that the populations are independent. The results of the Mann-Whitney tests are shown in Table 7.29.

The medians of the Lot Means for Intermediate and Surface courses, with a P-value of 0.3077, are not different from one another. Similarly, with a P-value of 0.1665, the medians of the Lot Std Devs, cannot be declared significantly different. This supports the use of one set of tolerances for both Intermediate and Surface course mixes.

Table 7.28. Summary of VMA Test Results for Each Project

Number		Total Number of		Mean of *		Std Deviation**	
Project	JMF	Lots	Tests	All Tests	Lot Means	Project	Lot
Intermediate Course							
P01	J02	4	8	0.021	-0.0346	0.5575	0.7095
P01	J10	18	39	-0.2841	-0.3032	0.4725	0.3657
P01	J23	6	12	-0.025	-0.0232	0.4910	0.6908
P02	J04	14	30	0.218	0.4242	0.5880	0.3765
P02	J09	18	34	0.040	0.0211	0.6398	0.5249
P04	J08	5	10	0.607	0.6070	0.7628	0.9022
P05	J27	8	15	0.051	0.0413	0.4265	0.4077
P10	J31	41	77	0.2103	0.2279	0.6405	0.5970
P10	J37	12	22	0.402	0.4317	0.7225	0.5353
P10	J82	8	15	0.651	0.6731	0.5945	0.3279
P17	J22	6	11	-0.468	-0.4875	0.5188	0.6221
P21	J34	3	8	0.2300	0.1942	0.1737	0.1290
P25	J29	7	12	0.438	0.3879	0.4818	0.4023
P27	J53	14	15	0.035	0.0300	0.4632	0.4786
P27	J60	15	15	0.611	0.6107	0.5202	—
P28	J42	13	15	0.169	0.1958	0.5161	0.5716
P32	J76	12	43	-0.0809	-0.0884	0.4439	0.4136
P33	J73	8	25	0.1468	0.1714	0.4241	0.2938
Total/Average		**212**	**406**	**0.1651**	**0.1711**	**0.5243**	**0.4911**
Surface Course							
P01	J07	9	30	0.2430	0.2536	0.4805	0.4326
P01	J19	14	18	-0.036	0.0307	0.6343	0.4564
P02	J05	6	8	0.353	0.3975	0.3223	0.2083
P02	J13	14	18	0.233	0.2046	0.6190	0.3567
P02	J15	6	18	0.404	0.3438	0.5998	0.4860
P04	J14	5	17	0.356	0.3465	0.5180	0.5125
P05	J25	8	8	-0.221	-0.2213	0.7627	—
P06	J24	5	15	-0.210	-0.2100	0.5100	0.5491
P07	J30	19	40	-0.0288	0.0262	0.4594	0.4234
P09	J35	3	9	0.230	0.2300	0.4447	0.3995
P09	J83	3	8	-0.331	-0.3622	0.5793	0.6334
P10	J12	13	19	0.249	0.2435	0.6966	0.3057
P11	J41	4	10	0.3030	0.2931	0.2468	0.3680
P12	J38	6	14	-0.454	-0.5500	0.6565	0.6036
P13	J03	8	16	-0.089	-0.0267	0.4260	0.3149
P13	J43	8	19	0.155	0.2220	0.5851	0.5881
Continued							

Table 7.28. Summary of VMA Test Results for Each Project (*continued*)

Number		Total Number of		Mean of *		Std Deviation**	
Project	JMF	Lots	Tests	All Tests	Lot Means	Project	Lot
Surface Course (*cont*)							
P14	J16	13	32	-0.7066	-0.6616	0.5427	0.4245
P16	J20	3	9	-0.234	-0.2344	0.4529	0.4793
P18	J48	7	12	-0.057	-0.0107	0.6577	0.3949
P19	J49	7	20	-0.590	-0.5126	0.5948	0.4926
P20	J50	17	46	-0.2063	-0.2124	0.4182	0.3178
P21	J39	6	15	-0.7020	-0.6738	0.2255	0.1744
P22	J54	3	12	0.217	0.3628	0.7651	0.7207
P24	J56	18	40	-0.2148	-0.1542	0.5214	0.3821
P24	J64	7	13	-0.2123	-0.1971	0.2673	0.1920
P24	J67	6	10	-0.354	-0.3350	0.4534	0.5878
P25	J36	6	10	0.700	0.7069	0.7762	0.8118
P26	J58	12	13	0.288	0.2204	0.5575	0.6824
P26	J62	9	31	0.3458	0.3665	0.4341	0.3949
P26	J69	18	53	0.1757	0.2076	0.4618	0.2928
P27	J55	5	15	0.4627	0.4627	0.3515	0.3754
P27	J61	9	9	-0.286	-0.2856	0.5550	—
P27	J71	9	27	0.3057	0.3144	0.3086	0.5121
P28	J39	9	24	-0.4029	-0.4229	0.2105	0.1827
P29	J59	9	26	-0.0165	-0.0273	0.3254	0.2577
P30	J65	4	8	0.4800	0.4800	0.1793	0.2270
P32	J72	8	34	0.1409	0.1268	0.4499	0.3933
P32	J79	24	96	0.0493	0.0514	0.5533	0.4482
P33	J77	6	22	0.126	0.1761	0.6578	0.4098
P34	J62	7	28	0.0946	0.0602	0.4099	0.3731
P34	J81	7	13	0.469	0.3186	0.4789	0.5110
P35	J32	6	14	0.233	0.2633	0.4628	0.3182
P35	J38	16	36	0.1622	0.1899	0.3280	0.3607
Total/Average		**382**	**935**	**0.0331**	**0.0419**	**0.4870**	**0.4233**

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

Table 7.29. Results of Mann-Whitney Tests on the VMA Lot Means and Lot Std Devs

Course	No. of Lots	Median of Lot Means	P-Value*	No. of Lots	Median of Lot Std Devs	P-Value*
Intermediate	18	0.1828	0.3077	17	0.4786	0.1665
Surface	43	0.1268		41	0.3995	

* Values in bold are statistically significantly different at the $\alpha = 0.05$ level.

Table 7.30 shows Lot standard deviation results for the combined Intermediate and Surface course projects (from Table 7.28), but with the projects sorted from the smallest to largest Lot (i.e., within-lot) standard deviations. The projects are listed in increasing order of the Lot standard deviation to facilitate selecting a typical process standard deviation. The table also shows the total number of lots and tests for all VMA projects, the averages for both the Project standard deviation values and for the Lot standard deviation values, and percentiles based on ranked order for both the Project and Lot standard deviation values.

SCDOT can use Table 7.30 to assist in selecting the "typical" variability to use to establish specification limits. As noted in the discussion above, there is no single "correct" way to establish this value. A subjective decision must be made regarding the standard deviation to select. The percentile values shown in the table should assist in making the decision. To get a "picture" of the results in Table 7.30, Figure 7.15 shows the empirical cumulative distribution function (CDF) for the combined Lot standard deviation values.

As the reference lines show, there is not an obvious natural break point on the plot until approximately the 90^{th} percentile, which corresponds to a standard deviation of about 0.63. Another possible choice might be at around a standard deviation of 0.55, which corresponds to approximately the 77^{th} percentile on the CDF plot. Somewhere within the range of these two values would be a reasonable choice for the typical process standard deviation for VMA.

Table 7.30. Summary of VMA Test Results for Combined Intermediate and Surface Projects

Number		Total Number of		Mean of *		Std Deviation*		
Project	JMF	Lots	Tests	All Tests	Lot Means	Project	Lot	Course
P27	J60	15	15	0.611	0.6107	0.5202	—	Interm
P05	J25	8	8	-0.221	-0.2213	0.7627	—	Surface
P27	J61	9	9	-0.286	-0.2856	0.5550	—	Surface
P21	J34	3	8	0.2300	0.1942	0.1737	0.1290	Interm
P21	J39	6	15	-0.7020	-0.6738	0.2255	0.1744	Surface
P28	J39	9	24	-0.4029	-0.4229	0.2105	0.1827	Surface
P24	J64	7	13	-0.2123	-0.1971	0.2673	0.1920	Surface
P02	J05	6	8	0.353	0.3975	0.3223	0.2083	Surface
P30	J65	4	8	0.4800	0.4800	0.1793	0.2270	Surface
P29	J59	9	26	-0.0165	-0.0273	0.3254	0.2577	Surface
P26	J69	18	53	0.1757	0.2076	0.4618	0.2928	Surface
P33	J73	8	25	0.1468	0.1714	0.4241	0.2938	Interm
P10	J12	13	19	0.249	0.2435	0.6966	0.3057	Surface
P13	J03	8	16	-0.089	-0.0267	0.4260	0.3149	Surface
P20	J50	17	46	-0.2063	-0.2124	0.4182	0.3178	Surface
P35	J32	6	14	0.233	0.2633	0.4628	0.3182	Surface
P10	J82	8	15	0.651	0.6731	0.5945	0.3279	Interm
P02	J13	14	18	0.233	0.2046	0.6190	0.3567	Surface
P35	J38	16	36	0.1622	0.1899	0.3280	0.3607	Surface
P01	J10	18	39	-0.2841	-0.3032	0.4725	0.3657	Interm
P11	J41	4	10	0.3030	0.2931	0.2468	0.3680	Surface
P34	J62	7	28	0.0946	0.0602	0.4099	0.3731	Surface
P27	J55	5	15	0.4627	0.4627	0.3515	0.3754	Surface
P02	J04	14	30	0.218	0.4242	0.5880	0.3765	Interm
P24	J56	18	40	-0.2148	-0.1542	0.5214	0.3821	Surface
P32	J72	8	34	0.1409	0.1268	0.4499	0.3933	Surface
P18	J48	7	12	-0.057	-0.0107	0.6577	0.3949	Surface
P26	J62	9	31	0.3458	0.3665	0.4341	0.3949	Surface
P09	J35	3	9	0.230	0.2300	0.4447	0.3995	Surface
P25	J29	7	12	0.438	0.3879	0.4818	0.4023	Interm
P05	J27	8	15	0.051	0.0413	0.4265	0.4077	Interm
P33	J77	6	22	0.126	0.1761	0.6578	0.4098	Surface
P32	J76	12	43	-0.0809	-0.0884	0.4439	0.4136	Interm
P07	J30	19	40	-0.0288	0.0262	0.4594	0.4234	Surface
P14	J16	13	32	-0.7066	-0.6616	0.5427	0.4245	Surface
P01	J07	9	30	0.2430	0.2536	0.4805	0.4326	Surface
P32	J79	24	96	0.0493	0.0514	0.5533	0.4482	Surface
P01	J19	14	18	-0.036	0.0307	0.6343	0.4564	Surface
P27	J53	14	15	0.035	0.0300	0.4632	0.4786	Interm
P16	J20	3	9	-0.234	-0.2344	0.4529	0.4793	Surface

Continued

Table 7.30. Summary of VMA Test Results for Combined Intermediate and Surface Projects (*continued*)

Number		Total Number of		Mean of *		Std Deviation*		
Project	**JMF**	**Lots**	**Tests**	**All Tests**	**Lot Means**	**Project**	**Lot**	**Course**
P02	J15	6	18	0.404	0.3438	0.5998	0.4860	Surface
P19	J49	7	20	-0.590	-0.5126	0.5948	0.4926	Surface
P34	J81	7	13	0.469	0.3186	0.4789	0.5110	Surface
P27	J71	9	27	0.3057	0.3144	0.3086	0.5121	Surface
P04	J14	5	17	0.356	0.3465	0.5180	0.5125	Surface
P02	J09	18	34	0.040	0.0211	0.6398	0.5249	Interm
P10	J37	12	22	0.402	0.4317	0.7225	0.5353	Interm
P06	J24	5	15	-0.210	-0.2100	0.5100	0.5491	Surface
P28	J42	13	15	0.169	0.1958	0.5161	0.5716	Interm
P24	J67	6	10	-0.354	-0.3350	0.4534	0.5878	Surface
P13	J43	8	19	0.155	0.2220	0.5851	0.5881	Surface
P10	J31	41	77	0.2103	0.2279	0.6405	0.5970	Interm
P12	J38	6	14	-0.454	-0.5500	0.6565	0.6036	Surface
P17	J22	6	11	-0.468	-0.4875	0.5188	0.6221	Interm
P09	J83	3	8	-0.331	-0.3622	0.5793	0.6334	Surface
P26	J58	12	13	0.288	0.2204	0.5575	0.6824	Surface
P01	J23	6	12	-0.025	-0.0232	0.4910	0.6908	Interm
P01	J02	4	8	0.021	-0.0346	0.5575	0.7095	Interm
P22	J54	3	12	0.217	0.3628	0.7651	0.7207	Surface
P25	J36	6	10	0.700	0.7069	0.7762	0.8118	Surface
P04	J08	5	10	0.607	0.6070	0.7628	0.9022	Interm
Total/Average		**594**	**1341**	**0.0721**	**0.0800**	**0.4980**	**0.4432**	
					50%	**0.4910**	**0.4117**	
					60%	**0.5214**	**0.4608**	
					70%	**0.5793**	**0.5120**	
					80%	**0.6190**	**0.5813**	
					90%	**0.6578**	**0.6481**	

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

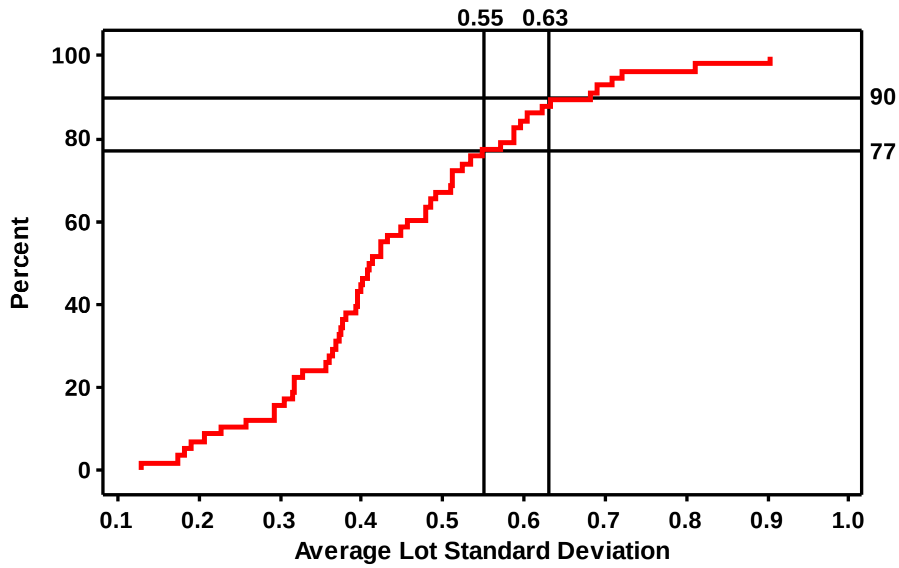

Figure 7.15. CDF for AV for Lot Standard Deviations for Intermediate and Surface Projects

PWL Values for the VMA Projects. The VMA projects did not exhibit the same concern that was found with the Density projects where many of the projects had relatively low average PWL values. A different problem with the VMA projects was that many of the projects did not have sufficient sample sizes to calculate a PWL value for the lots. There must be at least 3 test results for a lot to be able to estimate the PWL value for the lot. Rather than to combine lots, which is what would have been done in the field to determine the PWL to use for determining the payment factor, lots that had at least 3 tests were evaluated to determine their estimated PWL values. This resulted in PWL calculations for 207 lots.

Of the 207 lots, 19 had PWL values less than 90, which would result in some form of price reduction. Only 4 of the projects had average lot PWL values less than 90, and one of those had an average lot PWL value 89.92.

Summary

Analyses were conducted on project test results for Asphalt Content, Air Voids, and VMA. The primary goal of these analyses was to determine values to use to represent the typical variability for each of these characteristics. This is a subjective decision that ultimately must be made by SCDOT. Some potential values were identified during the analyses, and these are used as examples for additional evaluations in subsequent chapters.

The values for typical standard deviations that SCDOT might consider to represent the typical within-lot variability used to evaluate existing specification limits include:

Asphalt Content:	Base Course:	0.25% – 0.295%
	Intermediate Course:	0.21% – 0.26%
	Surface Course:	0.195% – 0.215%

Air Voids: 0.525% – 0.59%

VMA: 0.55% – 0.63%

Important Note: The above values consider only the "within-lot" process standard deviation for each of the characteristics. If SCDOT would also like to consider some form of "target-miss" variability, then the appropriate standard deviations should likely be larger than those shown above. This issue is discussed in the next chapter that deals with payment considerations.

CHAPTER 8 — PAYMENT CONSIDERATIONS

Background

In Chapter 6 a range of within-lot standard deviation values was calculated for Density. In Chapter 7, similar within-lot standard deviation ranges were developed for asphalt content (AC), air voids (AV), and VMA. In this chapter, the potential variability of the population mean about the target value is considered in addition to the within-lot standard deviation values to develop an overall process standard deviation for each of the acceptance characteristics. These standard deviation values are compared with the current SCDOT specification limits to investigate whether or not these limits are still appropriate.

Variability of the Process Mean

The typical within-lot standard deviation serves as a measure of variability within the process for a typical contractor on a typical project. This standard deviation can be used to help decide upon specification limits for the acceptance characteristic. However, as discussed in Chapter 5, another factor that may need to be considered in addition to the within–lot variability is the capability of contractors to center their processes on the target value.

AC, AV, and VMA all have target values about which two–sided specification limits are established. The typical within-lot standard deviation can be used to establish these specification limits. The STD, however, must decide whether or not a typical contractor can be expected to always be able to center its process exactly on the target value. If the STD believes this to be possible, then the typical process standard deviation that was developed from the individual project values can be used when setting the specification limits. If, on the other hand, the STD believes that a typical contractor's process mean may vary about the target value, then it may be necessary to consider this fact when developing specification limits.

One approach would be to combine the "process center" variability and the "within–lot" variability by adding their associated variances, not their standard deviations. This assumes that the amount of process variability is independent of where the process is centered; an assumption that seems reasonable, particularly as long as the target miss is not very large.

If the STD does not believe that the contractor's process is constant throughout the life of a project, as would typically be the case when the agency has decided to use lot–by–lot acceptance, then there is no way to know how much of the lot–to–lot variation in sample means is from the natural variation of the sampling process and how much is due to misses, changes, or adjustments in the contractor's target mean during the project.

Therefore, a second approach might be to calculate a standard deviation based on combining all of the project data into one data set. While this is not a good way to establish a typical within–lot standard deviation, this approach will provide a larger standard deviation value that includes the lot–to–lot variation among the individual lot means. A decision to use this approach assumes that any "process center" variation within the project will be accounted for when all the test results are combined. The various project standard deviations could then be used to arrive at a typical process standard deviation that attempts to include both the "within–lot" and the possible "process center" variability.

Density

As noted in Chapter 6, since the “target” values for Density are not in the centers of their respective specification limits, there is no real benefit to the contractor to attempt to hit these targets with its process. The contractor maximizes it chances of meeting the PWL requirement by aiming for the center of the specification limits. This allows for the largest standard deviation that can be obtained while still meeting the specification requirements for full payment. So, even though the specification lists “target” values, these target values were not considered when performing analyses on the density test results.

Selecting the Project Variability. With no “process target” variability available, if SCDOT thought it necessary to account for variability of the contractor’s process mean, the best option would be to use the standard deviation for all tests on a given project.

Interstate Paving Projects. Table 8.1 shows the Density results for the Interstate paving projects. The table shows the average and standard deviation for all the average project lot means, as well as percentiles based on ranked order for both the Project and Lot standard deviation values. Also, Figure 8.1 shows the empirical CDF for the Project standard deviation values.

As the reference lines show, there is somewhat of a natural break at around the 65th percentile. Actually, at around 1.38, there is very little difference between the 65th and 80th percentiles.

In Chapter 6, the within-lot standard deviation was shown to be around 1.16 for Interstate projects. SCDOT will need to decide whether to use the within-lot or project standard deviation when establishing its specification limits for Density.

Table 8.1. Summary of Density Test Results for Interstate Paving Projects

Number		Mean of *		Std Deviation*	
Project	**JMF**	**All Tests**	**Lot Means**	**Project**	**Lot**
P01	J10	92.90	92.85	0.599	0.515
P01	J07	93.26	93.24	0.801	0.543
P01	J07	92.73	92.77	0.591	0.546
P23	J63	93.11	93.11	0.584	0.607
P01	J02	93.94	93.56	0.908	0.848
P32	J72	93.07	93.06	0.861	0.854
P32	J79	92.77	92.77	0.943	0.868
P03	J15	93.23	93.41	1.272	0.957
P26	J62	92.85	92.84	1.366	1.052
P32	J76	93.27	93.27	1.072	1.059
P26	J69	93.39	93.40	1.210	1.126
P33	J77	92.67	92.72	1.486	1.161
P32	J74	93.20	93.20	1.417	1.417
P33	J73	93.18	93.17	1.377	1.459
P34	J62	92.74	93.01	1.820	1.500
P23	J33	91.64	91.63	1.374	1.649
Total / Average		**Mean**	**93.00**	**1.105**	**1.010**
		St Dev	**0.445**		
			50%	**1.141**	**1.005**
			60%	**1.272**	**1.059**
			70%	**1.370**	**1.144**
			80%	**1.377**	**1.417**
			90%	**1.452**	**1.480**

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

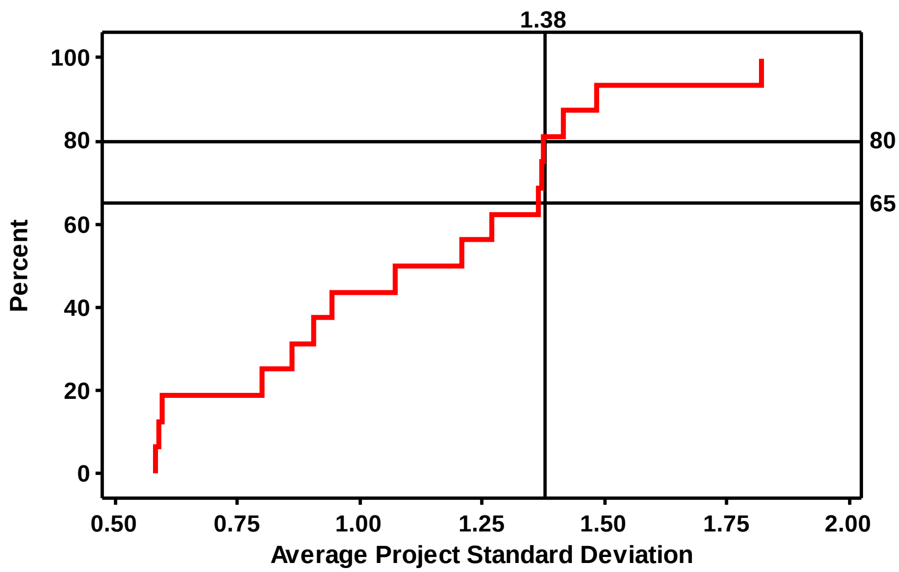

Figure 8.1. CDF for the Project Standard Deviations for Density for Interstate Projects

Other Paving Projects. Table 8.2 shows the Density results for the Other paving projects. The table shows the average and standard deviation for all the average project lot means, as well as percentiles based on ranked order for both the Project and Lot standard deviation values.

The first thing that is apparent in the table is the large standard deviation value of 1.436 for the lot means for the projects. This reflects the high degree of variability among the different projects regarding the contractors' abilities to meet the target Density in the specification requirements. Indeed, this standard deviation was in general greater than the within-lot standard deviation values for the various projects. This indicates that regardless the standard deviation, many contractors had difficulty meeting the density requirements.

Figure 8.2 shows the empirical CDF for the Project standard deviation values. As the reference lines show, there is a natural break at around the 80th percentile, with a corresponding standard deviation value of about 1.47.

In Chapter 6, the within-lot standard deviation was shown to be around 1.20 to 1.26 for Other projects. SCDOT will need to decide whether to use the within-lot or project standard deviation when establishing its specification limits for Density.

Table 8.2. Summary of Density Test Results for Other Paving Projects

Number		Mean of *		Std Deviation*	
Project	JMF	All Tests	Lot Means	Project	Lot
P31	J71	94.12	94.15	0.517	0.616
P27	J55	92.29	92.30	0.674	0.632
P20	J50	92.38	92.42	0.938	0.945
P06	J24	91.47	91.69	1.751	0.995
P24	J56	93.12	93.20	1.078	1.001
P03	J04	93.73	93.59	1.388	1.053
P16	J20	91.58	91.58	1.087	1.063
P27	J70	92.95	92.92	1.036	1.091
P26	J59	91.03	91.22	1.343	1.170
P14	J16	92.46	92.55	1.313	1.179
P06	J26	90.05	90.05	1.181	1.181
P08	J11	88.65	88.65	1.203	1.203
P28	J39	93.26	93.28	1.298	1.242
P04	J14	89.77	89.80	1.312	1.262
P01	J23	93.75	93.77	1.160	1.403
P36	J09	92.76	92.83	1.439	1.524
P13	J03	92.01	92.01	1.567	1.567
P15	J44	92.68	92.68	1.465	1.584
P30	J65	93.74	93.80	2.486	1.989
P18	J48	91.55	91.65	1.824	2.042
Total / Average		**Mean**	**92.21**	**1.303**	**1.237**
		St Dev	**1.436**		
			50%	**1.305**	**1.090**
			60%	**1.325**	**1.174**
			70%	**1.403**	**1.188**
			80%	**1.485**	**1.290**
			90%	**1.758**	**1.569**

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

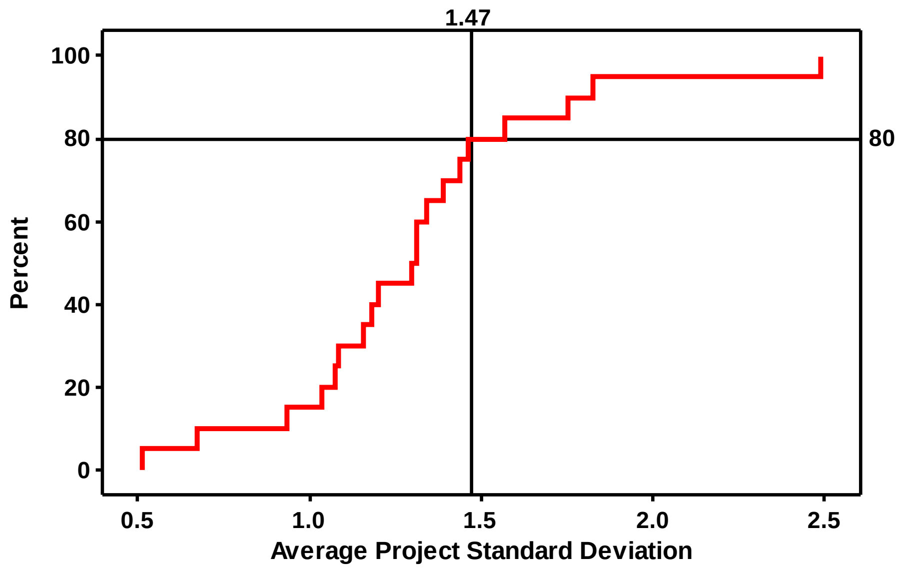

Figure 8.2. CDF for the Project Standard Deviations for Density for Other Projects

Density Specification Limits. As noted in Chapter 6, for Interstate paving projects the lower and upper specification limits for density were 92.2 and 96.0, respectively. The limits for Other paving projects were 91.2 and 96.0. For the projects on which data were obtained, the target values for density were 94.0 for Interstate paving projects and 93.0 for Other paving projects. The current SCDOT specification requirements, effective May 2010, have the same specification limits, but now call for a target value of 94.0 for both “Interstate and US Primary Routes” and for “All Other Paving.”

The typical process standard deviation that was used to develop the current Density specification limits was 1.09 (3). This value was used to determine the lower specification limits of 92.2 and 91.2. Note that each of these limits is 1.80 below the target value. This value was determined when SCDOT chose to set the limit such that 5% of the acceptable quality level (AQL) population would be below the limit. For any normal distribution, the point that is 1.645 standard deviation units below the mean will have 5% of the population below it. The specification limit therefore needed to be 1.645 × 1.09 = 1.80 from the target value.

Next, it was necessary to consider how the standard deviation values compare with the existing SCDOT specification limits. Using a standard deviation value of 1.20, which is within the 1.16 to 1.26 range identified in Chapter 6, the acceptable quality level (AQL) is therefore a population with a mean of 94.0 and a standard deviation of 1.20. Note that the situation would be worse if one of the higher Project standard deviations, 1.38 or 1.47, were used. Using a population mean of 94.0, standard deviation of 1.20, and the specification limits, the AQL can be calculated in terms of PWL. Figure 8.3 shows a plot of the AQL population.

The AQL population also can be defined in terms of PWL by calculating the area under the normal curve between the lower and upper specification limits. Figure 8.4 shows the AQL population along with the specification limits for Interstate paving projects. The area within the specification limits, i.e., the PWL, can be calculated using a spreadsheet or statistical software program, or by using equation 8.1 and 8.2 to calculate the *Z*-values to use with a table of the standard normal distribution.

$$Z_L = \frac{\mu - L}{\sigma} \quad \textbf{(8.1)}$$

$$Z_U = \frac{U - \mu}{\sigma} \quad \textbf{(8.2)}$$

Where:
- Z_L = *Z*-value corresponding to the lower specification limit.
- L = Lower specification limit.
- Z_U = *Z*-value corresponding to the upper specification limit.
- U = Upper specification limit.
- $\bar{X}$ = Population mean.
- σ = Population standard deviation.

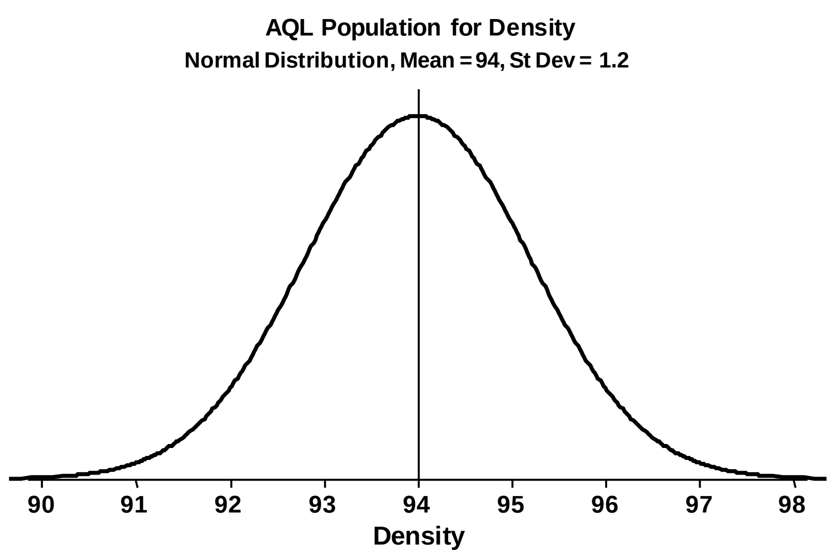

Figure 8.3. Plot of the AQL Population for Density

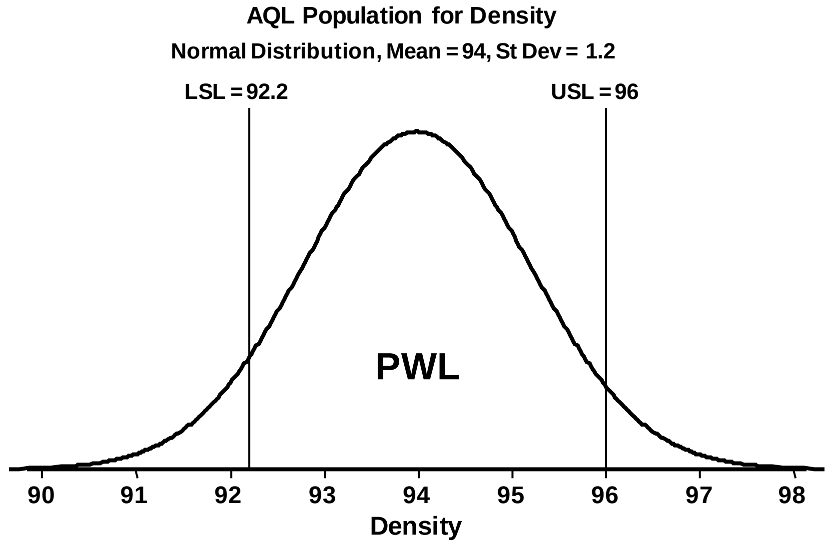

Figure 8.4. AQL Population for Density in Terms of PWL on Interstate Paving Projects

The PWL for the AQL population was calculated as 88.54. This is less than the PWL of 90 that is required for the contractor to receive 100 percent payment for the material placed.

Since the specified target value of 94.0 is not in the center of the specification region, it might be possible to increase the PWL value by centering the process at the center of the specification range, i.e., at 94.1. However, this raises the PWL only to 88.67, which is still below the 90 PWL requirement for full payment.

Therefore, SCDOT is faced with several options:

1. Decide that a standard deviation value of approximately 1.20 is appropriate and use the current specification limits. This has the effect of requiring the contractor to provide better than AQL quality to average 100 percent payment in the long run. To do this, the contractor would need to produce a population with standard deviation less than 1.20.

2. Decide that a standard deviation value of 1.20 was appropriate and modify the current specification limits so that the AQL population will have 90 percent within the revised limits.

   It is relatively simple to calculate the new limits if the mean is at the center of the specification region. For example, if the target mean remains at 94.0, then with a standard deviation of 1.20, it can be calculated that the specification limits would need to be 92.03 and 95.97 to have exactly 90 PWL. These would likely be rounded to 92 and 96.

   If SCDOT wishes to keep the lower specification limit at 92.2, then the mid-point for a symmetric specification region would correspond to the population mean that has 5% below the lower specification limit of 92.2. So, the population would need to have a mean that is $1.645 \times 1.20 = 1.974$ units above the lower specification limit, or a value of 94.174.

The upper specification limit would then be 1.974 units above the mean, or a value of 96.148.

3. Decide that a standard deviation less than 1.20 was appropriate and use the current specification limits and target value. Using a trial-and-error process with Excel, it easily can be determined that selecting a standard deviation value of 1.15 (which is very near the value of 1.16 that was originally identified above for Interstate paving) will yield exactly 90.00 for the PWL of the AQL population.

The second and third options seem to be the better choice. Although, the first option really turns out to be the same as the third option. The third option merely quantifies the decrease in standard deviation that is alluded to in option 1. Since the selection of the appropriate process standard deviation is subjective, option 3 is the easiest to implement since it does not require any modification to the current specification limits or target value. While this is the easiest option, the analyses of the project data indicate that the contractors may have a difficult time consistently providing the necessary process standard deviation.

A possible standard deviation value that was calculated in Chapter 6 to use with Other paving projects was 1.20. Due to the fact the lower specification limit is 91.2 rather than 92.2, the AQL population for Other paving projects will be 94.24 PWL (see Figure 8.5). So, the current specification limits and target value for Other paving should not present a particular problem to meet with respect to variability. However, Table 8.2 shows that for the projects in this study there was quite a bit of difficulty in achieving the 93.0 target value that was in place at the time of the projects.

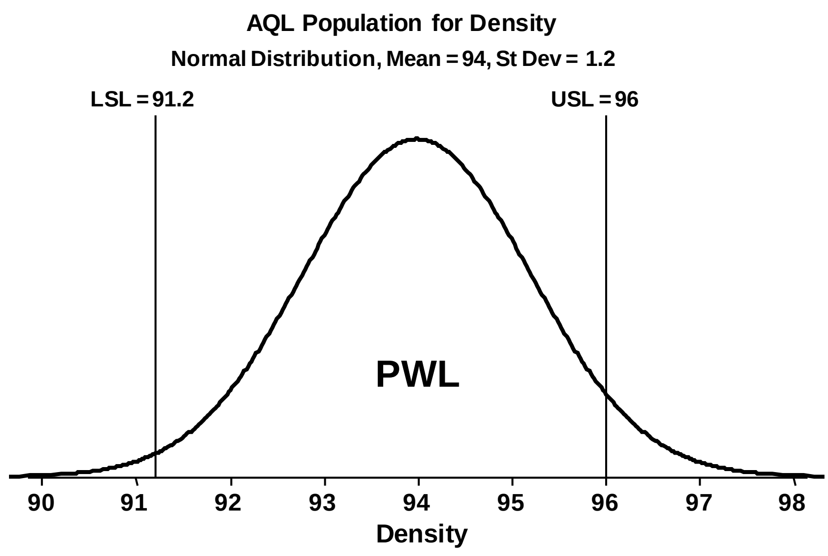

Figure 8.5. AQL Population for Density in Terms of PWL on Other Paving Projects

If a higher standard deviation in the range from 1.38 or 1.47, as calculated above, were selected as the typical standard deviation, then the situation would be much worse. For example, Figure 8.6 shows the AQL population if the current SCDOT specification limits for Interstate projects were used and the typical standard deviation was selected as 1.40. This results in an AQL of 82.4 in terms of PWL. This is quite far from the PWL of 90 that is required for full payment.

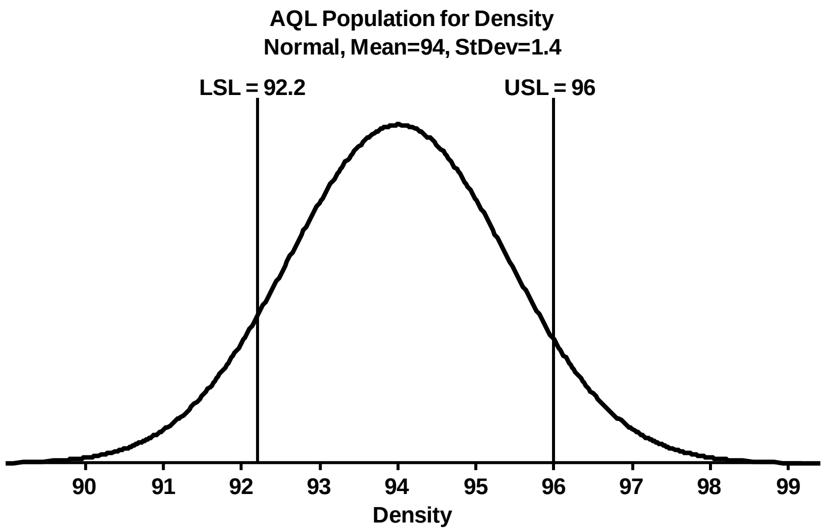

Figure 8.6. AQL Population for Density in Terms of PWL on Interstate Paving Projects with Standard Deviation = 1.40

Note of Caution: As noted in Chapter 5, a STD may choose to establish the typical standard deviation value to use based on "data from a number of past projects that it considered acceptable." Considering that nearly two-thirds of the projects from which density data were obtained had average project PWL values less than 90 PWL, SCDOT must decide whether or not it wishes to establish the typical project standard deviation based on these data.

If SCDOT believes that these projects represent the state-of-the-art regarding the process capability of a typical contractor, then SCDOT may need to re-evaluate their target density value and their density specification limits. If SCDOT believes that these projects do not represent what a typical contractor is capable of providing, then additional data from other representative projects will need to be obtained for analysis.

Asphalt Content

As noted in Chapter 7, the AC test data had specific target values. It was not possible to compare directly the actual test results since each project and each mix design had its own set of target values. It was possible, however, to normalize the data by considering the AC as differences from their target values. This made it possible to make comparisons among the various lots, mix designs, projects, mix types, and courses that could not be done on the actual test values.

Selecting the Project Variability. With a target value, if SCDOT thought it necessary, it could combine any potential "process target" variability with the selected "within-lot" variability to determine the overall typical process variability for AC. One approach to do this would be to add the "process center" variance and the "within–lot" variance. Another approach, as discussed above, would be to use the "Project" standard deviation values to select the typical process standard deviation.

Base Course. Table 8.3 shows the AC results for Base course mixes. The table shows the average and standard deviation for the average project Lot means, as well as percentiles based on ranked order for both the Project and Lot standard deviation values.

Table 8.3. Summary of AC Test Results for Each Base Course Project

Number		Mean of *		Std Deviation*	
Project	**JMF**	**All Tests**	**Lot Means**	**Project**	**Lot**
P27	J66	0.0455	0.0455	0.2035	—
P24	J57	0.1375	0.1375	0.1110	0.0517
P02	J28	0.0383	0.0404	0.2475	0.1832
P01	J01	0.0673	0.0398	0.2318	0.1933
P28	J47	-0.0250	-0.0385	0.2407	0.2193
P01	J18	-0.0480	-0.0564	0.2435	0.2237
P01	J06	0.0978	0.0942	0.2163	0.2512
P02	J17	-0.0147	0.0022	0.2983	0.3225
P01	J21	0.1085	0.1324	0.2574	0.3360
P26	J45	0.0620	0.0423	0.3723	0.3406
Total/Average		**Mean**	**0.0439**	**0.2422**	**0.2357**
		Std Dev	**0.0648**		
			50%	**0.2421**	**0.2237**
			60%	**0.2451**	**0.2457**
			70%	**0.2505**	**0.2940**
			80%	**0.2656**	**0.3279**
			90%	**0.3057**	**0.3369**

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

In Chapter 7, the typical Base course within-lot standard deviation was found to be in the 0.25 to 0.295 range. For illustration, a value of 0.27 is used. In Table 8.3, the standard deviation of the project Lot means, 0.0648, might be used as an estimate for the process target standard deviation. Equation 8.3 can be used to combine these into a single typical process standard deviation.

$$\sqrt{(0.27)^2 + (0.0648)^2} = 0.278 \approx 0.28 \quad \textbf{(8.3)}$$

Using the lower and upper limits of the within-lot standard deviation results in limits of 0.258 to 0.302, or approximately 0.26 to 0.30.

Figure 8.7 shows the empirical CDF for the Project standard deviation values in Table 8.3. As the reference lines show, an obvious choice appears at the 80th percentile and a Project standard deviation of approximately 0.26, which is a little less than the one calculated using the within-lot and process target variabilities.

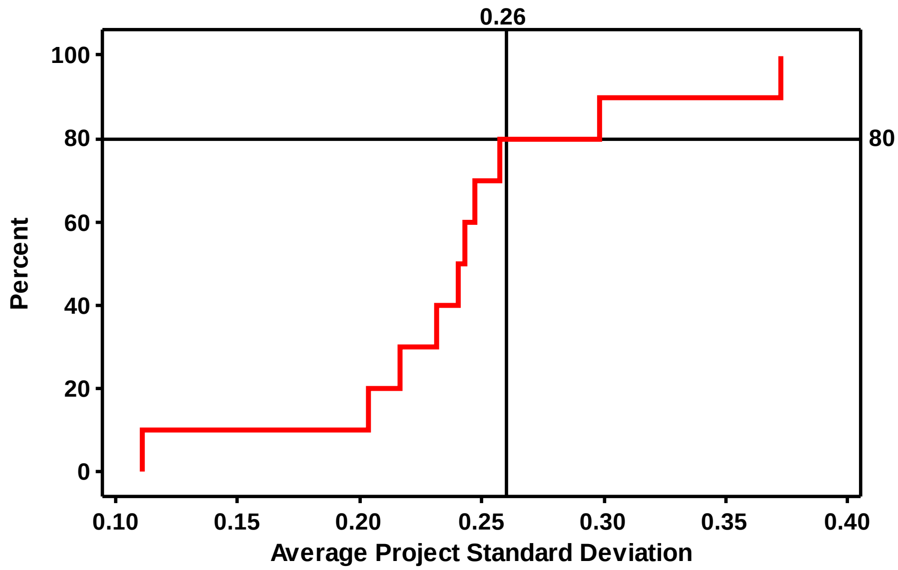

Figure 8.7. CDF for the Project Standard Deviations for AC for Base Course

Intermediate Course. Table 8.4 shows the AC results for Intermediate course mixes. The table shows the average and standard deviation for the average project Lot means, as well as percentiles based on ranked order for both the Project and Lot standard deviation values.

Table 8.4. Summary of AC Test Results for Each Intermediate Course Project

Number		Mean of *		Std Deviation*	
Project	JMF	All Tests	Lot Means	Project	Lot
P27	J60	0.2613	0.2613	0.2445	—
P28	J42	0.0847	0.0877	0.1950	0.1241
P10	J82	-0.0313	-0.0238	0.1963	0.1291
P21	J34	0.1025	0.0467	0.1861	0.1294
P05	J27	-0.1187	-0.1200	0.1290	0.1494
P01	J10	0.0036	0.0162	0.2016	0.1559
P27	J53	-0.0000	0.0134	0.2079	0.1566
P10	J37	0.0250	0.0396	0.2067	0.1764
P24	J51	0.0287	0.0457	0.1627	0.1806
P32	J76	0.0935	0.0920	0.2078	0.1813
P01	J02	0.1217	0.1150	0.1734	0.1915
P02	J09	0.0218	0.1190	0.2479	0.2058
P25	J29	-0.1567	-0.1614	0.2091	0.2127
P02	J04	0.1290	0.1815	0.2260	0.2131
P17	J22	0.0036	-0.0175	0.2648	0.2322
P33	J73	0.0520	0.0783	0.2283	0.2585
P04	J08	0.1800	0.1959	0.3053	0.2916
P10	J31	0.0129	0.0222	0.2583	0.2984
P01	J23	0.1050	0.0936	0.3111	0.4165
Total/Average		**Mean**	**0.0571**	**0.2190**	**0.2057**
		Std Dev	**0.1011**		
			50%	**0.2079**	**0.1864**
			60%	**0.2226**	**0.2072**
			70%	**0.2380**	**0.2131**
			80%	**0.2521**	**0.2480**
			90%	**0.2729**	**0.2936**

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

In Chapter 7, the typical Intermediate course within-lot standard deviation was found to be in the 0.21 to 0.26 range. For illustration, a value of 0.24 is used. In Table 8.4, the standard deviation of the project Lot means might be used as an estimate for the process target standard deviation. Equation 8.4 can be used to combine these into a single typical process standard deviation.

$$\sqrt{(0.24)^2 + (0.1011)^2} = 0.260 \tag{8.4}$$

Using the lower and upper limits of the within-lot standard deviation results in limits of 0.233 to 0.279, or approximately 0.23 to 0.28.

Figure 8.8 shows the empirical CDF for the Project standard deviation values in Table 8.4. As the reference lines show, an obvious choice appears at approximately the 80th percentile and a Project standard deviation of about 0.25, which is consistent with the one calculated using the within-lot and process target variabilities.

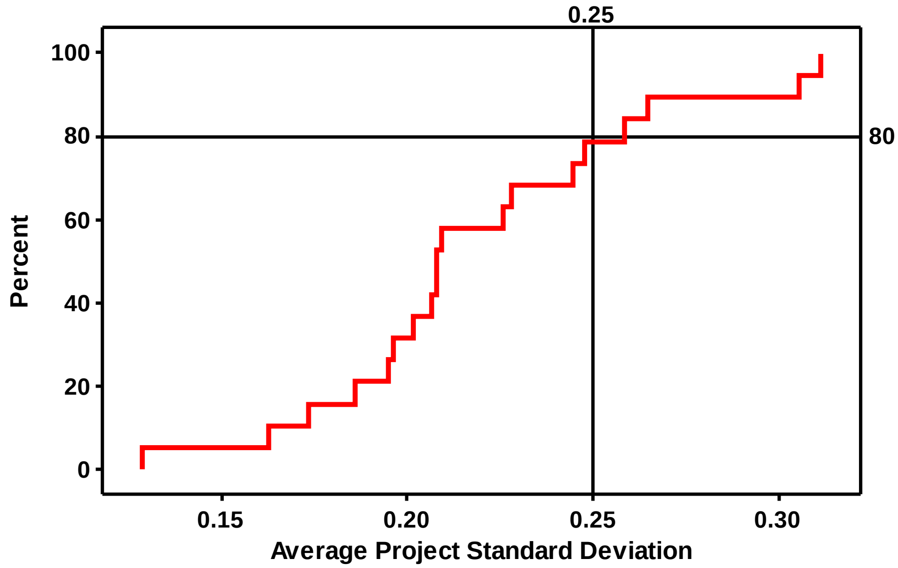

Figure 8.8. CDF for the Project Standard Deviations for AC for Intermediate Course

Surface Course. Table 8.5 shows the AC results for Surface course mixes. The table shows the average and standard deviation for the average project Lot means, as well as percentiles based on ranked order for both the Project and Lot standard deviation values.

In Chapter 7, the typical Surface course within-lot standard deviation was found to be in the 0.195 to 0.215 range. For illustration, a value of 0.205 is used. In Table 8.5, the standard deviation of the project Lot means might be used as an estimate for the process target standard deviation. Equation 8.6 can be used to combine these into a single typical process standard deviation.

$$\sqrt{(0.205)^2 + (0.0788)^2} = 0.220 \quad \textbf{(8.6)}$$

Using the lower and upper limits of the within-lot standard deviation results in limits of 0.210 to 0.229, or approximately 0.21 to 0.23.

Figure 8.9 shows the empirical CDF for the Project standard deviation values in Table 8.5. As the reference lines show, an obvious choice appears at approximately the 80th percentile and a Project standard deviation of 0.21, which is consistent with the one calculated using the within-lot and process target variabilities.

Table 8.5. Summary of AC Test Results for Each Surface Course Project

Number		Mean of *		Std Deviation*	
Project	JMF	All Tests	Lot Means	Project	Lot
P05	J25	-0.1313	-0.1313	0.1884	—
P27	J61	-0.0589	-0.0589	0.1290	—
P33	J75	-0.0150	-0.0150	0.1885	—
P24	J64	0.1431	0.1443	0.0574	0.0473
P22	J54	0.0467	0.0647	0.0845	0.0609
P24	J67	0.0590	0.1667	0.6117	0.0682
P02	J05	-0.0050	-0.0117	0.1506	0.0798
P34	J80	-0.0058	-0.0286	0.1030	0.0806
P30	J65	-0.0100	0.0000	0.0905	0.1000
P07	J30	-0.0940	-0.0971	0.1463	0.1034
P21	J39	0.0007	-0.0026	0.1283	0.1078
P02	J13	-0.0572	-0.0318	0.2949	0.1130
P35	J38	0.0536	0.0495	0.1249	0.1171
P11	J41	0.0710	0.0721	0.1731	0.1190
P26	J52	-0.0621	-0.0525	0.1452	0.1211
P32	J79	0.1139	0.1106	0.1622	0.1253
P29	J59	-0.0458	-0.0494	0.1427	0.1296
P13	J43	-0.0011	-0.0020	0.1554	0.1305
P35	J32	-0.0507	-0.0294	0.1513	0.1347
P09	J35	-0.0178	-0.0178	0.1492	0.1349
P06	J24	0.0647	0.0647	0.1732	0.1438
P01	J19	0.0828	0.1007	0.1435	0.1462
P28	J39	0.0429	0.0149	0.1542	0.1486
P34	J62	-0.0232	-0.0225	0.2043	0.1496
P26	J69	0.0029	-0.0201	0.1949	0.1531
P12	J38	0.0536	0.0676	0.1820	0.1592
P20	J50	0.0202	0.0484	0.1923	0.1648
P18	J48	0.1117	0.1164	0.2138	0.1701
P05	J40	-0.1344	-0.1180	0.1756	0.1726
P32	J46	-0.0220	-0.0157	0.1792	0.1736
P26	J62	0.0145	0.0082	0.1791	0.1741
P02	J15	-0.0122	0.0501	0.2058	0.1750
P01	J07	-0.0243	-0.0212	0.1808	0.1811
P32	J72	0.0706	0.0773	0.1740	0.1819
P27	J71	0.0559	0.0597	0.1621	0.1882
P09	J83	-0.0413	-0.0333	0.1954	0.1891
P14	J16	-0.1769	-0.1827	0.2113	0.1937
P04	J14	0.0618	0.0575	0.1937	0.2051
P10	J12	-0.0374	-0.0373	0.2781	0.2083
P16	J20	-0.1811	-0.1811	0.2351	0.2103
P19	J49	-0.0775	-0.0788	0.2602	0.2105

Continued

Table 8.5. Summary of AC Test Results for Each Surface Course Project (*continued*)

Number		Mean of *		Std Deviation*	
Project	JMF	All Tests	Lot Means	Project	Lot
P27	J55	0.1287	0.1287	0.1947	0.2122
P24	J56	0.0000	0.0759	0.2507	0.2161
P33	J77	0.0973	0.0988	0.2472	0.2295
P26	J58	-0.0031	0.0050	0.1707	0.2481
P34	J81	0.0923	0.0971	0.2117	0.2600
P25	J36	0.0570	0.0458	0.2081	0.2906
P13	J03	-0.0100	-0.0458	0.2735	0.3268
P33	J78	0.0492	0.0419	0.3541	0.3556
P26	J68	-0.0970	-0.0879	0.4339	0.4153
Total/Average		**Mean**	**0.0079**	**0.1962**	**0.1708**
		Std Dev	**0.0078**		
			50%	**0.1800**	**0.1648**
			60%	**0.1929**	**0.1746**
			70%	**0.2048**	**0.1900**
			80%	**0.2181**	**0.2105**
			90%	**0.2740**	**0.2529**

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

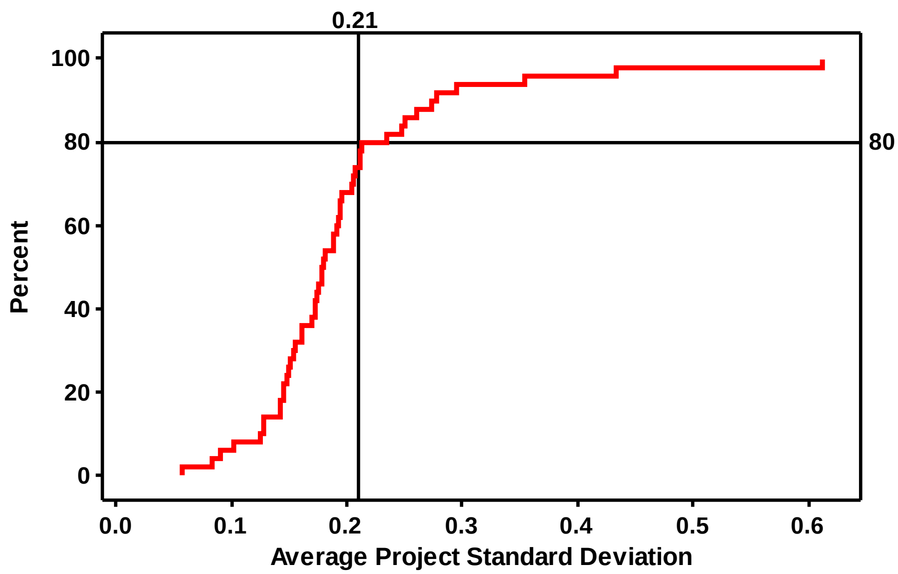

Figure 8.9. CDF for the Project Standard Deviations for AC for Surface Course

Asphalt Content Specification Limits. As noted in Chapter 7, different allowable tolerances (specification limits) currently apply to Base, Intermediate, and Surface courses. For each course, tolerances were developed by multiplying 1.645 times the typical process standard deviation for the course. The typical process standard deviations that SCDOT used were 0.30 for Base course, 0.26 for Intermediate course, and 0.22 for Surface course (3). These calculations resulted in tolerances of 1.645 × 0.3 = 0.50 for Base, 1.645 × 0.26 = 0.43 for Intermediate, and 1.645 × 0.22 = 0.36 for Surface.

The current standard deviations can be compared with those in the previous sections that were calculated from the data collected for this report. Table 8.6 shows such a comparison.

Table 8.6. Comparison of Current SCDOT Standard Deviations with Those from the New Project Data

Course	Std Dev Assumed in Current Specification	From Combined Within-Lot & Target Std Dev	From Total Project Std Dev 80th Percentile
Base	0.30	0.26-0.30	0.26
Intermediate	0.26	0.23-0.28	0.25
Surface	0.22	0.21-0.23	0.21

In Table 8.6 there are no obvious inconsistencies among the currently assumed standard deviation values and those calculated based on the project data for the current research. Based on these values, the SCDOT may consider tightening slightly the Base AC tolerances. However, based on the limited number of projects for which Base course data were provided, a change at this time may not be warranted. There is no compelling evidence that indicates that a change is warranted for either the Intermediate or Surface tolerances.

Air Voids

As noted in Chapter 7, the AV test data had specific target values. It was not possible to compare directly the actual test results since each project and each mix design had its own set of target values. It was possible, however, to normalize the data by considering the AV as differences from their target values. This made it possible to make comparisons among the various lots, mix designs, projects, mix types, and courses that could not be done on the actual test values.

Selecting the Project Variability. With a target value, if SCDOT thought it necessary, it could combine any potential “process target” variability with the selected “within-lot” variability to determine the overall typical process variability for AV. One approach to do this would be to add the “process center” variance and the “within–lot” variance. Another approach, as discussed above, would be to use the “Project” standard deviation values to select the typical process standard deviation.

Table 8.7 shows the AV results. The table shows the average and standard deviation for the average project Lot means, as well as percentiles based on ranked order for both the Project and Lot standard deviation values.

In Chapter 7, the typical within-lot standard deviation was found to be in the 0.525 to 0.59 range. For illustration, a value of 0.56 is used. In Table 8.7, the standard deviation of the project Lot means, 0.3524, might be used as an estimate for the process target standard deviation. Equation 8.7 can be used to combine these into a single typical process standard deviation.

$$\sqrt{(0.56)^2 + (0.3524)^2} = 0.662 \approx 0.66 \quad \textbf{(8.7)}$$

Using the lower and upper limits of the within-lot standard deviation results in limits of 0.632 to 0.687, or approximately 0.63 to 0.69.

Figure 8.10 shows the empirical CDF for the Project standard deviation values in Table 8.7. There is not an obvious natural break point, although as the reference lines show, likely choices include a Project standard deviation of 0.64 at the 80^{th} percentile or 0.685 at the 85^{th} percentile. This is approximately the same range as the one calculated using the within-lot and process target variabilities.

Table 8.7. Summary of AV Test Results

Number		Mean of *		Std Deviation*	
Project	JMF	All Tests	Lot Means	Project	Lot
P27	J60	0.0080	0.0080	0.6414	—
P05	J25	0.011	0.0113	0.5534	—
P27	J61	-0.364	-0.3644	0.5365	—
P27	J53	-0.1810	-0.1811	0.4510	0.0443
P21	J39	-0.8340	-0.7936	0.1504	0.1451
P24	J64	-0.6423	-0.5964	0.2932	0.1935
P26	J58	0.281	0.1821	0.6810	0.2038
P10	J37	0.5327	0.5371	0.3971	0.2207
P10	J82	0.7847	0.7869	0.2928	0.2216
P28	J39	-0.5963	-0.5436	0.2858	0.2291
P30	J65	0.5100	0.4867	0.2434	0.2316
P25	J29	0.6360	0.5929	0.5074	0.2375
P35	J38	0.0358	0.0815	0.3844	0.2381
P32	J72	-0.0374	-0.0719	0.5010	0.2384
P29	J59	-0.0069	-0.0072	0.2840	0.2487
P02	J04	-0.1630	-0.0838	0.5799	0.2696
P18	J48	-0.442	-0.4002	0.8357	0.2787
P05	J27	0.2327	0.2256	0.3932	0.2823
P02	J13	0.457	0.3721	0.5307	0.2880
P11	J41	0.106	0.0977	0.4256	0.3034
P34	J81	0.075	0.0907	0.5851	0.3057
P32	J76	-0.6007	-0.5974	0.3272	0.3108
P01	J10	-0.3559	-0.4066	0.4875	0.3224
P09	J35	0.293	0.2933	0.5066	0.3475
P21	J34	-0.0100	0.0833	0.3834	0.3477
P01	J23	-0.328	-0.3075	0.3550	0.3523
P04	J14	0.244	0.2433	0.5231	0.3691
P02	J15	0.532	0.2926	0.5602	0.3942
P02	J05	0.331	0.3942	0.4435	0.3944
P01	J07	0.3303	0.3323	0.5090	0.3991
P33	J77	0.462	0.4626	0.6375	0.4186
P27	J55	0.133	0.1333	0.4469	0.4258
P32	J79	-0.2536	-0.2436	0.4877	0.4356
P10	J31	0.1560	0.1524	0.5677	0.4411
P02	J09	-0.0912	-0.0825	0.5091	0.4415
P26	J69	0.1649	0.2549	0.6703	0.4460
P35	J32	0.399	0.3861	0.5372	0.4463
P20	J50	-0.2567	-0.3337	0.5495	0.4515
P06	J24	-0.391	-0.3907	0.4286	0.4613
P01	J02	-0.301	-0.2750	0.5772	0.4763
P33	J73	0.1260	0.0860	0.5295	0.4808

Continued

Table 8.7. Summary of AV Test Results (*continued*)

Number		Mean of *		Std Deviation*	
Project	JMF	All Tests	Lot Means	Project	Lot
P09	J83	-0.310	-0.3633	0.6073	0.4908
P26	J62	0.335	0.3689	0.6000	0.4910
P24	J67	-0.192	-0.1569	0.7268	0.5045
P07	J30	0.0193	0.0884	0.5036	0.5144
P14	J16	-0.447	-0.3851	0.7389	0.5168
P01	J19	-0.4180	-0.3925	0.5957	0.5251
P04	J08	0.1330	0.1330	0.4534	0.5619
P34	J62	0.152	0.1174	0.6853	0.5621
P10	J12	0.415	0.3935	0.6317	0.5627
P27	J71	0.2059	0.2039	0.5061	0.5727
P19	J49	-0.514	-0.4204	0.5826	0.5758
P12	J38	-0.643	-0.7899	0.7625	0.5774
P13	J03	-0.212	-0.0487	0.7148	0.5782
P28	J42	-0.0290	-0.0092	0.4540	0.5938
P25	J36	0.375	0.4125	0.6240	0.6116
P24	J56	-0.263	-0.1499	0.8253	0.6368
P17	J22	-0.4240	-0.3875	0.5813	0.6717
P13	J43	0.067	0.1515	0.8538	0.7440
P16	J20	0.164	0.1644	0.7841	0.7990
P22	J54	0.112	0.2432	0.8910	0.8222
Total/Average		**Mean**	**0.0013**	**0.5363**	**0.4182**
		Std Dev	**0.3524**		
			50%	0.5307	0.43070
			60%	0.5677	0.45346
			70%	0.5957	0.50315
			80%	0.6414	0.56246
			90%	0.7389	0.59914

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

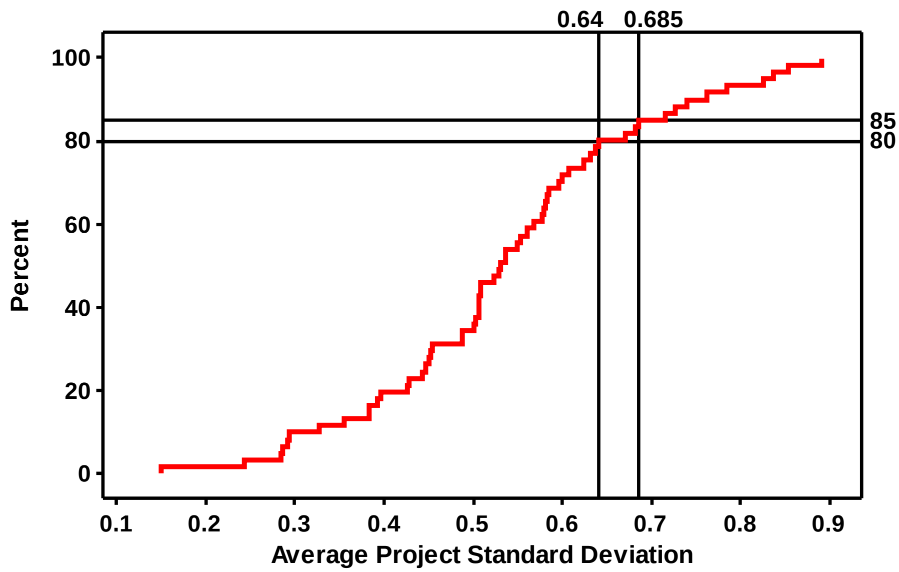

Figure 8.10. CDF for the Project Standard Deviations for AV

Air Voids Specification Limits. The current specification tolerances for AV were developed by multiplying 1.645 times the typical process standard deviation. The typical process standard deviation that SCDOT used was 0.70 (3). This calculation resulted in the current tolerances of 1.645 × 0.7 = 1.15.

The currently assumed standard deviation value is consistent with the ranges calculated based on the project data for the current research. Based on these values, the SCDOT may consider tightening slightly the AV tolerances, however, the results do not provide compelling evidence that a change is warranted.

VMA

As noted in Chapter 7, the VMA test data had specific target values. It was not possible to compare directly the actual test results since each project and each mix design had its own set of target values. It was possible, however, to normalize the data by considering the VMA as differences from their target values. This made it possible to make comparisons among the various lots, mix designs, projects, mix types, and courses that could not be done on the actual test values.

Selecting the Project Variability. With a target value, if SCDOT thought it necessary, it could combine any potential "process target" variability with the selected "within-lot" variability to determine the overall typical process variability for VMA. One approach to do this would be to add the "process center" variance and the "within–lot" variance. Another approach, as discussed above, would be to use the “Project” standard deviation values to select the typical process standard deviation.

Table 8.8 shows the VMA results. The table shows the average and standard deviation for the average project Lot means, as well as percentiles based on ranked order for both the Project and Lot standard deviation values.

In Chapter 7, the typical within-lot standard deviation was found to be in the 0.55 to 0.63 range. For illustration, a value of 0.59 is used. In Table 8.8, the standard deviation of the project Lot means, 0.3279, might be used as an estimate for the process target standard deviation. Equation 8.8 can be used to combine these into a single typical process standard deviation.

$$\sqrt{(0.59)^2 + (0.3279)^2} = 0.675 \qquad \textbf{(8.8)}$$

Using the lower and upper limits of the within-lot standard deviation results in limits of 0.64 to 0.71.

Figure 8.11 shows the empirical CDF for the Project standard deviation values in Table 8.8. There appears to be a natural break point at a Project standard deviation of approximately 0.66 at the 90^{th} percentile. This is within the range calculated using the within-lot and process target variabilities.

VMA Specification Limits. The current specification tolerances for VMA were developed by multiplying 1.645 times the typical process standard deviation. The typical process standard deviation that SCDOT used was 0.70 (3). This calculation resulted in the current tolerances of 1.645 × 0.7 = 1.15.

The currently assumed standard deviation value is consistent with the ranges calculated based on the project data for the current research. Based on these values, the results do not provide compelling evidence that a change is warranted.

Table 8.8. Summary of VMA Test Results

Number		Mean of *		Std Deviation*	
Project	JMF	All Tests	Lot Means	Project	Lot
P27	J60	0.611	0.6107	0.5202	—
P05	J25	-0.221	-0.2213	0.7627	—
P27	J61	-0.286	-0.2856	0.5550	—
P21	J34	0.2300	0.1942	0.1737	0.1290
P21	J39	-0.7020	-0.6738	0.2255	0.1744
P28	J39	-0.4029	-0.4229	0.2105	0.1827
P24	J64	-0.2123	-0.1971	0.2673	0.1920
P02	J05	0.353	0.3975	0.3223	0.2083
P30	J65	0.4800	0.4800	0.1793	0.2270
P29	J59	-0.0165	-0.0273	0.3254	0.2577
P26	J69	0.1757	0.2076	0.4618	0.2928
P33	J73	0.1468	0.1714	0.4241	0.2938
P10	J12	0.249	0.2435	0.6966	0.3057
P13	J03	-0.089	-0.0267	0.4260	0.3149
P20	J50	-0.2063	-0.2124	0.4182	0.3178
P35	J32	0.233	0.2633	0.4628	0.3182
P10	J82	0.651	0.6731	0.5945	0.3279
P02	J13	0.233	0.2046	0.6190	0.3567
P35	J38	0.1622	0.1899	0.3280	0.3607
P01	J10	-0.2841	-0.3032	0.4725	0.3657
P11	J41	0.3030	0.2931	0.2468	0.3680
P34	J62	0.0946	0.0602	0.4099	0.3731
P27	J55	0.4627	0.4627	0.3515	0.3754
P02	J04	0.218	0.4242	0.5880	0.3765
P24	J56	-0.2148	-0.1542	0.5214	0.3821
P32	J72	0.1409	0.1268	0.4499	0.3933
P18	J48	-0.057	-0.0107	0.6577	0.3949
P26	J62	0.3458	0.3665	0.4341	0.3949
P09	J35	0.230	0.2300	0.4447	0.3995
P25	J29	0.438	0.3879	0.4818	0.4023
P05	J27	0.051	0.0413	0.4265	0.4077
P33	J77	0.126	0.1761	0.6578	0.4098
P32	J76	-0.0809	-0.0884	0.4439	0.4136
P07	J30	-0.0288	0.0262	0.4594	0.4234
P14	J16	-0.7066	-0.6616	0.5427	0.4245
P01	J07	0.2430	0.2536	0.4805	0.4326
P32	J79	0.0493	0.0514	0.5533	0.4482
P01	J19	-0.036	0.0307	0.6343	0.4564
P27	J53	0.035	0.0300	0.4632	0.4786
P16	J20	-0.234	-0.2344	0.4529	0.4793

Table 8.8. Summary of VMA Test Results (*continued*)

Number		Mean of *		Std Deviation*	
Project	JMF	All Tests	Lot Means	Project	Lot
P02	J15	0.404	0.3438	0.5998	0.4860
P19	J49	-0.590	-0.5126	0.5948	0.4926
P34	J81	0.469	0.3186	0.4789	0.5110
P27	J71	0.3057	0.3144	0.3086	0.5121
P04	J14	0.356	0.3465	0.5180	0.5125
P02	J09	0.040	0.0211	0.6398	0.5249
P10	J37	0.402	0.4317	0.7225	0.5353
P06	J24	-0.210	-0.2100	0.5100	0.5491
P28	J42	0.169	0.1958	0.5161	0.5716
P24	J67	-0.354	-0.3350	0.4534	0.5878
P13	J43	0.155	0.2220	0.5851	0.5881
P10	J31	0.2103	0.2279	0.6405	0.5970
P12	J38	-0.454	-0.5500	0.6565	0.6036
P17	J22	-0.468	-0.4875	0.5188	0.6221
P09	J83	-0.331	-0.3622	0.5793	0.6334
P26	J58	0.288	0.2204	0.5575	0.6824
P01	J23	-0.025	-0.0232	0.4910	0.6908
P01	J02	0.021	-0.0346	0.5575	0.7095
P22	J54	0.217	0.3628	0.7651	0.7207
P25	J36	0.700	0.7069	0.7762	0.8118
P04	J08	0.607	0.6070	0.7628	0.9022
Total/Average		**Mean**	**0.0800**	**0.4980**	**0.4432**
		Std Dev	**0.3279**		
			50%	**0.4910**	**0.4117**
			60%	**0.5214**	**0.4608**
			70%	**0.5793**	**0.5120**
			80%	**0.6190**	**0.5813**
			90%	**0.6578**	**0.6481**

* **All Tests:** the mean of all individual test results on the project
Lot Means: the mean of all the individual lot means on the project

** **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

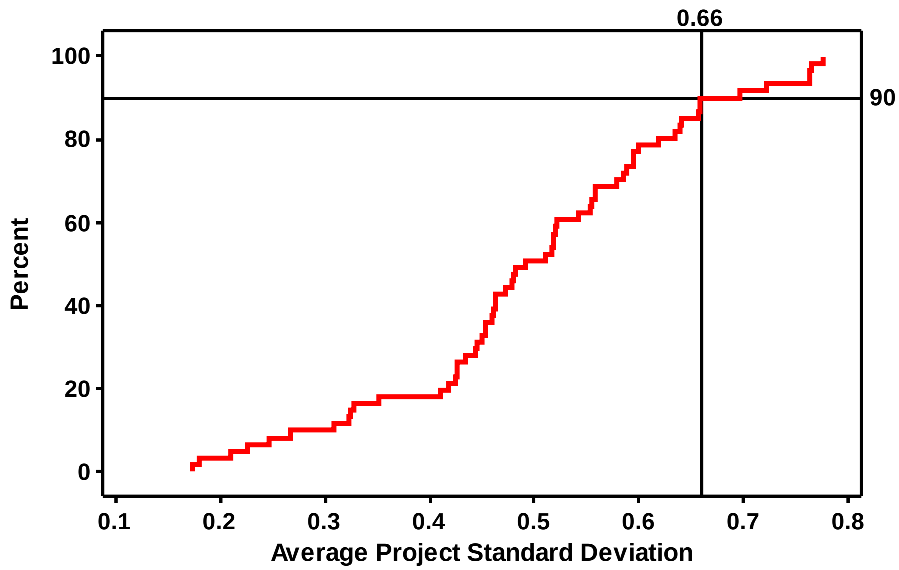

Figure 8.10. CDF for the Project Standard Deviations for VMA

Payment Considerations

SCDOT uses equation 8.9 along with the estimated PWL value for the lot to determine the payment factor for each quality characteristic, i.e., Density, AC, AV, and VMA.

$$PF = 55 + 0.5(TPWL) \quad \textbf{(8.9)}$$

Where: PF = Percent pay factor for each quality characteristic.
$TPWL$ = Total estimated percent within limits.

Once the individual payment factors have been calculated, the payment factor for the lot is determined from the composite payment equation in equation 8.10.

$$LPF = 0.30(PF_{AC}) + 0.25(PF_{AV}) + 0.10(PF_{VMA}) + 0.35(PF_{Den}) \quad \textbf{(8.10)}$$

Where: LPF = Percent pay factor for the lot.
PF_{AC} = Percent pay factor for asphalt content.
PF_{AV} = Percent pay factor for air voids.
PF_{VMA} = Percent pay factor for VMA.
PF_{Den} = Percent pay factor for density

Correlated Characteristics. Equation 8.10 implicitly assumes that the quality characteristics are statistically independent of one another. The test data were analyzed to investigate any possible correlations among the acceptance quality characteristics. Since there is a one–to–one correspondence among each AC, AV, and VMA test it was possible to calculate linear correlation coefficients for the 3 pairwise combinations of AC–AV, AC–VMA, and AV–VMA.

However, since the lots for AC, AV, and VMA were based on tonnage at the plant, whereas the lots for density were based on paving lane length, there was no direct comparison possible between individual density and plant tests. There was, however, a direct correspondence between the plant test means and the density test means for each lot on a project. While field conditions in addition to the materials will affect the density obtained in the field, nevertheless the Density, AC, AV, and VMA means for each lot were analyzed to identify whether or not correlation was present.

Since there may be different levels or lack of correlation for different courses, mix types, job mix formulas, etc., each project was treated individually when calculating the correlation coefficients. Table 8.9 shows the correlation coefficient for the individual plant test values for each Intermediate course project for which AC, AV, and VMA results were all available. Table 8.10 shows similar information for Surface course projects. To obtain better estimates for the correlation coefficients, projects with fewer than 10 sets of plant tests were not included in the analyses.

Table 8.9. Summary of Correlation Coefficients for Individual Tests for AC, AV, and VMA for Intermediate Course Projects

Project No.	JMF No.	No. of Tests	Linear Correlation Coefficient		
			AC-AV*	AC-VMA*	AV-VMA*
P01	J10	39	**-0.437**	**0.570**	**0.487**
P01	J23	12	**-0.791**	**0.920**	-0.491
P02	J04	30	**-0.429**	**0.508**	**0.558**
P02	J09	34	-0.237	**0.706**	**0.517**
P04	J08	21	-0.301	**0.877**	0.194
P10	J31	77	**-0.369**	**0.603**	**0.518**
P10	J37	22	-0.313	**0.723**	0.170
P10	J82	15	0.348	**0.902**	**0.711**
P17	J22	11	**-0.604**	*0.530*	0.354
P25	J29	12	-0.485	*0.508*	*0.500*
P27	J53	19	*-0.450*	**0.591**	*0.452*
P27	J60	15	**-0.584**	0.413	*0.497*
P28	J42	15	-0.312	**0.623**	**0.545**
P32	J76	43	*-0.271*	**0.752**	*0.271*
P33	J73	25	**-0.654**	**0.494**	0.334
Total / Average		**390**	**-0.393**	**0.648**	**0.374**

***** Values in **Bold** are significantly different from 0 at the 0.05 significance level.
Values in *Italics* are significantly different from 0 at the 0.10 significance level.

The results in Table 8.9 show that AC and AV are negatively correlated, whereas AC and VMA as well as AV and VMA are positively correlated. For the AC-AV correlations, 14 of 15 projects showed negative correlation coefficients, with 7 of the values significantly different than 0 at the 0.05 level of significance and another 2 values significantly different than 0 at the 0.10 level. For the AC-VMA correlations, all 15 projects showed positive correlation coefficients, with 12 of the values significantly different than 0 at the 0.05 level of significance and another 2 values significantly different than 0 at the 0.10 level. For the AV-VMA correlations, 14 of 15 projects showed positive correlation coefficients, with 6 of the values significantly different than 0 at the 0.05 level of significance and another 4 values significantly different than 0 at the 0.10 level.

Similar trends are shown in Table 8.10. For the AC-AV correlations, 33 of 37 projects showed negative correlation coefficients, with 19 of the values significantly different than 0 at the 0.05 level of significance and another 4 values significantly different than 0 at the 0.10 level. For the AC-VMA correlations, 34 of 37 projects showed positive correlation coefficients, with 18 of the values significantly different than 0 at the 0.05 level of significance and another 4 values significantly different than 0 at the 0.10 level. For the AV-VMA correlations, 36 of 37 projects showed positive correlation coefficients, with 30 of the values significantly different than 0 at the 0.05 level of significance.

Table 8.11 shows the correlation coefficient for the plant test lot means and the density test lot means for each project. Since the plant test correlations are considered in Tables 8.9 and 8.10, Table 8.11 includes only the Density correlation coefficient for each of the three plant test characteristics. Specifically, the Density-AC, Density-AV, and Density-VMA correlations are presented in Table 8.11.

The values in Table 8.11 are not nearly as consistent as those in Tables 8.9 and 8.10. For example, for Intermediate course both the Density-AC and Density-VMA comparisons have 2 positive and 2 negative correlation coefficients and the Density-AV comparison has 1 negative and 3 positive coefficients. Only 1 of the 12 correlation coefficients is different than 0 at the 0.05 significance level, and another 2 are different than 0 at the 0.10 significance level.

The results are more consistent for the Surface course comparisons. For the Density-AC correlation coefficients, 11 of 17 projects showed Negative correlation coefficients, with 7 of the values significantly different than 0 at the 0.05 level of significance. All of the coefficients that were significantly different than 0 were positive. For the Density-AV correlation coefficients, 11 of 17 projects showed negative correlation coefficients, with 2 of the values significantly different than 0 at the 0.05 level of significance and another 2 values significantly different than 0 at the 0.10 level. All of the coefficients that were significantly different than 0 were negative. For the Density-VMA correlation coefficients, 8 projects showed negative correlation coefficients and 9 projects showed positive correlation coefficients. None of the values were significantly different than 0 at the 0.05 level of significance. Two of the values were significantly different than 0 at the 0.10 level, but one of these was negative and the other was positive.

Table 8.10. Summary of Correlation Coefficients for Individual Tests for AC, AV, and VMA for Surface Course Projects

Project No.	JMF No.	No. of Tests	Linear Correlation Coefficient		
			AC-AV*	AC-VMA*	AV-VMA*
P01	J07	30	**-0.383**	**0.495**	**0.612**
P01	J19	18	0.111	**0.603**	**0.857**
P02	J13	18	*-0.409*	**0.725**	0.323
P02	J15	18	-0.236	**0.607**	**0.627**
P04	J14	17	*-0.415*	*0.433*	**0.623**
P05	J25	23	0.128	**0.650**	**0.833**
P06	J24	15	-0.098	**0.642**	**0.612**
P07	J30	40	*-0.270*	**0.430**	**0.751**
P10	J12	19	-0.304	**0.612**	**0.560**
P11	J41	10	**-0.796**	0.415	0.210
P12	J38	14	-0.387	0.210	**0.819**
P13	J03	16	**-0.715**	0.325	0.426
P13	J43	19	**-0.651**	-0.251	**0.897**
P14	J16	32	**-0.580**	0.141	**0.723**
P18	J48	12	-0.463	0.189	**0.782**
P19	J49	20	*-0.381*	**0.623**	**0.482**
P20	J50	46	**-0.518**	**0.360**	**0.609**
P21	J39	15	**-0.549**	**0.882**	-0.092
P22	J54	12	-0.249	0.093	**0.920**
P24	J56	40	**-0.707**	-0.061	**0.618**
P24	J64	13	0.217	**0.722**	**0.751**
P24	J67	10	-0.125	0.182	**0.785**
P25	J36	10	0.290	**0.727**	**0.867**
P26	J58	13	-0.411	0.219	**0.798**
P26	J62	31	**-0.649**	0.093	**0.627**
P26	J69	53	**-0.580**	*0.237*	**0.653**
P27	J55	15	**-0.657**	*0.490*	0.333
P27	J71	27	**-0.494**	*0.333*	**0.655**
P28	J39	24	**-0.682**	**0.621**	0.103
P29	J59	16	-0.324	**0.696**	**0.449**
P32	J72	34	**-0.412**	**0.490**	**0.591**
P32	J79	96	**-0.257**	**0.433**	**0.579**
P33	J77	22	**-0.782**	0.110	0.307
P34	J62	28	**-0.767**	-0.060	**0.683**
P34	J81	13	**-0.538**	0.394	**0.558**
P35	J32	14	-0.384	0.300	**0.764**
P35	J38	36	**-0.439**	**0.350**	**0.681**
Total / Average		**889**	**-0.402**	**0.391**	**0.605**

***** Values in **Bold** are significantly different from 0 at the 0.05 significance level.
Values in *Italics* are significantly different from 0 at the 0.10 significance level.

Table 8.11. Summary of Correlation Coefficients for Lot Test Means for Density Compared with AC, AV, and VMA

Project No.	JMF No.	No. of Lots	Linear Correlation Coefficient		
			Den-AC*	**Den-AV***	**Den-VMA***
Intermediate Course					
P01	J02	4	-0.470	0.059	-0.575
P01	J10	7	*-0.744*	**0.856**	0.237
P32	J76	12	0.067	-0.352	-0.123
P33	J73	8	0.606	0.256	*0.637*
Total / Average		**31**	**-0.135**	**0.205**	**0.044**
Surface Course					
P01	J07	4	-0.216	0.164	0.062
P01	J07	4	0.703	0.238	*0.910*
P04	J14	5	**0.903**	-0.523	-0.100
P06	J24	5	0.425	0.224	0.631
P14	J16	6	**0.603**	-0.271	0.426
P16	J20	3	0.935	*-0.993*	-0.738
P18	J48	3	**0.999**	-0.238	0.188
P20	J50	7	0.165	**-0.787**	*-0.677*
P24	J56	7	-0.649	0.168	-0.204
P26	J62	9	**0.677**	-0.388	0.077
P26	J69	16	-0.105	-0.310	-0.407
P27	J55	4	0.552	-0.812	-0.871
P28	J39	4	-0.592	0.554	-0.099
P32	J72	8	**0.772**	*-0.660*	-0.418
P32	J79	24	**0.437**	-0.101	0.221
P33	J77	6	**0.903**	**-0.892**	-0.432
P34	J62	4	-0.089	0.270	0.540
Total / Average		**119**	**0.378**	**-0.256**	**-0.052**

***** Values in **Bold** are significantly different from 0 at the 0.05 significance level.
Values in *Italics* are significantly different from 0 at the 0.10 significance level.

The results in Tables 8.9 and 8.10 indicate that the plant characteristics are probably not statistically independent of one another. Table 8.11 is less conclusive regarding potential correlations between Density and the plant characteristics of AC, AV, and VMA. It is logical to anticipate that the characteristics of the HMA will be correlated to the field Density since the characteristics of the mix should influence the ability to achieve compaction. However, there are many factors other than the mix that can influence the compaction in the field. Factors such as rolling patterns, climate conditions, waiting time prior to unloading, etc., may lead to the lack of correlation exhibited by the data.

Affect of Correlation on Payment. It has been shown that correlation among the characteristics used in a composite payment equation such as equation 8.10 will not impact the average payment that the contractor will receive in the long run for a given quality of material (3, 5, 18). For example, if the contractor produced the identical population for say 10,000 lots, the average payment for these lots would be very near the correct payment that would be made for each of the individual lots if the constant population were known with certainty. If an infinite number of lots with the same population were produced, typically the same average payment would be obtained whether or not the payment characteristics were correlated or independent.

However, while the average payment would remain the same, the variability of the individual estimates about this average would tend to increase as the magnitude of the correlation coefficients increases. This is to be expected. There will be times when one of the variables is outside the specifications and has a corresponding price reduction. However, sometimes when this occurs the other variable will be well inside the specification and will have either full payment or a payment incentive (bonus). However, if the two variables are highly correlated, if one variable is outside the specification on the high side it is likely that the other variable will also be on the high side. In which case the two payment factors will both yield price reductions. On the other hand, if one variable is well within the specifications the other one is also likely well within the specifications, and this will lead to both variables indicating a bonus payment. The long–term average payment will be the same whether or not the two variables are correlated, but the correlated variables will have a greater amount of spread among the individual lot payment factors.

The affect of correlation among the payment characteristics will likely have more impact on the contractor than on the STD. This is because the STD will operate under the same specification on many more projects than will an individual contractor that performs a limited number of projects for the STD. The larger potential individual lot payment error associated with the correlated characteristics will have many more opportunities to offset one another on the high and low payment sides for the STD. If a large underpayment error occurs on a project, the contractor will likely not have sufficient additional lots for which overpayments can make up for the large underpayment.

Summary

The potential variability of the population mean about the target value was considered in addition to the within-lot standard deviation values to develop an overall process standard deviation for each of the acceptance characteristics. These standard deviation values were then compared with the current SCDOT specification limits to investigate whether or not these limits are still appropriate.

The standard deviation that was identified as the typical overall variability for Density is greater than the one used by SCDOT to establish the specification limits. A STD may establish the typical standard deviation value based on data from a number of past projects that it considered “acceptable.” Since nearly two-thirds of the projects from which density data were obtained had average project PWL values less than 90 PWL, SCDOT must decide whether or not it wishes to establish the typical project standard deviation based on the data provided for the current research study.

If SCDOT believes that these projects represent the state-of-the-art regarding the process capability of a typical contractor, then SCDOT may need to re-evaluate their target density value and their density specification limits. If SCDOT believes that these projects do not represent what a typical contractor is capable of providing, then additional data from other representative projects will need to be obtained for analysis.

The values for typical standard deviations that SCDOT might consider to represent the typical overall variability used to evaluate existing specification limits include:

Asphalt Content:	Base Course:	0.26% – 0.30%
	Intermediate Course:	0.23% – 0.28%
	Surface Course:	0.21% – 0.23%

Air Voids: 0.63% – 0.69%

VMA: 0.64% – 0.71%

In the plant test data there were no obvious inconsistencies among the currently assumed standard deviation values and those calculated based on the project data for the current research. There was therefore no compelling evidence to indicate that a change is specification limits is warranted.

Correlation analyses showed that there were correlations among the plant characteristics of AC, AV, and VMA. AC was negatively correlated with AV and positively correlated with VMA. AV was positively correlated with VMA. The correlation results were less consistent regarding correlations among Density and the plant characteristics, although there was some evidence that Density and AC may be positively correlated in Surface course mixes. These correlations would not impact the average payment that the contractor will receive in the long run for a given quality of material. However, the variability of the individual estimates about this average would tend to increase as the magnitude of the correlation coefficients increases.

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CHAPTER 9 — VERIFICATION TESTING

Background

Currently, the majority of STDs are using contractor tests for acceptance (8). During the 1990's many STDs experienced a decline in resources that meant staff cuts. QC and Acceptance Testing were observed to be an easy and practical area to place more responsibility on the contractor and to reduce work load on STD testing personnel. To do this, a methodology for verification testing is needed to ensure the STD is getting the quality it desires.

The SCDOT has adopted the use of contractor tests in the acceptance decision for HMA paving materials. SCDOT developed and implemented verification testing procedures that were in effect for the projects for which data were obtained for the current study. Verification tests were conducted on independent samples obtained by the SCDOT and tested for AC, AV, and VMA. The verification test results were compared with the contractors' acceptance tests to verify the contractor tests before they were used in the acceptance decision.

Verification Test Procedures

An overview of the verification procedures that were used on the projects for which data were provided is presented first. The verification test data are then presented and analyzed in following sections.

In general, SCDOT personnel independently obtained samples that were then tested for AC, AV, and VMA in SCDOT verification laboratories. These verification test results were then compared with the contractor acceptance test results using the *F*-test to compare the variances of the two samples and the two-sample *t*-test to compare the means of the two samples. If neither of these tests declared a significant difference at the 0.05 level, then the contractor acceptance tests were used to determine the payment factors. If one or both of the tests concluded that the two samples were different, then the SCDOT verification tests were used to determine the payment factors.

The procedure called for the comparison of verification and acceptance tests to be conducted on 5-lot data sets. That is, the tests for lots 1-5 were compared and a decision was made whether to use the contractor's or the SCDOT's tests to determine the payment factors for the material in the 5 lots. This procedure was then repeated for lots 6-10, 11-15, etc., for each subsequent set of 5 lots on the project. If the last data set to compare had fewer than 5 lots, then previous lots were added to obtain the 5 lots used in the comparisons.

Note that SCDOT has modified the verification procedures, but the new procedures were not in effect on the projects for which data were obtained. The discussion of the data and their analyses is based on the verification procedures in effect at the time the projects were constructed. Comments concerning the new procedures are presented after the data analysis is presented and discussed.

Verification Test Data

The acceptance test results and their corresponding verification test results were provided by SCDOT for 10 projects. Most of these projects were different than those that were analyzed above for determining typical process variability values. As such, the verification projects are referred to as V01 to V10. All of the test results along with the *F*-test and *t*-test results are presented in Appendix D.

Asphalt Content Comparisons. Table 9.1 presents a summary of the verification comparisons for AC. A total of 53 different data sets were compared, most of which consisted of 5 lots. One set had 7 lots and one had only 2 lots, although its results were disregarded by SCDOT when they decided to use the contractor's tests. In the table, the lots with the X **+** Y format indicate cases where the final comparison set had fewer than 5 lots (the number before the **+** sign) to which a number of lots (the number after the **+** sign) that had been used in previous comparisons were added to make a total of 5 lots.

The number of contractor tests in the comparisons varied from as few as 3 to as many as 28. The X **+** Y format is again used to indicate the number of new tests and previously used tests in the comparison. The number of SCDOT tests in the comparisons varied from 3 to 13.

Of the 53 AC comparisons, 13 times the contractor tests were rejected in favor of using the SCDOT verification tests to determine the payment factor. Six of these occurred on the same project, V05, and 3 of those were on the 3 Intermediate B lots. The *F*-test failed 6 times in the 53 comparisons, while the *t*-test failed 8 times.

Air Voids Comparisons. Table 9.2 presents a summary of the verification comparisons for AV. A total of 29 different data sets were compared, most of which consisted of 5 lots. One set had 7 lots and one had only 4 lots. The same X **+** Y format described for Table 9.1 indicates cases where the final comparison set had fewer than 5 lots to which a number of lots that had been used in previous comparisons were added to make a total of 5 lots.

The number of contractor tests in the comparisons varied from as few as 3 to as many as 28. The X **+** Y format is again used to indicate the number of new tests and previously used tests in the comparison. The number of SCDOT tests in the comparisons varied from 3 to 13.

Of the 29 AV comparisons, 14 times the contractor tests were rejected in favor of using the SCDOT verification tests to determine the payment factor. Seven of these occurred on the same project, V05, and 3 of those were on the 3 Intermediate B lots. The *F*-test and *t*-test each failed 7 times in the 29 comparisons. A rejection rate of nearly 50% (14/29) seems extremely high. Some potential reasons for the high failure rate are discussed in following sections.

Table 9.1. Summary of the Verification Comparisons for AC

Project	Mix Type	No. of Lots	No. of Tests		Result		Use Contr. Test?
			Contractor	SCDOT	*F*-test	*t*-test	
V01	Interm B	4	19	7	Pass	Pass	Yes
	Surf A	5	7	6	**Fail**	Pass	**No**
V02	Interm B	5	7	5	Pass	Pass	Yes
	Surf A	5	19	9	Pass	Pass	Yes
		5	18	7	**Fail**	Pass	**No**
		5	23	7	Pass	Pass	Yes
		5	20	9	Pass	Pass	Yes
		2 + 3*	6 + 12*	1 + 5*	Pass	Pass	Yes
	Surf B	5	18	11	Pass	Pass	Yes
		5	18	7	Pass	Pass	Yes
		5	19	7	**Fail**	Pass	**No**
		5	13	6	Pass	Pass	Yes
V03	Surf E	5	10	5	Pass	Pass	Yes
		5	7	5	Pass	Pass	Yes
		2	6	3	**Fail**	Pass	Yes
		5	14	8	Pass	Pass	Yes
		5	18	8	Pass	Pass	Yes
		5	14	5	**Fail**	Pass	**No**
V04	Surf B	6	25	11	**Fail**	Pass	**No**
V05	Interm B	5	20	6	Pass	**Fail**	**No**
		5	14	6	Pass	**Fail**	**No**
		4 + 1*	11 + 4*	5 + 1*	Pass	**Fail**	**No**
	Surf A	5	20	5	Pass	Pass	Yes
		5	17	8	Pass	Pass	Yes
		5	22	10	Pass	Pass	Yes
		5	23	9	Pass	**Fail**	**No**
		5	15	5	Pass	Pass	Yes
	Surf B	5	22	7	Pass	Pass	Yes
		3 + 2*	12 + 8*	5 + 2*	Pass	**Fail**	**No**
	Surf E	4	4	5	Pass	Pass	Yes
		5	10	8	Pass	Pass	Yes
		3	3	4	Pass	Pass	Yes
		5	5	6	Pass	**Fail**	**No**
		5	5	6	Pass	Pass	Yes
		4	6	6	Pass	Pass	Yes
		3	5	6	Pass	Pass	Yes
V06	Interm C	5	6	4	Pass	Pass	Yes
V07	Base A	5	15	5	Pass	Pass	Yes
		5	14	8	Pass	Pass	Yes
		5	7	4	Pass	Pass	Yes
		5	6	7	Pass	Pass	Yes
		5	5	6	Pass	Pass	Yes
		5	5	5	Pass	Pass	Yes
		5	5	4	Pass	Pass	Yes
		5	5	5	Pass	Pass	Yes
V08	Surf E	5	5	8	Pass	Pass	Yes
V09	Surf A	7	28	13	Pass	Pass	Yes
	Surf E	5	9	7	Pass	Pass	Yes
V10	Interm B	5	16	7	Pass	Pass	Yes
		3 + 2*	8 + 9*	5 + 2*	Pass	**Fail**	**No**
	Surf A	5	19	9	Pass	Pass	Yes
		2 + 3*	4 + 11*	5 + 4*	Pass	**Fail**	**No**
	Surf E	5	5	6	Pass	Pass	Yes
		5	5	5	Pass	Pass	Yes

* the second number refers to lots/tests from the previous data set that were repeated in the current data set so as to have 5 lots for the verification comparisons

Table 9.2. Summary of the Verification Comparisons for AV

Project	Mix Type	No. of Lots	No. of Tests		Result		Use Contr. Test?
			Contractor	SCDOT	*F*-test	*t*-test	
V01	Interm B	4	19	7	Pass	Pass	Yes
	Surf A	5	7	6	Pass	Pass	Yes
V02	Interm B	5	7	5	Pass	Pass	Yes
	Surf A	5	19	9	**Fail**	Pass	**No**
		5	18	7	**Fail**	Pass	**No**
		5	23	7	**Fail**	Pass	**No**
		5	20	9	Pass	Pass	Yes
		2 + 3*	6 + 12*	1 + 5*	Pass	Pass	Yes
	Surf B	5	18	11	Pass	Pass	Yes
		5	18	7	**Fail**	Pass	**No**
		5	19	7	Pass	**Fail**	**No**
		5	13	6	Pass	**Fail**	**No**
V04	Surf B	6	25	11	**Fail**	Pass	**No**
V05	Interm B	5	20	6	**Fail**	Pass	**No**
		5	14	6	Pass	**Fail**	**No**
		4 + 1*	11 + 4*	5 + 1*	Pass	Pass	Yes
	Surf A	5	20	5	Pass	**Fail**	**No**
		5	17	8	Pass	**Fail**	**No**
		5	22	10	Pass	**Fail**	**No**
		5	23	9	Pass	Pass	Yes
		5	15	5	Pass	Pass	Yes
	Surf B	5	22	7	Pass	**Fail**	**No**
		3 + 2*	12 + 8*	5 + 2*	**Fail**	Pass	**No**
V06	Interm C	5	6	4	Pass	Pass	Yes
V09	Surf A	7	28	13	Pass	Pass	Yes
V10	Interm B	5	16	7	Pass	Pass	Yes
		3 + 2*	8 + 9*	5 + 2*	Pass	Pass	Yes
	Surf A	5	19	9	Pass	Pass	Yes
		2 + 3*	4 + 11*	9	Pass	Pass	Yes

* the second number refers to lots/tests from the previous data set that were repeated in the current data set so as to have 5 lots for the verification comparisons

VMA Comparisons. Table 9.3 presents a summary of the verification comparisons for AV. A total of 29 different data sets were compared, most of which consisted of 5 lots. One set had 7 lots and one had only 4 lots. The same X + Y format described for Table 9.1 indicates cases where the final comparison set had fewer than 5 lots to which a number of lots that had been used in previous comparisons were added to make a total of 5 lots.

The number of contractor tests in the comparisons varied from as few as 3 to as many as 28. The X + Y format is again used to indicate the number of new tests and previously used tests in the comparison. The number of SCDOT tests in the comparisons varied from 3 to 13.

Of the 29 AV comparisons, 16 times the contractor tests were rejected in favor of using the SCDOT verification tests to determine the payment factor. The *F*-test failed 4 times in the 29 comparisons, while the *t*-test failed 12 times. A rejection rate over 50% (16/29) seems extremely high. The verification procedures apparently did not work as planned on project V05 since all 10 of the VMA comparisons on the project failed. Unless the contractor was not concerned and ignored the differences, it would normally be expected that an investigation would find the source of the problem before 10 data sets failed to compare.

Table 9.3. Summary of the Verification Comparisons for VMA

Project	Mix Type	No. of Lots	No. of Tests		Result		Use Contr. Test?
			Contractor	SCDOT	*F*-test	*t*-test	
V01	Interm B	4	19	7	Pass	Pass	Yes
	Surf A	5	7	6	Pass	Pass	Yes
V02	Interm B	5	7	5	Pass	Pass	Yes
	Surf A	5	19	9	**Fail**	Pass	**No**
		5	18	7	Pass	Pass	Yes
		5	23	7	**Fail**	Pass	**No**
		5	20	9	Pass	Pass	Yes
		2 + 3*	6 + 12*	1 + 5*	Pass	**Fail**	**No**
	Surf B	5	18	11	Pass	Pass	Yes
		5	18	7	**Fail**	Pass	**No**
		5	19	7	Pass	Pass	Yes
		5	13	6	Pass	**Fail**	**No**
V04	Surf B	6	25	11	**Fail**	Pass	**No**
V05	Interm B	5	20	6	Pass	**Fail**	**No**
		5	14	6	Pass	**Fail**	**No**
		4 + 1*	11 + 4*	5 + 1*	Pass	**Fail**	**No**
	Surf A	5	20	5	Pass	**Fail**	**No**
		5	17	8	Pass	**Fail**	**No**
		5	22	10	Pass	**Fail**	**No**
		5	23	9	Pass	**Fail**	**No**
		5	15	5	Pass	**Fail**	**No**
	Surf B	5	22	7	Pass	**Fail**	**No**
		3 + 2*	12 + 8*	5 + 2*	Pass	**Fail**	**No**
V06	Interm C	5	6	4	Pass	Pass	Yes
V09	Surf A	7	28	13	Pass	Pass	Yes
V10	Interm B	5	16	7	Pass	Pass	Yes
		3 + 2*	8 + 9*	5 + 2*	Pass	Pass	Yes
	Surf A	5	19	9	Pass	Pass	Yes
		2 + 3*	4 + 11*	9	Pass	Pass	Yes

* the second number refers to lots/tests from the previous data set that were repeated in the current data set so as to have 5 lots for the verification comparisons

Issues with Verification Procedures

A number of potential issues were identified while reviewing the verification procedures and analyzing the verification test result data. Each of these issues is discussed in the following sections.

Variability and Specification Limits. As discussed in Chapter 5, one of the most important issues for a STD is to develop a value for typical variability that is consistent with the way in which a lot is defined under the acceptance plan. Since the SCDOT specification is based on lot-by-lot acceptance, the variability used to establish the specification limits must be that which is appropriate for a typical lot. To determine this, the unbiased individual standard deviation values for each lot were calculated and then these lot standard deviations were averaged to get a typical "within-lot" standard deviation for the process.

The decision regarding the standard deviation value to use to establish the specification limits must be made subjectively by the SCDOT. Although, some ranges for possible values are presented in Chapters 6-8. Once this value is selected, the specification limits can be established accordingly as discussed in Chapter 8. The verification procedure used by SCDOT includes comparing the acceptance and verification tests from 5 lots. If the values compare, then there is no issue since the contractor acceptance tests for each lot are then used to determine an individual payment factor for each lot. This is the way that the specification was intended to operate, and the specification limits have been established for this lot-by-lot acceptance approach.

An issue arises, however, if the acceptance and verification tests do not compare. In this instance, the SCDOT uses the verification test results to establish a single payment factor for the combined 5 lots. This is not the way in which the specification originally was intended to operate, and this approach is not necessarily consistent with the specification limits that were developed for lot-by-lot acceptance. That is, the within-lot variability, which does not include potential lot-to-lot variability of the process, may not be the same as the variability associated with 5-lot increments.

This means that the specification limits that SCDOT selected for lot-by-lot acceptance may be too narrow to use when basing the acceptance decision on tests obtained from 5 different lots. This fact is illustrated in Chapters 6 and 7 when both the Lot standard deviations and Project standard deviations were calculated. Table 9.4 summarizes the Lot and Project standard deviation results for AC, AV, and VMA. For each mean standard deviation the Project value is greater than the Lot value, and the same is the case for most of the percentile results as well.

To further investigate this situation, two projects with the largest numbers of lots and tests were explored in more detail. For these two projects, the individual Lot standard deviations were calculated as well as the standard deviations for the 5-Lot increments on each project. The averages for each of these types of standard deviations were then calculated. The example calculations for AC for one of the projects are shown in Table 9.5. A summary of the results for AC, AV, and VMA for both projects is presented in Table 9.6. As shown in the table, the average 5-lot standard deviations are all larger than their corresponding Lot standard deviations.

Since the selection of the standard deviation to use when developing specification limits is subjective, SCDOT will need to decide whether or not the use of different specification limits for lot-by-lot acceptance and for 5-Lot increment acceptance is warranted. The Project, Lot, and 5-Lot standard deviation values calculated in this report would seem to support the use of different specification limits.

Table 9.4. Summary of the Lot and Project Standard Deviation Results for AC, AV, & VMA

Characteristic	Course	Avg/Percentile	Project * Std Dev	Lot * Std Dev
AC	Base	Mean	0.2422	0.2357
		50%	0.2421	0.2237
		60%	0.2451	0.2457
		70%	0.2505	0.2940
		80%	0.2656	0.3279
		90%	0.3057	0.3369
	Intermediate	Mean	0.2190	0.2057
		50%	0.2079	0.1864
		60%	0.2226	0.2072
		70%	0.2380	0.2131
		80%	0.2521	0.2480
		90%	0.2729	0.2936
	Surface	Mean	0.1962	0.1708
		50%	0.1800	0.1648
		60%	0.1929	0.1746
		70%	0.2048	0.1900
		80%	0.2181	0.2105
		90%	0.2740	0.2529
AV	Intermediate & Surface	Mean	0.5363	0.4182
		50%	0.5307	0.43070
		60%	0.5677	0.45346
		70%	0.5957	0.50315
		80%	0.6414	0.56246
		90%	0.7389	0.59914
VMA	Intermediate & Surface	Mean	0.4980	0.4432
		50%	0.4910	0.4117
		60%	0.5214	0.4608
		70%	0.5793	0.5120
		80%	0.6190	0.5813
		90%	0.6578	0.6481

* **Project:** the unbiased standard deviation estimate of all individual test results on the project
Lot: the average of the unbiased standard deviation estimates for all lots on the project

Table 9.5. Calculation of the Average Lot and 5-Lot Standard Deviations for AC for Project P32, JMF J79.

Lot No.	No. of Tests	Unbiased Lot SD	5-Lot Increment	No. of Lots	Total No. of Tests	Unbiased 5-Lot SD
2	6	0.0760	1	5	22	0.1442
3	5	0.0700				
4	4	0.1391				
5	3	0.1441				
6	4	0.1863				
7	3	0.0832	2	5	18	0.1200
8	3	0.0705				
9	3	0.0642				
10	4	0.1133				
11	5	0.2044				
12	4	0.1659	3	5	22	0.1905
13	5	0.1736				
14	3	0.1194				
15	5	0.0994				
16	5	0.1291				
17	5	0.2230	4	5	21	0.1820
18	5	0.1035				
19	3	0.0862				
20	5	0.2228				
21	3	0.0881				
22	3	0.1387	5	4	13	0.0971
23	4	0.1035				
24	3	0.0427				
25	3	0.1601				
Average		**0.1253**				**0.1468**

Table 9.6. Summary of the Lot and 5-Lot Standard Deviation Results

Proj/JMF	Total No. of Tests	No. of Lots	No. of Increments	Characteristic	Unbiased Lot SD	Unbiased 5-Lot SD
P32/J79	96	24	5	AC	0.1253	0.1468
				AV	0.4356	0.4822
				VMA	0.4482	0.5107
P26/J69	53	16*	3**	AC	0.1531	0.1785
				AV	0.4460	0.4714
				VMA	0.2928	0.4493

***** 2 of 18 lots had sample sizes of 1 and hence no standard deviation could be calculated
****** 3 increment of 5-lots were used; the final 3-lot increment was not used in calculations

Sample Size, Lot Size, and Payment Risks. The quality index approach to estimating PWL provides an unbiased estimate for the population PWL. As a result, as long as there is a sufficient bonus provision, the expected payment that a contractor would receive in the long run for a given quality of material will be equal to the payment that the contractor would receive if the population were known with certainty. However, while the average payment in the long run will be correct, due to sampling variability there is a high degree of variability in the individual lot payment factors that will be calculated for the given population. That is, sometimes a sample will give results that over-estimate the quality and thus the payment, while other times the sample will under-estimate the payment for a given population. However, over a large number of lots, the high and low estimates for lot PWL will tend to balance out to give the correct average payment factor.

If there are only a small number of lots on a project, then it will be possible that a significantly low estimated PWL value could negatively impact the payment that the contractor should have received. Similarly, larger PWL estimates could be obtained that would provide a larger payment than is deserved. Given the payment equation used by SCDOT, i.e., $PF = 55 + 0.5(PWL)$, the under-payment error for an individual lot has the potential to be much greater than the over-payment error, which is limited to the maximum bonus of 5%.

Also, the variability associated with the estimate of the lot PWL can be reduced by increasing the sample size obtained from each lot. Therefore, the risks to both parties of the total project payment being in error can be reduced by having a larger number of smaller lots and/or by having a larger sample size for each lot. In the event that the SCDOT verification tests are used to determine the payment factor, the sample size may increase but the number of lots on the project is considerably reduced. Not only is the number of lots reduced, but the amount of material at risk is also greatly increased for each payment factor determination.

When the verification tests are used for payment determination instead of the larger number of acceptance tests, the risks to both SCDOT and the contractor will increase due to the greater amount of material that is being evaluated with typically much fewer tests. Rather than having each lot evaluated on the basis of 3-5 tests, 5 lots may be evaluated on the basis of 7-9 tests. In this scenario, based on the preceding discussions the contractor would seem to be exposed to a greater payment risk than would the SCDOT.

Cause of the Difference. *F*-tests and *t*-tests can determine when there may be a difference between the contractor acceptance tests and the STD verification tests. On the other hand, the fact that the test does not conclude that there is a difference does not prove that the two sets of test results are the same. A major drawback of the *F*-test and *t*-test procedures is that they can determine only whether or not a difference between the two data sets is likely. They do not, however, provide any information regarding the reason for the difference between the acceptance and verification tests.

These tests also do not indicate which of the data sets is “correct” and which is “wrong.” Indeed, regardless of the result of the hypothesis test, either of the data sets could be “wrong,” they both could be “wrong,” or they both could be “correct.” The lower the P-value the more confident we are that the two data sets actually are different, but they both could still be “wrong.” However, most STDs will assume that their data are “correct” in the event that the *F*-test or *t*-test finds a difference between the acceptance and verification tests. In reality, an investigation should be conducted in an effort to determine “why” the two sets of tests were found to be different.

Any differences between the two sets of tests may be due to a number of different factors. The one that a STD is likely to first think of is that the contractor has “manipulated” the results to ensure that full payment is obtained. While there is always some chance that this is the case, other possibilities may be more likely. For example, differences in sampling or testing procedures could account for differences. In this event, the material sampled by both parties could be identical but differences still might be identified when comparing the results.

The smaller sample, which is usually the verification tests, could be influenced by one bad truck load from which one of the limited number of verification samples was taken. With a smaller sample size one errant value would have a bigger impact on the sample mean and standard deviation. It could be that only one “bad” lot caused the statistical tests to not compare. In such an instance the contractor could be penalized on all 5 lots for errors that occurred on only 1 of the lots in the comparison data.

One potential concern and a likely candidate for the cause of differences between contractor acceptance and STD verification test results is the difference in test procedures that is an inherent part of the process. For example, the acceptance samples taken by the contractor may very well be split, prepared, and tested within a very short time after being taken from the truck at the plant. In such cases the sample would likely not need to be re-heated. On the other hand, the STD verification sample must be transported to another lab and likely will require re-heating. Additionally, the verification tests may be conducted anywhere from a few hours to several days after the sample was taken from the truck.

As a result, any differences between the acceptance and verification tests may well be due to differences in testing procedures rather than differences in the material. It may be that, due to the differences in procedures, the two sets of tests should not be expected to compare on a routine basis. The verification procedures used by SCDOT, and indeed by most if not all STDs, are based on the assumption that sampling, storage, and testing procedures do not contribute to any differences detected when comparing the different test results.

Recommendation. It is strongly recommended, therefore, that SCDOT implement a research study to examine whether or not re-heating, lack of re-heating, delays before testing, and lack of delay have any effect on the resulting test results. Without such a study it is difficult to state with confidence that differences between the acceptance tests and verification tests are due to differences in the material that was sampled and tested by the two parties.

Procedural Issues. The issues discussed above are major issues that could possibly cast doubt on the validity of the verification results. There are some other minor issues dealing with some of the procedures identified in the verification test results provided by SCDOT. The following discussions relate to the procedures that were being used on the projects for which verification test results were provided by SCDOT.

Re-Use of Lot Test Results. The SCDOT verification procedures contained the following statement: "If the last data set is less than 5 LOTS, then go back to the previous LOTS far enough to yield the 5 LOTS needed in the data set." This process was generally, but not always, used on the projects that were provided. For example, Table 9.1 shows 5 instances where this procedure was followed on the final verification data set to yield the necessary 5 lots for the verification comparisons. But the table also shows that on 2 other projects 6 lots and 7 lots were combined into a single verification data set for the project.

To illustrate the process, Table 9.7 shows the final two verification data sets for a project on which 3 lots were used in both of the data sets. This may raise a question concerning "double jeopardy." For example, what if both of the data sets did not compare, but this result was due to 1 or 2 of the lots that appeared in both of the comparisons? The question that arises then is could 1 bad lot be the cause of 6, 7, or 8 lots not comparing, with the result being that a limited number of verification tests replaced many valid contractor acceptance tests?

Note that in Table 9.7 the first 5-Lot data set passed both the *F*-test and *t*-test. The second 5-Lot data set, which included lots 3, 4, and 5 from the first 5-Lot data set, did not pass the *t*-test and as a result the contractor tests were not used. Only 4 new contractor acceptance tests and 5 SCDOT verification tests were included in the comparison, which included 11 contractor and 4 SCDOT tests that had already been "verified." If the 7 lots had been combined into a single verification data set, both the *F*-test and *t*-test would have passed for the 7 lots.

With any verification process there is no "right" answer since any assumption that is made has potential advantages and disadvantages. However, SCDOT may wish to consider a policy that would allow for the final verification data set to be comprised of up to 6 or 7 lots. Then another decision would need to be made regarding how to deal with the situation when there are 3 or 4 lots in the final data set. It would seem reasonable to consider 4 lots as sufficient for the final verification data set. The decision with 3 lots might be to use the 3 lots as the final data set, or possibly to take the last 8 lots and split them into two 4-lot data sets for verification purposes. This latter approach would be consistent with adopting 4 as the minimum lot size on which a verification decision can be made.

Table 9.7. Composition of Verification Lots for AC on Project V10, Surface A

5-Lot Data Set	Lot No.	Contractor	SCDOT	*F*-test	*t*-test	Use Contr. Tests?
1	1	4.60	4.72	Pass	Pass	Yes
		4.22	4.90			
		4.73	4.70			
		4.37				
	2	4.60				
		4.99	4.56			
		4.72	4.77			
		4.61				
	3	4.84				
		5.05				
		4.89	5.12			
		4.92	5.11			
	4	4.59				
		4.80				
		4.36	5.09			
		4.76				
	5	4.32	4.80			
		4.71				
		4.69				
2	6	4.51	4.92	Pass	Fail	No
		4.90	5.41			
		5.16	5.55			
	7	4.96	4.95			
			4.85			
	3	*4.84*				
		5.05				
		4.89	*5.12*			
		4.92	*5.11*			
	4	*4.59*				
		4.80				
		4.36	*5.09*			
		4.76				
	5	*4.32*	*4.80*			
		4.71				
		4.69				

<u>Test Distribution.</u> The uneven distribution of verification tests among the lots raised some potential issues. To illustrate some of these potential issues, Table 9.8 shows some examples of the distribution of verification tests within a number of selected verification data sets. While, if there is a constant process, there is nothing inherently wrong with not distributing the verification tests equally among the lots. However, the fact that lot-by-lot acceptance is being used indicates that some variability may be anticipated between lots. Some of the lots, which were selected solely for illustration, in Table 9.8 might raise some questions. For example, in the first data set ⅔ of the tests are from 2 of 5 lots. In many instances 2 of 5 lots had no sample taken from them. For project V07, 60% of the tests are from the last lot.

Table 9.8. Selected Examples of Distribution of Verification Test within 5-Lot Data Sets

Project	Number of Verification Tests					
	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Total
V02	4	2	1	1	1	9
	1	0	2	2	1	6
	2	0	1	0	3	6
V03	1	0	2	2	0	5
	1	2	0	0	2	5
V05	3	0	2	0	2	7
V07	1	1	0	0	3	5
V10	0	3	2	2	0	7

Outliers. A review of the verification test results shows that there were occasions where a single test result might have been responsible for the two data sets not comparing. An example of such an occurrence is shown in Table 9.9. The analyses in the table are for AV on project V02. The point in question is the first verification test. The value of 6.72 is 70% greater than the next largest verification test result. The other 3 verification tests taken on that lot were very close to the contractor's acceptance test results. If the 6.72 value is disregarded the *F*-test on the remaining data has a P-value of 0.18, and there would be no reason to believe that the variances were different between the two data sets.

SCDOT may wish to consider whether to implement an outlier procedure such as those presented in ASTM E-178-08, *Standard Practice for Dealing With Outlying Observations*. The procedure that would apply in this case is to calculate the test statistic, T_n, from equation 9.1 and then to compare it to the critical values in Table 1 of E-178.

$$T_n = \frac{(x_n - \overline{x})}{s} \qquad \textbf{(9.1)}$$

In the example in Table 9.9, the sample mean, $\overline{x}$, is 3.324 and the sample standard deviation, s, is 1.4155. So, T_n = (6.72 – 3.324) / 1.4155 = 2.399. The critical value (from Table 1 in ASTM E-178) for the 0.01 significance level is 2.323. So, the value of 6.72 would be considered an outlier and eliminated from the data set.

While such a procedure would add complexity to the acceptance plan, it hopefully would rarely need to be employed.

Table 9.9. Illustration of a Possible Outlier Affecting the *F*-test for AV on Project V02

Lot No.	Contractor Tests	SCDOT Tests
1	4.06	**6.72**
	2.46	3.93
	2.60	2.14
		2.57
2	3.07	3.03
	2.35	2.32
	2.37	
	2.21	
3	2.52	2.41
	2.28	
	2.60	
4	2.10	3.07
	2.12	
	2.54	
5	3.12	
	3.34	
	3.37	
	2.77	
	2.29	3.73
	2.94	
F-test P-Value	With 6.72	0.0002
	Without 6.72	0.1815

Split Sample Comparisons

The SCDOT HMA quality assurance program includes a “Split Test Sample Program.” The differences between the contractor’s results and SCDOT results on the split samples are compared with the allowable differences shown in Table 9.10.

Table 9.10. Allowable Differences between Contractor Tests and SCDOT Split Sample Tests

Test Parameter		Allowable Difference
Asphalt Binder Content, %		± 0.40
Maximum Specific Gravity		± 0.035
Bulk Specific Gravity of Cores		± 0.035
Gradation (Base, Shoulder Widening, Surface Type E & OGFC only)	1/2” and greater	± 7.0
	3/8”	± 6.0
	No. 4	± 6.0
	No. 8	± 5.0
	No. 30	± 4.0
	No. 100	± 3.0

There are two methods for establishing or evaluating allowable tolerances such as those in Table 9.10. The first is through a research testing program where split samples are tested in two labs and the standard deviation of the differences can be calculated for each characteristic. This is similar to a round-robin testing program that would be used to establish precision limits for an ASTM or AASHTO standard test method. However, the split sample research program would be based on plant mixed material, rather than laboratory-prepared specimens.

If a research study is not economical, then the D2S limits from the standard test procedures could serve as a starting point. These limits are developed under close to ideal condition, so they should be thought of as absolute lower limits on allowable tolerances. Without a research study to base decisions, a subjective decision regarding whether to use the D2S, or how much to increase them to account for the less than ideal conditions in the field, must be made by SCDOT.

Since no split sample test data were provided for the current research, it was not possible to perform any statistical analyses to evaluate the allowable tolerances in Table 9.10. The tolerances are, however, within the general range of similar tolerances used by other STDs that were identified during the literature search for the current project. Some of these tolerances are shown in Table 3.8, and are repeated here as Table 9.11.

Table 9.11. Tolerances Used to Compare Acceptance and Verification Tests

State	Density	Air Voids	AC Content	Gradation 5/8" or 3/8"	Gradation No. 200	VMA	Bulk Specific Gravity	Max. Specific gravity
AR	2.0%	1.0%	0.30%			1.0%		
FL			0.55%	5.5%	1.5%		0.016	0.022
GA			0.50%	4.0%	2.0%			
MS			0.40%	6.0%	2.0%		0.030	0.020
NE		0.5%	0.50%	5.0%		0.5%		
NY				5.0%			0.200	0.011
NC	2.0%		0.50%	5.0%	2.0%	1.0%	0.030	0.020
ND				7.0%	2.5%		0.040	0.035
VA 1 test 2 tests 3 tests 4 tests 8 tests			 0.60% 0.43% 0.33% 0.30% 0.21%	 8.0% 5.7% 4.4% 4.0% 2.8%	 2.0% 1.4% 1.1% 1.0% 0.7%			

Current SCDOT Verification Program

The current SCDOT verification program requirements are stated in SC-T-97 (05/10), *Method for Verification of Contractor HMA Acceptance Test Results*. These requirements include procedure changes from those used when the data for the current research project were obtained. These new changes are discussed in the following sections.

Verification Testing. The new procedures call for taking verification samples that are split three ways: one for the contractor to test, one for the SCDOT verification test, and one to be retained as a possible dispute resolution sample. The verification sample will not be taken from the same truck as an acceptance sample. The contractor is required to test their portion of each day's first verification sample. The verification split sample cannot be used as an acceptance sample. The contractor has the option whether or not to test their portions of the other verification samples. The contractor and SCDOT split verification tests are compared with the allowable tolerances shown in Table 9.12. If the tests do not compare, the contractor can request to have the dispute resolution sample tested. Dispute resolution testing will be done at the OMR Central Laboratory, and the Central Laboratory's results will be used for verification purposes in lieu of the Field Verification Laboratory's results.

Table 9.12. Allowable Tolerances for Contractor-SCDOT Split-Sample Verification Tests

Characteristic	Tolerance		
	Surface	Intermediate	Base
Asphalt Binder Content, %	0.36	0.43	0.50
Air Voids, %	1.15		—
VMA, %	1.15		—

The procedure for establishing the verification data set for the *F*-test and *t*-test comparison has been revised. Rather than to require 5-Lot increments, the procedure now states the following (SC-T-97 (05/10)):

> The data set to be evaluated will be test results of 7 or more verification tests conducted by the Department. Contractor HMA quality acceptance test results and SCDOT verification test results from Lot 1 thru a minimum of 7 verification tests will be statistically analyzed and a decision to accept the Contractor HMA quality acceptance test results will be based on whether the data set is believed equal and therefore, have come from the same population. If the analysis of the data set proves a non-comparison of the test results, then the SCDOT verification test results will be used for acceptance.
>
> The second data set will comprise test results from the next Contractor's acceptance tests following data set 1 thru a minimum of 7 verification tests, statistically analyzed and a decision will be made whether to accept or reject the Contractor HMA quality acceptance test results.
>
> The third data set will comprise test results from the next Contractor's acceptance tests following data set 2 thru a minimum of 7 verification tests, statistically analyzed and a

decision will be made whether to accept or reject the Contractor HMA quality acceptance test results.

This process continues until production is completed. If the last data set is less than the minimum of 7 verification tests, then go back to the previous LOTS far enough to yield the number of test needed in the data set.

The new procedure uses *F*-tests and *t*-tests; however the tests are now conducted at the 0.01 level of significance rather than at the 0.05 level that was used previously.

Comments on the New Procedures. The new procedures address some issues that were present with the old procedures, and create some additional ones.

Split Sample Verification Tests. The use of split samples for verification tests addresses a potential major concern of contractors since it provides the contractor with a "check" on the verification test results to be used by SCDOT. When the verification and acceptance tests do not check, it is natural that the contractor will be concerned that there was some issue or problem with the STD's verification sampling and testing. Having the contractor run the split sample test helps to alleviate this potential concern.

Since the verification sample cannot be used as an acceptance test, this places an additional testing load on the contractor. There will be at least one additional "required" test each time SCDOT personnel visit the plant to obtain verification samples. And, many contractors will also test some or all of the split samples that are "optional" for them to test. This is not necessarily an issue, since experience has shown that many contractors prefer to have their own split-sample results to compare with the SCDOT test results.

The allowable tolerances on the split sample test results are the same as the specification tolerances for each of the characteristics. As noted above, the best way to establish tolerances for split sample comparisons is through a research testing program to establish the standard deviation of the split sample differences for each characteristic. If a research study is not economical, then the D2S limits from the standard test procedures could serve as a starting point, with the limits being increased somewhat to account for the less than ideal conditions in the field.

There is not widespread precedent for using the specification tolerances as the allowable tolerances for split sample comparisons. The initial thought might be that they are likely to be on the large side since they should have been developed to account for more material variability than should be present in split samples. However, it is difficult to assess the use of these tolerances since the specification limits are established in a totally different manner than typically would be used to establish limits on allowable split sample tolerances.

The specification limits were established to allow an AQL population that has 90 PWL. As such, they were based on being 1.645 standard deviations from the target value. The standard deviation used is the one that was selected as the typical standard deviation to represent the process in question. On the other hand, split sample allowable tolerances are typically based on a selected level of significance. For example, for a 0.05 level of significance, the tolerances would be established as 1.96 standard deviations (rounded to 2 in the D2S limits). The standard deviation used here is the standard deviation of the differences between the split samples if they came from the same population. This standard deviation would be expected to be smaller than the typical process standard deviation, and would be established by a research study. There is no way to know exactly how the split sample tolerances should compare with the specification tolerances that were established with a totally different purpose in mind.

Recommendation. It is strongly recommended that SCDOT implement a research study to determine appropriate standard deviations to use when establishing split sample allowable tolerances. Without such a study it is difficult to determine the appropriateness of the current tolerances that are shown in Table 9.12.

7-Test Minimum for Verification Lots. The new 7-test minimum for verification lots provides more flexibility and, depending upon how it is implemented, has the potential to benefit both the contractors and SCDOT. For example, if sufficient verification testing is performed, then statistical verification comparisons can be done more frequently than waiting tilll after 5 lots have been completed. This might allow for less material to be at risk when the final payment factor determination is made after the verification comparisons are completed.

One potential point of concern is the wording that says that the “data set to be evaluated will be test results of 7 or more verification tests.” The term “or more” makes this an open-ended definition for the verification data set. Will this be interpreted to mean that a statistical analysis will take place after every 7 tests? If not, how will the completion of the data set be established? Who will decide how many verification tests will be necessary to trigger the statistical evaluations? SCDOT may wish to clarify the term “or more” by establishing an upper limit on the number of verification tests or lots before the *F*-test and *t*-test evaluations are performed.

Level of Significance. The change to the 0.01 level of significance should provide increased confidence that the two data sets actually are different when they do not compare in the *F*-tests or *t*-tests. It will make it less likely to incorrectly declare differences when the data sets are not different. However, the lower significance level will also make it more difficult to identify that the data sets are different when they actually are different. Since the ramifications of declaring the data sets different when they are not different can be severe, the switch to 0.01 would seem to be a good decision.

Closing

The current procedure for establishing the data set for verification comparisons seems to be an improvement over the prior 5-lot approach. However, some more clarification regarding the upper limit of the size of the data set would be an improvement.

SCDOT should conduct two research studies. First, to establish how much, if any, the delay and re-heating aspects of SCDOT’s verification tests impacts affects whether the contractor acceptance tests and SCDOT verification tests should compare with one another. The second project needs to determine appropriate standard deviations to use when establishing split sample allowable tolerances. Both of these studies are needed to be able to evaluate fully the verification procedures currently in use by SCDOT.

The addition of contractor and dispute resolution splits to the verification tests is an improvement to the verification procedures. This approach is similar to one in the literature review in Chapter 2, which was recommended in an FHWA technical advisory. The approaches would be the same if SCDOT takes a verification test from each lot on the project and if the contractor's split verification test also served as one of the acceptance tests. This procedure is outlined in Figure 2.1, which is repeated here as Figure 9.1.

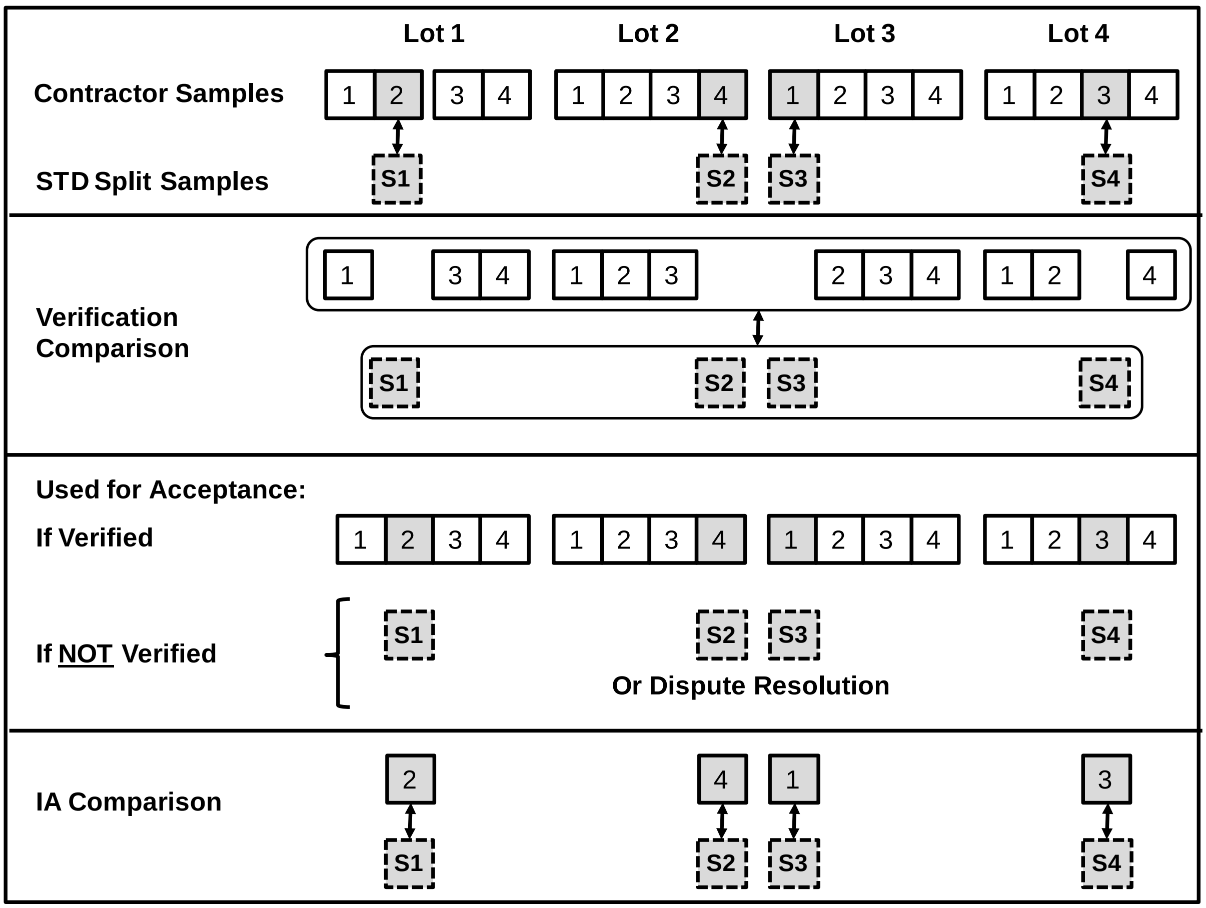

Figure 9.1. Verification and IA Testing Utilizing Split Samples (after 4)

Summary

Acceptance test results and their corresponding verification test results were provided by SCDOT for 10 projects. Most of these projects were different than those that were analyzed above for determining typical process variability values.

Of 53 AC comparisons that were made, 13 times the contractor acceptance tests were rejected in favor of using the SCDOT verification tests to determine the payment factor. For AV, 14 times out of 29 comparisons the contractor tests and SCDOT verification tests did not compare. Similarly, for VMA the tests did not compare in 16 of 29 comparisons.

A number of issues with the previous and the current SCDOT verification procedures were presented and discussed. For example, when SCDOT verification tests are used to determine the payment factor there is a question whether it is appropriate to use the specification limits that were developed for lot-by-lot acceptance since the verification data spanned 5 different lots. Sample calculations showed that the 5-lot standard deviation values were greater than the with-lot standard deviations.

Using the verification tests to determine payment factors for 5-lot increments causes a decrease in the number of lots and a corresponding increase in the size of the lots for which payment decisions are made. This will tend to increase the risks to both SCDOT and the contractor due to the greater amount of material that is being evaluated with typically much fewer tests.

The fact that the acceptance tests and verification tests are declared “different” by the statistical tests provides no information concerning the “cause” of the difference. Any differences between the two sets of tests may be due to a number of different factors. These factors could include differences in sampling and testing procedure, such as re-heating, the effect of one outlier in the smaller number of verification tests, or even contractor manipulated test result data. A procedure for identifying outliers, such as ASTM E-1780-08, should be considered as a possible addition to existing verification procedures.

SCDOT should conduct a research study to identify if differences in procedures, such as re-heating and time delays before testing, can be the cause of the data sets failing to compare. Another study needs to be conducted to establish the standard deviation values to use to develop allowable tolerance limits for split sample comparisons.

CHAPTER 10 — SUMMARY, FINDINGS, AND RECOMMENDATIONS

Summary

This study was conducted to perform a formal and complete analysis of the SCDOT HMA specification in light of information that had become available since it was last analyzed. A Research Steering Committee comprised of SCDOT, FHWA, and Industry representatives provided oversight of the process.

A literature review was conducted to identify reports and publications that address various aspects of the use of contractor tests for acceptance as well as any procedures for validating contractor tests. In addition, a brief survey instrument was developed and sent by SCDOT to all state materials engineers by means of the Materials Engineer LISTSERVE. The survey instrument was also sent to FHWA’s Federal Lands Highways division. To obtain more in-depth information, it was planned that in-person interviews be conducted with a few selected STDs that use contractor test results in the acceptance decision.

Extensive statistical analyses were conducted to determine appropriate standard deviation values to represent the variability of each of the acceptance characteristics used by SCDOT. Test result data from SCDOT projects were obtained from SCDOT. A total of 1,260 density test results were provided. In all, density data were provided from 22 different projects, with some projects having multiple HMA mixes involved. A total of 1,775 asphalt content (AC) tests were provided from 30 different projects, with some projects having multiple HMA mixes involved. Since no voids testing was done on Base course mixes, open graded friction course (OGFC) mixes, or Surface E mixes, there were only 1,343 air voids (AV) and VMA tests provided.

Analyses were conducted on the project test results for Density, AC, AV, and VMA with the primary goal of determining values to use to represent the typical variability for each characteristic. This is a subjective decision that ultimately must be made by SCDOT. These variabilities are necessary to evaluate the appropriateness of the existing specification limits. A correlation analysis was also conducted to identify whether correlations existed among Density and the plant characteristics.

Finally, SCDOT verification test results were analyzed and compared with their corresponding contractor acceptance tests. The previous and current SCDOT verification procedures were evaluated and issues concerning each were presented and discussed.

Findings

The general findings of each of the primary phases of the research effort are presented in the following sections.

Literature Review. From the publications identified in the literature search, it is apparent that there was no industry-wide consensus on the adequacy of using contractor tests for acceptance. The number of STDs identified during the literature review with statistical data analysis over a large number of projects was limited to GA, NC, FL, AL, KY, KS, CA, and NM.

These published results look at data from a statewide, multi-project standpoint down to a single project with 6 or more test results for analysis. Consistent results are not typical as there was no distinguishable pattern of data coming from the same or different populations.

There are a number of potential reasons that significant differences arise in contractor and STD performed tests. With knowledge of these potential reasons the STD can make an effort to minimize its chance of affecting the validation procedure. Some of these reasons are provided below in no particular order:

- The number of specimens tested by contractor and state agency technicians.
- The time differences between sampling and testing of specimens often found between contractors and state agencies.
- Differences in procedures.
- Failure to follow prescribed procedures.
- Incorrectly calibrated testing equipment.

Survey Results. A total of 42 states/agencies, including 40 states, the FHWA Western Federal Lands Highway Division (WFLHD) and the province of Ontario, Canada (ONT), responded to the survey. A majority of the responding agencies (28 of 42, or 67%) in some way incorporate contractor test results into the acceptance decision. Only 9 of these 28 agencies use *F*-tests and *t*-tests when comparing contractor acceptance tests with the agency's verification tests.

Interview Results. Due to the increasing workloads experienced by STDs, it was very difficult and time consuming to set up formal interviews. The interviews that were conducted did not yield significantly more information than could be obtained from the surveys and from the specifications and procedures manuals of the various STDs. It was therefore concluded that eliminating the formal interviews in favor of telephone calls and emails to solicit additional information on an as needed basis was a better approach than continuing with formal STD interviews.

Results of Density Analyses. The range of values that SCDOT might consider for the typical Density standard deviation used to evaluate existing specification limits includes 1.16% to 1.26%. These values are greater than the standard deviation of 1.09 that SCDOT used to establish the current Density specification limits. As a result, contractors on the projects for which data were obtained were not able consistently to meet the specification requirements.

Results of Plant Tests Analyses. The values for typical standard deviations that SCDOT might consider to represent the typical within-lot variability used to evaluate existing specification limits include:

Asphalt Content: Base Course: 0.25% – 0.295%
Intermediate Course: 0.21% – 0.26%
Surface Course: 0.195% – 0.215%

Air Voids: 0.525% – 0.59%

VMA: 0.55% – 0.63%

The above values consider only the "within-lot" process standard deviation for each of the characteristics. If SCDOT would also like to consider some form of "target-miss" variability, then the appropriate standard deviations should likely be larger than those shown above.

Issues Concerning Payment. The potential variability of the population mean about the target value was considered in addition to the within-lot standard deviation values to develop an overall "process" standard deviation for each of the acceptance characteristics. These standard deviation values were then compared with the current SCDOT specification limits to investigate whether or not these limits are still appropriate.

The standard deviation that was identified as the typical overall project variability for Density is greater than the one used by SCDOT to establish the specification limits. A STD may establish the typical standard deviation value based on data from a number of past projects that it considered "acceptable." Since nearly two-thirds of the projects from which Density data were obtained had average project PWL values less than 90 PWL, SCDOT must decide whether or not it wishes to establish the typical project standard deviation based on the data provided for the current research study.

If SCDOT believes that these projects represent the state-of-the-art regarding the process capability of a typical contractor, then SCDOT may need to re-evaluate their target density value and their density specification limits. If SCDOT believes that these projects do not represent what a typical contractor is capable of providing, then additional data from other representative projects will need to be obtained for analysis.

The values for typical standard deviations that SCDOT might consider to represent the typical overall project variability used to evaluate existing specification limits for plant tests include:

Asphalt Content: Base Course: 0.26% – 0.30%
Intermediate Course: 0.23% – 0.28%
Surface Course: 0.21% – 0.23%

Air Voids: 0.63% – 0.69%

VMA: 0.64% – 0.71%

In the plant test data there were no obvious inconsistencies among the currently assumed standard deviation values and those calculated based on the project data for the current research. There was therefore no compelling evidence to indicate that a change in specification limits is warranted.

Correlation analyses showed that there were correlations among the plant characteristics of AC, AV, and VMA. AC was negatively correlated with AV and positively correlated with VMA. AV was positively correlated with VMA. The correlation results were less consistent regarding correlations among Density and the plant characteristics, although there was some evidence that Density and AC may be positively correlated in Surface course mixes. These correlations would not impact the average payment that the contractor will receive in the long run for a given quality of material. However, the variability of the individual estimates about this average payment would tend to increase as the magnitude of the correlation coefficients increases. This would therefore place on the contractor a greater payment risk than would be the case for statistically independent acceptance characteristics.

Verification Testing. Acceptance test results and their corresponding verification test results were provided by SCDOT for 10 projects. Most of these projects were different than those that were analyzed for determining typical process variability values.

Of 53 AC comparisons that were made, 13 times the contractor acceptance tests were rejected in favor of using the SCDOT verification tests to determine the payment factor. For AV, 14 times out of 29 comparisons the contractor tests and SCDOT verification tests did not compare. Similarly, for VMA the tests did not compare in 16 of 29 comparisons.

A number of issues with the previous and the current SCDOT verification procedures were presented and discussed. For example, when SCDOT verification tests are used to determine the payment factor there is a question whether it is appropriate to use the specification limits that were developed for lot-by-lot acceptance since the verification data spanned 5 different lots. Sample calculations showed that the 5-lot standard deviation values were greater than the within-lot standard deviations.

Using the verification tests to determine payment factors for 5-lot increments causes a decrease in the number of lots and a corresponding increase in the size of the lots for which payment decisions are made. This will tend to increase the risks to both SCDOT and the contractor due to the greater amount of material that is being evaluated with typically much fewer tests. However, the risks to the contractor will be greater than to SCDOT.

The fact that the acceptance tests and verification tests are declared “different” by the statistical tests provides no information concerning the “cause” of the difference. Any differences between the two sets of tests may be due to a number of different factors. These factors could include differences in sampling and testing procedure, such as re-heating; the effect of one outlier in the smaller number of verification tests; or even contractor manipulated test result data.

Recommendations

Based on the data provided and the analyses that were conducted the following recommendations are made:

- Based on analyses of the Density test result data provided by SCDOT, the current Density specification requirements need to be modified, or else SCDOT needs to decide that the Density data provided are not representative of the quality of work that can be provided by qualified contractors. Based on the data provided, the specification limits need to be widened by a small amount and the Density target value needs to be lowered. If SCDOT believes that these data are not valid, then it should implement an additional research study to evaluate Density data from other projects that SCDOT believes to be representative. These new data would be analyzed to determine the appropriate standard deviation that would be used to evaluate the existing Density specification limits.

- The current specification limits for AC, AV, and VMA still appear to be appropriate based on the test result data that were provided and analyzed. Therefore, no changes are recommended for the specification tolerances for these characteristics.

- SCDOT should re-evaluate the specification limits that are used when the contractor acceptance tests do not compare during the verification process and the SCDOT verification tests are subsequently used to determine the payment factors. If the specification limits were developed for lot-by-lot acceptance, then they may not be appropriate to use when making the decision based on data from multiple lots. SCDOT needs to evaluate the analysis results presented in this report and then decide if they believe that the standard deviation values are different enough to warrant consideration for making changes to the specification limits when the verification tests are used for the acceptance decision.

- SCDOT may wish to consider modifying their verification procedures so that when the verification and acceptance tests compare, the contractor’s portion of the split sample verification tests is used along with the acceptance tests. This would increase the lot size by 1 for any lot from which a verification test was taken. It also is allowable under the FHWA Technical Advisory on the use of contractor tests for acceptance (4). This approach is shown in Figures 2.1 and 9.1.

- It is recommended that SCDOT reconsider their procedure for determining the verification data set at the end of a project. Rather than using the same test results in two different verifications, it is recommended that they consider a combination of increasing the size of the last verification data set and adding the last partial data set to the previous data set and then dividing the resulting set into two equal sized sets.

- It is recommended that SCDOT obtain at least one verification sample from each lot on a project. The practice on the projects for which verification data were provided led to some rather uneven distributions of the verification tests among the 5 lots. On one project, 60% of the verification tests were from the last of five lots in the data set.

- It is strongly recommended that SCDOT implement a research study to examine whether or not re-heating, lack of re-heating, delays before testing, and lack of delay have an effect on the resulting test results. Without such a study it is difficult to state with confidence that differences between the acceptance tests and verification tests are due to differences in the material that was sampled and tested by the two parties, and not due to differences in testing procedures.

- It is recommended that SCDOT modify the current wording in SC-T-97 (5/10) that states that the "data set to be evaluated will be test results of 7 or more verification tests." The term "or more" makes this an open-ended definition for the verification data set and raises questions such as the following. Will this be interpreted to mean that a statistical analysis will take place after every 7 tests? If not, how will the completion of the data set be established? Who will decide how many verification tests will be necessary to trigger the statistical evaluations? SCDOT may wish to clarify the term "or more" by establishing an upper limit on the number of verification tests or lots before the *F*-test and *t*-test evaluations are performed.

- SCDOT should consider implementing a procedure for identifying outliers, such as ASTM E-1780-08, as a possible addition to existing verification procedures. This could prevent having a single outlier result in a verification data set failing to compare.

- It is strongly recommended that SCDOT implement a research study to determine appropriate standard deviations to use when establishing split sample allowable tolerances. Without such a study it is difficult to determine the appropriateness of the current tolerances that are the same as the specification tolerance limits. Specification tolerances and allowable differences for split samples serve two totally different purposes and generally are not developed using the same procedures.

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APPENDIX A — TEST RESULT DATA

The following pages present all of the test result data from projects that were provided by SCDOT. The data are divided into 2 categories. The first category is the density results from the field. The second, plant test results, includes asphalt content (AC), air voids (AV), and voids in the mineral aggregate (VMA). Table A.1 contains the density test results and Table A.2 includes the plant test results.

In the following tables, each project is identified with a unique number, ranging from P01 to P36. Each of these numbered projects corresponds with a unique SCDOT project file number. Since many of the projects had more than one HMA mixture on the project, they also had more than one job mix formula (JMF) that was placed on the project. In the tables, each job mix number is identified with a unique number, ranging from J01 to J83.

Table A.1. Density Test Results Data

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P01	Binder 1	J02	1	95.54
P01	Binder 1	J02	1	93.68
P01	Binder 1	J02	1	93.76
P01	Binder 1	J02	1	94.37
P01	Binder 1	J02	1	93.07
P01	Binder 1	J02	1	94.25
P01	Binder 1	J02	1	94.12
P01	Binder 1	J02	1	94.21
P01	Binder 1	J02	1	95.58
P01	Binder 1	J02	1	95.14
P01	Binder 1	J02	2	92.47
P01	Binder 1	J02	3	92.51
P01	Binder 1	J02	3	94.05
P01	Binder 1	J02	3	94.21
P01	Binder 1	J02	3	94.37
P01	Binder 1	J02	3	93.89
P01	Binder 1	J02	4	92.47
P01	Binder 1	J02	4	92.51
P01	Binder 1	J02	4	94.05
P01	Binder 1	J02	4	94.21
P01	Binder 1	J02	4	94.37
P01	Binder 1	J02	4	93.89
P01	Interm B	J10	1	92.33
P01	Interm B	J10	1	92.41
P01	Interm B	J10	1	92.21
P01	Interm B	J10	4	93.10
P01	Interm B	J10	4	92.34
P01	Interm B	J10	4	93.18
P01	Interm B	J10	4	93.66
P01	Interm B	J10	5	92.56
P01	Interm B	J10	5	92.43
P01	Interm B	J10	5	92.39
P01	Interm B	J10	5	92.76
P01	Interm B	J10	7	92.70
P01	Interm B	J10	7	93.91
P01	Interm B	J10	7	94.36
P01	Interm B	J10	7	92.30
P01	Interm B	J10	7	92.22
P01	Interm B	J10	13	93.27
P01	Interm B	J10	13	92.30
P01	Interm B	J10	13	92.71
P01	Interm B	J10	18	92.59
P01	Interm B	J10	18	93.07
P01	Interm B	J10	18	93.88
P01	Interm B	J10	18	92.63
P01	Interm B	J10	18	92.59
P01	Interm B	J10	20	92.95
P01	Interm B	J10	20	93.79
P01	Interm B	J10	20	92.87
P01	Interm B	J10	20	92.91

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P01	Interm B	J10	20	92.71
P01	Interm B	J10	20	93.87
P01	Interm B	J23	1	93.52
P01	Interm B	J23	1	94.77
P01	Interm B	J23	1	92.52
P01	Interm B	J23	1	94.57
P01	Interm B	J23	1	93.04
P01	Interm B	J23	2	92.62
P01	Interm B	J23	2	93.34
P01	Interm B	J23	2	95.63
P01	Surf 1C	J07	8	92.22
P01	Surf 1C	J07	8	92.71
P01	Surf 1C	J07	8	92.71
P01	Surf 1C	J07	8	92.35
P01	Surf 1C	J07	8	92.51
P01	Surf 1C	J07	10	93.50
P01	Surf 1C	J07	10	93.42
P01	Surf 1C	J07	10	94.11
P01	Surf 1C	J07	10	93.18
P01	Surf 1C	J07	11	93.17
P01	Surf 1C	J07	11	93.21
P01	Surf 1C	J07	11	92.65
P01	Surf 1C	J07	11	93.66
P01	Surf 1C	J07	11	93.01
P01	Surf 1C	J07	11	93.42
P01	Surf 1C	J07	12	94.49
P01	Surf 1C	J07	12	92.96
P01	Surf 1C	J07	12	92.75
P01	Surf 1C	J07	12	95.51
P01	Surf 1C	J07	12	92.35
P01	Surf 1C	J07	12	93.93
P01	Surf 1C	J07	12	93.93
P01	Surf B	J07	2	92.76
P01	Surf B	J07	2	92.60
P01	Surf B	J07	2	92.60
P01	Surf B	J07	2	92.27
P01	Surf B	J07	2	93.28
P01	Surf B	J07	4	92.21
P01	Surf B	J07	4	92.69
P01	Surf B	J07	4	93.50
P01	Surf B	J07	4	93.54
P01	Surf B	J07	5	92.45
P01	Surf B	J07	5	92.78
P01	Surf B	J07	5	92.37
P01	Surf B	J07	6	92.41
P01	Surf B	J07	6	92.41
P01	Surf B	J07	6	92.49
P01	Surf B	J07	6	92.21
P01	Surf B	J07	6	92.21
P01	Surf B	J07	7	92.49

Table A.1. Density Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P01	Surf B	J07	7	94.55
P01	Surf B	J07	7	92.81
P03	Interm B	J04	1	94.33
P03	Interm B	J04	1	93.97
P03	Interm B	J04	1	92.08
P03	Interm B	J04	1	93.49
P03	Interm B	J04	1	91.68
P03	Interm B	J04	5	92.98
P03	Interm B	J04	5	94.36
P03	Interm B	J04	5	94.12
P03	Interm B	J04	5	95.78
P03	Interm B	J04	7	94.45
P03	Interm B	J04	7	93.80
P03	Interm B	J04	7	94.25
P03	Interm B	J04	7	94.65
P03	Interm B	J04	7	94.94
P03	Interm B	J04	7	92.99
P03	Interm B	J04	7	95.42
P03	Interm B	J04	7	94.45
P03	Interm B	J04	7	95.14
P03	Interm B	J04	7	95.63
P03	Interm B	J04	7	95.14
P03	Interm B	J04	7	94.49
P03	Interm B	J04	11	93.24
P03	Interm B	J04	11	94.42
P03	Interm B	J04	11	94.13
P03	Interm B	J04	14	92.29
P03	Interm B	J04	14	91.33
P03	Interm B	J04	14	93.10
P03	Interm B	J04	14	93.34
P03	Interm B	J04	14	92.01
P03	Interm B	J04	14	89.88
P03	Surf B	J15	3	93.44
P03	Surf B	J15	3	94.30
P03	Surf B	J15	3	92.83
P03	Surf B	J15	3	93.65
P03	Surf B	J15	4	93.59
P03	Surf B	J15	4	92.57
P03	Surf B	J15	4	91.92
P03	Surf B	J15	4	91.87
P03	Surf B	J15	5	94.00
P03	Surf B	J15	5	95.19
P03	Surf B	J15	5	91.23
P03	Surf B	J15	5	92.54
P03	Surf B	J15	5	94.00
P03	Surf B	J15	5	90.70
P03	Surf B	J15	5	93.84
P03	Surf B	J15	5	92.17
P03	Surf B	J15	5	93.68
P03	Surf B	J15	5	90.62
P03	Surf B	J15	6	93.53
P03	Surf B	J15	6	93.97
P03	Surf B	J15	6	93.44
P03	Surf B	J15	6	94.95
P03	Surf B	J15	7	93.72
P03	Surf B	J15	7	93.88
P03	Surf B	J15	7	95.14
P04	Surf 1R	J14	1	88.54
P04	Surf 1R	J14	1	88.34
P04	Surf 1R	J14	1	88.38
P04	Surf 1R	J14	1	90.19
P04	Surf 1R	J14	1	88.89
P04	Surf 1R	J14	1	89.21
P04	Surf 1R	J14	1	90.89
P04	Surf 1R	J14	1	85.40
P04	Surf 1R	J14	2	90.43
P04	Surf 1R	J14	2	91.14
P04	Surf 1R	J14	2	90.67
P04	Surf 1R	J14	2	90.71
P04	Surf 1R	J14	2	89.39
P04	Surf 1R	J14	2	90.27
P04	Surf 1R	J14	2	90.17
P04	Surf 1R	J14	2	89.47
P04	Surf 1R	J14	3	89.48
P04	Surf 1R	J14	3	91.74
P04	Surf 1R	J14	3	89.24
P04	Surf 1R	J14	3	91.66
P04	Surf 1R	J14	3	89.44
P04	Surf 1R	J14	3	88.92
P04	Surf 1R	J14	4	91.24
P04	Surf 1R	J14	4	91.28
P04	Surf 1R	J14	4	88.25
P04	Surf 1R	J14	4	90.68
P04	Surf 1R	J14	4	89.13
P04	Surf 1R	J14	4	89.13
P04	Surf 1R	J14	4	90.00
P04	Surf 1R	J14	4	91.16
P04	Surf 1R	J14	4	88.69
P04	Surf 1R	J14	5	91.06
P04	Surf 1R	J14	5	91.10
P04	Surf 1R	J14	5	88.08
P04	Surf 1R	J14	5	90.50
P04	Surf 1R	J14	5	88.95
P06	Surf 1	J26	1	89.98
P06	Surf 1	J26	1	90.56
P06	Surf 1	J26	1	89.57
P06	Surf 1	J26	1	90.07
P06	Surf 1	J26	1	89.61
P06	Surf 1	J26	1	91.30
P06	Surf 1	J26	1	92.12

Table A.1. Density Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P06	Surf 1	J26	1	88.38
P06	Surf 1	J26	1	88.38
P06	Surf 1	J26	1	91.63
P06	Surf 1	J26	1	89.04
P06	Surf 1	J26	1	90.80
P06	Surf 1	J26	1	90.35
P06	Surf 1	J26	1	88.96
P06	Surf 1D	J24	1	92.99
P06	Surf 1D	J24	1	90.40
P06	Surf 1D	J24	1	90.93
P06	Surf 1D	J24	1	90.12
P06	Surf 1D	J24	1	89.27
P06	Surf 1D	J24	1	88.90
P06	Surf 1D	J24	2	91.17
P06	Surf 1D	J24	2	91.17
P06	Surf 1D	J24	2	87.36
P06	Surf 1D	J24	2	88.10
P06	Surf 1D	J24	2	90.31
P06	Surf 1D	J24	2	90.84
P06	Surf 1D	J24	3	92.20
P06	Surf 1D	J24	3	92.85
P06	Surf 1D	J24	3	92.90
P06	Surf 1D	J24	3	92.00
P06	Surf 1D	J24	3	91.87
P06	Surf 1D	J24	4	92.61
P06	Surf 1D	J24	4	93.96
P06	Surf 1D	J24	4	93.34
P06	Surf 1D	J24	4	93.55
P06	Surf 1D	J24	5	92.34
P06	Surf 1D	J24	5	91.89
P06	Surf 1D	J24	5	93.15
P06	Surf 1D	J24	5	92.42
P08	Surf 1R	J11	1	89.90
P08	Surf 1R	J11	1	88.87
P08	Surf 1R	J11	1	90.10
P08	Surf 1R	J11	1	87.63
P08	Surf 1R	J11	1	89.62
P08	Surf 1R	J11	1	86.96
P08	Surf 1R	J11	1	88.39
P08	Surf 1R	J11	1	87.75
P13	Surf C	J03	10	91.82
P13	Surf C	J03	10	91.16
P13	Surf C	J03	10	93.42
P13	Surf C	J03	10	92.89
P13	Surf C	J03	10	91.12
P13	Surf C	J03	10	95.07
P13	Surf C	J03	10	91.61
P13	Surf C	J03	10	90.83
P13	Surf C	J03	10	90.21
P14	Surf C	J16	4	89.98
P14	Surf C	J16	4	92.10
P14	Surf C	J16	4	93.78
P14	Surf C	J16	4	93.70
P14	Surf C	J16	4	93.37
P14	Surf C	J16	4	93.17
P14	Surf C	J16	7	91.49
P14	Surf C	J16	7	93.62
P14	Surf C	J16	7	94.44
P14	Surf C	J16	7	92.55
P14	Surf C	J16	7	91.82
P14	Surf C	J16	7	93.33
P14	Surf C	J16	7	93.17
P14	Surf C	J16	8	92.37
P14	Surf C	J16	8	93.85
P14	Surf C	J16	8	92.86
P14	Surf C	J16	8	92.99
P14	Surf C	J16	8	91.67
P14	Surf C	J16	8	92.62
P14	Surf C	J16	10	92.19
P14	Surf C	J16	10	93.60
P14	Surf C	J16	10	90.20
P14	Surf C	J16	10	93.97
P14	Surf C	J16	10	90.44
P14	Surf C	J16	10	90.32
P14	Surf C	J16	10	93.68
P14	Surf C	J16	10	92.70
P14	Surf C	J16	10	88.68
P14	Surf C	J16	10	91.76
P14	Surf C	J16	11	92.66
P14	Surf C	J16	11	91.71
P14	Surf C	J16	11	92.82
P14	Surf C	J16	11	91.43
P14	Surf C	J16	11	92.00
P14	Surf C	J16	15	94.42
P14	Surf C	J16	15	92.50
P14	Surf C	J16	15	93.52
P14	Surf C	J16	15	91.84
P15	Surf C	J44	1	92.90
P15	Surf C	J44	1	93.42
P15	Surf C	J44	1	91.94
P15	Surf C	J44	2	92.71
P15	Surf C	J44	2	93.23
P15	Surf C	J44	2	91.75
P15	Surf C	J44	3	91.37
P15	Surf C	J44	3	94.36
P15	Surf C	J44	3	94.08
P15	Surf C	J44	3	90.57
P15	Surf C	J44	4	91.66
P15	Surf C	J44	4	94.67
P15	Surf C	J44	4	94.39

Table A.1. Density Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P15	Surf C	J44	4	90.86
P15	Surf C	J44	5	91.37
P15	Surf C	J44	5	94.36
P15	Surf C	J44	5	94.08
P15	Surf C	J44	5	90.57
P16	Surf C	J20	1	90.47
P16	Surf C	J20	1	93.43
P16	Surf C	J20	1	90.27
P16	Surf C	J20	1	91.33
P16	Surf C	J20	2	91.90
P16	Surf C	J20	2	91.08
P16	Surf C	J20	2	90.96
P16	Surf C	J20	2	90.67
P16	Surf C	J20	3	91.76
P16	Surf C	J20	3	91.60
P16	Surf C	J20	3	93.66
P16	Surf C	J20	3	91.85
P18	Surf C	J48	2	92.06
P18	Surf C	J48	2	90.37
P18	Surf C	J48	2	91.32
P18	Surf C	J48	2	94.20
P18	Surf C	J48	2	91.73
P18	Surf C	J48	2	93.25
P18	Surf C	J48	2	88.44
P18	Surf C	J48	4	93.78
P18	Surf C	J48	4	92.34
P18	Surf C	J48	4	89.91
P18	Surf C	J48	5	92.36
P18	Surf C	J48	5	93.35
P18	Surf C	J48	5	89.20
P18	Surf C	J48	5	93.02
P18	Surf C	J48	5	92.24
P18	Surf C	J48	5	88.75
P18	Surf C	J48	5	89.33
P18	Surf C	J48	5	92.24
P20	Surf C	J50	2	92.73
P20	Surf C	J50	2	93.80
P20	Surf C	J50	2	92.94
P20	Surf C	J50	2	94.13
P20	Surf C	J50	2	93.51
P20	Surf C	J50	2	92.03
P20	Surf C	J50	2	91.83
P20	Surf C	J50	2	91.83
P20	Surf C	J50	2	91.42
P20	Surf C	J50	2	93.10
P20	Surf C	J50	2	91.66
P20	Surf C	J50	4	91.75
P20	Surf C	J50	4	92.00
P20	Surf C	J50	4	91.88
P20	Surf C	J50	4	93.64

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P20	Surf C	J50	4	93.15
P20	Surf C	J50	4	91.14
P20	Surf C	J50	4	91.30
P20	Surf C	J50	4	91.63
P20	Surf C	J50	4	92.37
P20	Surf C	J50	4	91.55
P20	Surf C	J50	4	90.77
P20	Surf C	J50	4	91.05
P20	Surf C	J50	7	91.96
P20	Surf C	J50	7	91.77
P20	Surf C	J50	7	92.43
P20	Surf C	J50	7	91.89
P20	Surf C	J50	7	93.29
P20	Surf C	J50	7	91.52
P20	Surf C	J50	7	93.00
P20	Surf C	J50	7	92.22
P20	Surf C	J50	7	92.55
P20	Surf C	J50	7	90.04
P20	Surf C	J50	7	93.17
P20	Surf C	J50	8	92.08
P20	Surf C	J50	8	91.35
P20	Surf C	J50	8	93.48
P20	Surf C	J50	8	92.17
P20	Surf C	J50	8	92.08
P20	Surf C	J50	8	93.77
P20	Surf C	J50	8	92.08
P20	Surf C	J50	11	94.09
P20	Surf C	J50	11	92.94
P20	Surf C	J50	11	93.51
P20	Surf C	J50	11	91.58
P20	Surf C	J50	11	90.23
P20	Surf C	J50	11	93.39
P20	Surf C	J50	11	93.22
P20	Surf C	J50	11	92.77
P20	Surf C	J50	14	92.37
P20	Surf C	J50	14	92.82
P20	Surf C	J50	14	91.79
P20	Surf C	J50	14	91.96
P20	Surf C	J50	14	94.30
P20	Surf C	J50	14	94.34
P20	Surf C	J50	14	92.12
P20	Surf C	J50	14	92.70
P20	Surf C	J50	15	91.47
P20	Surf C	J50	15	93.15
P20	Surf C	J50	15	92.41
P20	Surf C	J50	15	92.66
P20	Surf C	J50	15	91.92
P20	Surf C	J50	15	93.11
P20	Surf C	J50	15	92.33
P20	Surf C	J50	15	92.95

Table A.1. Density Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P20	Surf C	J50	15	91.98
P20	Surf C	J50	15	91.59
P23	Interm B	J33	1	92.23
P23	Interm B	J33	1	93.40
P23	Interm B	J33	1	90.26
P23	Interm B	J33	2	91.49
P23	Interm B	J33	2	92.65
P23	Interm B	J33	2	89.54
P23	Interm B	J33	3	93.66
P23	Interm B	J33	3	92.98
P23	Interm B	J33	3	90.66
P23	Interm B	J33	3	91.50
P23	Interm B	J33	3	90.42
P23	Interm B	J33	4	93.29
P23	Interm B	J33	4	92.61
P23	Interm B	J33	4	90.30
P23	Interm B	J33	4	91.13
P23	Interm B	J33	4	90.06
P23	Surf B	J63	1	92.81
P23	Surf B	J63	1	92.25
P23	Surf B	J63	1	93.22
P23	Surf B	J63	2	93.15
P23	Surf B	J63	2	92.59
P23	Surf B	J63	2	93.56
P23	Surf B	J63	3	92.89
P23	Surf B	J63	3	92.32
P23	Surf B	J63	3	93.29
P23	Surf B	J63	4	92.93
P23	Surf B	J63	4	92.36
P23	Surf B	J63	4	93.33
P23	Surf B	J63	5	92.85
P23	Surf B	J63	5	94.10
P23	Surf B	J63	5	93.26
P23	Surf B	J63	6	93.15
P23	Surf B	J63	6	94.41
P23	Surf B	J63	6	93.56
P24	Surf C	J56	2	95.28
P24	Surf C	J56	2	95.28
P24	Surf C	J56	2	91.58
P24	Surf C	J56	2	91.29
P24	Surf C	J56	2	90.35
P24	Surf C	J56	2	91.75
P24	Surf C	J56	2	92.32
P24	Surf C	J56	2	93.18
P24	Surf C	J56	2	94.29
P24	Surf C	J56	2	92.69
P24	Surf C	J56	2	93.84
P24	Surf C	J56	6	93.43
P24	Surf C	J56	6	93.63
P24	Surf C	J56	6	93.39

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P24	Surf C	J56	6	94.74
P24	Surf C	J56	9	93.95
P24	Surf C	J56	9	93.66
P24	Surf C	J56	9	95.02
P24	Surf C	J56	9	93.79
P24	Surf C	J56	9	91.73
P24	Surf C	J56	9	93.09
P24	Surf C	J56	11	91.67
P24	Surf C	J56	11	91.22
P24	Surf C	J56	11	93.49
P24	Surf C	J56	11	91.96
P24	Surf C	J56	11	93.08
P24	Surf C	J56	11	92.99
P24	Surf C	J56	11	93.03
P24	Surf C	J56	11	93.08
P24	Surf C	J56	14	92.92
P24	Surf C	J56	14	93.49
P24	Surf C	J56	14	94.65
P24	Surf C	J56	14	93.37
P24	Surf C	J56	14	92.05
P24	Surf C	J56	14	92.79
P24	Surf C	J56	14	93.90
P24	Surf C	J56	14	92.55
P24	Surf C	J56	14	94.60
P24	Surf C	J56	17	92.50
P24	Surf C	J56	17	93.86
P24	Surf C	J56	17	93.16
P24	Surf C	J56	17	92.25
P24	Surf C	J56	17	93.65
P24	Surf C	J56	17	92.70
P24	Surf C	J56	17	93.61
P24	Surf C	J56	17	93.90
P24	Surf C	J56	17	92.70
P24	Surf C	J56	18	94.16
P24	Surf C	J56	18	92.89
P24	Surf C	J56	18	90.75
P24	Surf C	J56	18	94.04
P24	Surf C	J56	18	93.71
P24	Surf C	J56	18	93.30
P24	Surf C	J56	18	92.39
P24	Surf C	J56	18	92.85
P24	Surf C	J56	18	93.38
P26	Surf A	J62	1	93.69
P26	Surf A	J62	1	93.01
P26	Surf A	J62	1	94.53
P26	Surf A	J62	1	96.99
P26	Surf A	J62	1	94.21
P26	Surf A	J62	1	89.47
P26	Surf A	J62	1	92.00
P26	Surf A	J62	1	93.25

Table A.1. Density Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P26	Surf A	J62	2	93.47
P26	Surf A	J62	2	92.95
P26	Surf A	J62	2	94.83
P26	Surf A	J62	2	94.19
P26	Surf A	J62	3	92.67
P26	Surf A	J62	3	92.63
P26	Surf A	J62	3	92.14
P26	Surf A	J62	4	92.68
P26	Surf A	J62	4	92.36
P26	Surf A	J62	4	90.48
P26	Surf A	J62	4	89.68
P26	Surf A	J62	4	93.28
P26	Surf A	J62	5	93.29
P26	Surf A	J62	5	94.38
P26	Surf A	J62	5	92.41
P26	Surf A	J62	5	91.12
P26	Surf A	J62	5	92.85
P26	Surf A	J62	6	92.50
P26	Surf A	J62	6	92.30
P26	Surf A	J62	6	93.78
P26	Surf A	J62	6	93.38
P26	Surf A	J62	7	93.56
P26	Surf A	J62	7	92.95
P26	Surf A	J62	7	91.58
P26	Surf A	J62	7	93.64
P26	Surf A	J62	7	93.60
P26	Surf A	J62	8	93.18
P26	Surf A	J62	8	92.90
P26	Surf A	J62	8	93.62
P26	Surf A	J62	9	91.57
P26	Surf A	J62	9	90.93
P26	Surf A	J62	9	92.37
P26	Surf A	J62	9	91.97
P26	Surf A	J62	9	93.42
P26	Surf A	J69	1	91.60
P26	Surf A	J69	1	94.01
P26	Surf A	J69	1	94.25
P26	Surf A	J69	1	92.32
P26	Surf A	J69	1	94.17
P26	Surf A	J69	2	91.10
P26	Surf A	J69	2	89.70
P26	Surf A	J69	2	94.57
P26	Surf A	J69	2	93.22
P26	Surf A	J69	2	95.89
P26	Surf A	J69	2	93.54
P26	Surf A	J69	3	91.04
P26	Surf A	J69	3	94.68
P26	Surf A	J69	3	91.00
P26	Surf A	J69	3	94.56
P26	Surf A	J69	4	93.36
P26	Surf A	J69	4	94.16
P26	Surf A	J69	4	93.88
P26	Surf A	J69	4	94.88
P26	Surf A	J69	4	94.36
P26	Surf A	J69	5	93.07
P26	Surf A	J69	5	94.43
P26	Surf A	J69	5	93.51
P26	Surf A	J69	5	94.31
P26	Surf A	J69	6	94.46
P26	Surf A	J69	6	94.30
P26	Surf A	J69	6	94.14
P26	Surf A	J69	6	95.19
P26	Surf A	J69	6	93.34
P26	Surf A	J69	7	92.54
P26	Surf A	J69	7	92.70
P26	Surf A	J69	7	92.26
P26	Surf A	J69	7	94.58
P26	Surf A	J69	7	94.30
P26	Surf A	J69	7	93.86
P26	Surf A	J69	8	93.28
P26	Surf A	J69	8	92.52
P26	Surf A	J69	8	94.28
P26	Surf A	J69	8	92.84
P26	Surf A	J69	8	92.60
P26	Surf A	J69	9	92.39
P26	Surf A	J69	9	92.87
P26	Surf A	J69	9	94.95
P26	Surf A	J69	9	93.23
P26	Surf A	J69	9	93.23
P26	Surf A	J69	10	93.91
P26	Surf A	J69	10	91.95
P26	Surf A	J69	10	93.07
P26	Surf A	J69	10	92.27
P26	Surf A	J69	10	95.11
P26	Surf A	J69	11	92.40
P26	Surf A	J69	11	91.84
P26	Surf A	J69	11	93.64
P26	Surf A	J69	11	92.64
P26	Surf A	J69	11	93.40
P26	Surf A	J69	12	92.29
P26	Surf A	J69	12	91.25
P26	Surf A	J69	12	92.57
P26	Surf A	J69	12	91.49
P26	Surf A	J69	12	94.13
P26	Surf A	J69	12	92.53
P26	Surf A	J69	13	93.92
P26	Surf A	J69	13	93.12
P26	Surf A	J69	13	93.28
P26	Surf A	J69	13	95.28
P26	Surf A	J69	13	93.68

Table A.1. Density Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P26	Surf A	J69	13	93.48
P26	Surf A	J69	14	93.95
P26	Surf A	J69	14	95.07
P26	Surf A	J69	14	94.71
P26	Surf A	J69	14	95.15
P26	Surf A	J69	14	93.63
P26	Surf A	J69	14	93.79
P26	Surf A	J69	15	92.63
P26	Surf A	J69	15	91.46
P26	Surf A	J69	15	92.10
P26	Surf A	J69	15	95.69
P26	Surf A	J69	15	93.35
P26	Surf A	J69	16	94.11
P26	Surf A	J69	16	93.67
P26	Surf A	J69	16	92.83
P26	Surf C	J59	2	90.30
P26	Surf C	J59	2	92.94
P26	Surf C	J59	2	91.62
P26	Surf C	J59	2	91.14
P26	Surf C	J59	2	91.62
P26	Surf C	J59	2	92.50
P26	Surf C	J59	3	92.01
P26	Surf C	J59	3	93.60
P26	Surf C	J59	3	91.22
P26	Surf C	J59	3	92.65
P26	Surf C	J59	3	90.39
P26	Surf C	J59	3	92.09
P26	Surf C	J59	3	92.25
P26	Surf C	J59	3	92.53
P26	Surf C	J59	4	90.82
P26	Surf C	J59	4	91.38
P26	Surf C	J59	4	92.53
P26	Surf C	J59	4	88.68
P26	Surf C	J59	4	89.31
P26	Surf C	J59	4	89.47
P26	Surf C	J59	4	90.62
P26	Surf C	J59	5	89.96
P26	Surf C	J59	5	91.31
P26	Surf C	J59	5	91.07
P26	Surf C	J59	5	91.19
P26	Surf C	J59	5	89.96
P26	Surf C	J59	5	89.08
P26	Surf C	J59	5	90.95
P26	Surf C	J59	5	92.89
P26	Surf C	J59	5	88.29
P26	Surf C	J59	5	91.19
P26	Surf C	J59	5	90.55
P26	Surf C	J59	6	91.72
P26	Surf C	J59	6	90.01
P26	Surf C	J59	6	91.52

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P26	Surf C	J59	6	90.61
P26	Surf C	J59	6	91.80
P26	Surf C	J59	6	91.29
P26	Surf C	J59	7	90.24
P26	Surf C	J59	7	91.19
P26	Surf C	J59	7	92.06
P26	Surf C	J59	7	91.79
P26	Surf C	J59	7	90.12
P26	Surf C	J59	7	91.87
P26	Surf C	J59	7	90.36
P26	Surf C	J59	8	89.59
P26	Surf C	J59	8	92.12
P26	Surf C	J59	8	87.73
P26	Surf C	J59	8	88.68
P26	Surf C	J59	8	90.02
P26	Surf C	J59	8	88.32
P26	Surf C	J59	8	92.16
P26	Surf C	J59	8	91.88
P26	Surf C	J59	9	93.33
P26	Surf C	J59	9	91.94
P27	Surf B	J55	1	92.78
P27	Surf B	J55	1	92.09
P27	Surf B	J55	1	92.58
P27	Surf B	J55	1	93.58
P27	Surf B	J55	1	92.54
P27	Surf B	J55	3	91.33
P27	Surf B	J55	3	92.41
P27	Surf B	J55	3	93.34
P27	Surf B	J55	3	91.17
P27	Surf B	J55	3	91.37
P27	Surf B	J55	3	91.37
P27	Surf B	J55	4	92.79
P27	Surf B	J55	4	92.26
P27	Surf B	J55	4	91.78
P27	Surf B	J55	4	92.06
P27	Surf B	J55	4	92.87
P27	Surf B	J55	4	93.23
P27	Surf B	J55	4	92.51
P27	Surf B	J55	5	92.98
P27	Surf B	J55	5	91.95
P27	Surf B	J55	5	91.67
P27	Surf B	J55	5	92.30
P27	Surf B	J55	5	92.30
P27	Surf B	J55	5	91.71
P27	Surf B	J70	1	90.89
P27	Surf B	J70	1	93.45
P27	Surf B	J70	1	94.76
P27	Surf B	J70	1	94.20
P27	Surf B	J70	1	92.81
P27	Surf B	J70	2	94.80

Table A.1. Density Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P27	Surf B	J70	2	92.91
P27	Surf B	J70	2	92.91
P27	Surf B	J70	2	93.92
P27	Surf B	J70	2	92.27
P27	Surf B	J70	2	92.51
P27	Surf B	J70	2	94.20
P27	Surf B	J70	4	91.86
P27	Surf B	J70	4	93.10
P27	Surf B	J70	4	92.34
P27	Surf B	J70	4	91.98
P27	Surf B	J70	7	92.77
P27	Surf B	J70	7	93.13
P27	Surf B	J70	7	93.01
P27	Surf B	J70	7	91.09
P27	Surf B	J70	7	93.77
P27	Surf B	J70	8	93.71
P27	Surf B	J70	8	93.91
P27	Surf B	J70	8	92.51
P27	Surf B	J70	9	93.43
P27	Surf B	J70	9	92.06
P27	Surf B	J70	9	93.67
P27	Surf B	J70	9	91.26
P27	Surf B	J70	9	91.90
P27	Surf B	J70	9	93.87
P27	Surf B	J70	10	92.99
P27	Surf B	J70	10	91.39
P27	Surf B	J70	10	93.79
P28	Surf C	J39	4	93.31
P28	Surf C	J39	4	92.97
P28	Surf C	J39	4	93.06
P28	Surf C	J39	4	94.68
P28	Surf C	J39	4	91.60
P28	Surf C	J39	4	93.26
P28	Surf C	J39	4	91.98
P28	Surf C	J39	5	92.94
P28	Surf C	J39	5	93.32
P28	Surf C	J39	5	91.37
P28	Surf C	J39	5	93.90
P28	Surf C	J39	5	94.11
P28	Surf C	J39	5	91.78
P28	Surf C	J39	5	92.65
P28	Surf C	J39	5	93.77
P28	Surf C	J39	5	93.03
P28	Surf C	J39	5	96.10
P28	Surf C	J39	5	94.10
P28	Surf C	J39	6	94.65
P28	Surf C	J39	6	91.32
P28	Surf C	J39	6	90.66
P28	Surf C	J39	6	94.35
P28	Surf C	J39	6	95.43

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P28	Surf C	J39	6	92.15
P28	Surf C	J39	6	94.35
P28	Surf C	J39	8	94.18
P28	Surf C	J39	8	93.14
P28	Surf C	J39	8	93.14
P30	Surf B	J65	1	98.82
P30	Surf B	J65	1	91.45
P30	Surf B	J65	1	91.09
P30	Surf B	J65	1	92.60
P30	Surf B	J65	1	93.90
P30	Surf B	J65	2	94.60
P30	Surf B	J65	2	93.45
P30	Surf B	J65	2	94.01
P31	Surf B	J71	1	94.28
P31	Surf B	J71	1	94.04
P31	Surf B	J71	1	94.40
P31	Surf B	J71	1	93.72
P31	Surf B	J71	1	93.84
P31	Surf B	J71	2	93.45
P31	Surf B	J71	2	94.17
P31	Surf B	J71	2	95.09
P32	Interm B	J76	2	93.80
P32	Interm B	J76	2	93.52
P32	Interm B	J76	2	94.28
P32	Interm B	J76	2	94.00
P32	Interm B	J76	2	94.60
P32	Interm B	J76	2	93.60
P32	Interm B	J76	2	93.08
P32	Interm B	J76	2	95.20
P32	Interm B	J76	2	92.44
P32	Interm B	J76	3	94.14
P32	Interm B	J76	3	95.93
P32	Interm B	J76	3	94.54
P32	Interm B	J76	3	94.06
P32	Interm B	J76	3	92.43
P32	Interm B	J76	3	94.30
P32	Interm B	J76	4	92.56
P32	Interm B	J76	4	92.68
P32	Interm B	J76	4	93.52
P32	Interm B	J76	4	92.60
P32	Interm B	J76	4	91.80
P32	Interm B	J76	4	92.32
P32	Interm B	J76	4	93.04
P32	Interm B	J76	4	93.68
P32	Interm B	J76	4	92.92
P32	Interm B	J76	4	92.76
P32	Interm B	J76	5	93.20
P32	Interm B	J76	5	91.76
P32	Interm B	J76	5	94.32
P32	Interm B	J76	5	92.88

Table A.1. Density Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P32	Interm B	J76	5	92.80
P32	Interm B	J76	5	92.56
P32	Interm B	J76	5	92.92
P32	Interm B	J76	5	92.68
P32	Interm B	J76	5	94.73
P32	Interm B	J76	5	93.08
P32	Interm B	J76	6	92.97
P32	Interm B	J76	6	92.16
P32	Interm B	J76	6	93.28
P32	Interm B	J76	6	93.16
P32	Interm B	J76	6	93.52
P32	Interm B	J76	6	93.88
P32	Interm B	J76	6	91.88
P32	Interm B	J76	6	92.12
P32	Interm B	J76	6	93.12
P32	Interm B	J76	6	94.08
P32	Interm B	J76	7	94.44
P32	Interm B	J76	7	92.40
P32	Interm B	J76	7	91.96
P32	Interm B	J76	7	90.72
P32	Interm B	J76	7	92.56
P32	Interm B	J76	7	90.48
P32	Interm B	J76	8	93.31
P32	Interm B	J76	8	90.83
P32	Interm B	J76	8	92.91
P32	Interm B	J76	8	91.99
P32	Interm B	J76	8	93.63
P32	Interm B	J76	8	92.95
P32	Interm B	J76	8	91.79
P32	Interm B	J76	9	95.32
P32	Interm B	J76	9	95.60
P32	Interm B	J76	9	91.39
P32	Interm B	J76	9	92.39
P32	Interm B	J76	9	93.11
P32	Interm B	J76	9	92.19
P32	Interm B	J76	10	93.65
P32	Interm B	J76	10	92.34
P32	Interm B	J76	10	94.25
P32	Interm B	J76	10	94.53
P32	Interm B	J76	10	94.17
P32	Interm B	J76	10	92.81
P32	Interm B	J76	10	91.58
P32	Interm B	J76	10	93.25
P32	Interm B	J76	10	93.49
P32	Interm B	J76	11	93.92
P32	Interm B	J76	11	93.92
P32	Interm B	J76	11	93.80
P32	Interm B	J76	11	93.96
P32	Interm B	J76	11	93.60
P32	Interm B	J76	11	93.68
P32	Interm B	J76	11	93.56
P32	Interm B	J76	11	91.64
P32	Interm B	J76	11	94.32
P32	Interm B	J76	12	93.80
P32	Interm B	J76	12	93.92
P32	Interm B	J76	12	93.68
P32	Interm B	J76	12	93.48
P32	Interm B	J76	12	92.96
P32	Interm B	J76	12	93.68
P32	Interm B	J76	12	95.36
P32	Interm B	J76	12	95.12
P32	Interm B	J76	12	92.48
P32	Interm B	J76	12	92.44
P32	Interm B	J76	13	93.76
P32	Interm B	J76	13	94.20
P32	Interm B	J76	13	94.32
P32	Interm B	J76	13	93.63
P32	Interm B	J76	13	92.47
P32	Interm B	J76	13	92.59
P32	Interm B	J76	13	92.71
P32	Interm B	J76	14	94.28
P32	Interm B	J76	14	92.56
P32	Interm B	J76	14	95.24
P32	Interm B	J76	14	91.36
P32	Interm B	J76	14	93.84
P32	Interm B	J76	14	94.08
P32	Surf A	J74	1	93.95
P32	Surf A	J74	1	94.67
P32	Surf A	J74	1	94.31
P32	Surf A	J74	1	92.83
P32	Surf A	J74	1	92.31
P32	Surf A	J74	1	91.15
P32	Surf A	J79	2	92.34
P32	Surf A	J79	2	93.02
P32	Surf A	J79	2	92.22
P32	Surf A	J79	2	92.26
P32	Surf A	J79	2	92.78
P32	Surf A	J79	2	92.90
P32	Surf A	J79	2	93.38
P32	Surf A	J79	2	93.50
P32	Surf A	J79	2	92.90
P32	Surf A	J79	2	94.99
P32	Surf A	J79	3	93.32
P32	Surf A	J79	3	92.60
P32	Surf A	J79	3	92.52
P32	Surf A	J79	3	93.28
P32	Surf A	J79	3	92.27
P32	Surf A	J79	3	92.40
P32	Surf A	J79	3	93.32
P32	Surf A	J79	3	94.20

Table A.1. Density Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P32	Surf A	J79	4	92.64
P32	Surf A	J79	4	92.12
P32	Surf A	J79	4	94.52
P32	Surf A	J79	4	93.32
P32	Surf A	J79	4	92.32
P32	Surf A	J79	4	92.32
P32	Surf A	J79	4	92.92
P32	Surf A	J79	4	95.12
P32	Surf A	J79	4	93.36
P32	Surf A	J79	4	91.12
P32	Surf A	J79	5	92.99
P32	Surf A	J79	5	92.87
P32	Surf A	J79	5	91.59
P32	Surf A	J79	5	93.75
P32	Surf A	J79	6	92.52
P32	Surf A	J79	6	93.08
P32	Surf A	J79	6	92.08
P32	Surf A	J79	6	94.32
P32	Surf A	J79	6	92.48
P32	Surf A	J79	6	93.24
P32	Surf A	J79	6	93.00
P32	Surf A	J79	6	92.24
P32	Surf A	J79	6	91.88
P32	Surf A	J79	6	92.92
P32	Surf A	J79	7	92.73
P32	Surf A	J79	7	93.53
P32	Surf A	J79	7	93.25
P32	Surf A	J79	7	93.09
P32	Surf A	J79	8	92.88
P32	Surf A	J79	8	93.24
P32	Surf A	J79	8	93.64
P32	Surf A	J79	8	92.72
P32	Surf A	J79	8	92.08
P32	Surf A	J79	8	93.64
P32	Surf A	J79	8	93.20
P32	Surf A	J79	8	92.80
P32	Surf A	J79	9	93.11
P32	Surf A	J79	9	92.67
P32	Surf A	J79	9	93.39
P32	Surf A	J79	9	92.87
P32	Surf A	J79	10	93.28
P32	Surf A	J79	10	92.80
P32	Surf A	J79	10	94.08
P32	Surf A	J79	10	93.64
P32	Surf A	J79	10	93.08
P32	Surf A	J79	10	92.76
P32	Surf A	J79	10	92.68
P32	Surf A	J79	10	88.20
P32	Surf A	J79	10	92.24
P32	Surf A	J79	11	92.87
P32	Surf A	J79	11	91.51
P32	Surf A	J79	11	92.87
P32	Surf A	J79	11	92.93
P32	Surf A	J79	11	93.43
P32	Surf A	J79	11	92.79
P32	Surf A	J79	11	93.07
P32	Surf A	J79	11	93.71
P32	Surf A	J79	11	93.15
P32	Surf A	J79	12	93.00
P32	Surf A	J79	12	91.84
P32	Surf A	J79	12	92.68
P32	Surf A	J79	12	92.88
P32	Surf A	J79	12	93.12
P32	Surf A	J79	12	92.60
P32	Surf A	J79	12	93.04
P32	Surf A	J79	12	92.20
P32	Surf A	J79	12	93.28
P32	Surf A	J79	12	93.48
P32	Surf A	J79	12	92.40
P32	Surf A	J79	13	92.97
P32	Surf A	J79	13	92.18
P32	Surf A	J79	13	94.49
P32	Surf A	J79	13	93.09
P32	Surf A	J79	13	92.61
P32	Surf A	J79	14	90.77
P32	Surf A	J79	14	90.77
P32	Surf A	J79	14	90.81
P32	Surf A	J79	14	92.12
P32	Surf A	J79	14	91.84
P32	Surf A	J79	15	92.57
P32	Surf A	J79	15	92.73
P32	Surf A	J79	15	90.17
P32	Surf A	J79	15	93.41
P32	Surf A	J79	15	92.13
P32	Surf A	J79	15	92.21
P32	Surf A	J79	15	92.77
P32	Surf A	J79	15	93.81
P32	Surf A	J79	15	91.93
P32	Surf A	J79	15	92.81
P32	Surf A	J79	16	90.62
P32	Surf A	J79	16	93.65
P32	Surf A	J79	16	91.65
P32	Surf A	J79	16	91.81
P32	Surf A	J79	16	93.21
P32	Surf A	J79	16	92.33
P32	Surf A	J79	17	92.24
P32	Surf A	J79	17	92.40
P32	Surf A	J79	17	91.56
P32	Surf A	J79	17	93.92
P32	Surf A	J79	17	92.88

Table A.1. Density Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P32	Surf A	J79	17	90.92
P32	Surf A	J79	17	93.24
P32	Surf A	J79	17	93.68
P32	Surf A	J79	18	92.98
P32	Surf A	J79	18	91.94
P32	Surf A	J79	18	93.02
P32	Surf A	J79	18	92.22
P32	Surf A	J79	18	92.34
P32	Surf A	J79	19	92.97
P32	Surf A	J79	19	94.41
P32	Surf A	J79	19	93.45
P32	Surf A	J79	19	93.13
P32	Surf A	J79	20	93.80
P32	Surf A	J79	20	94.12
P32	Surf A	J79	20	90.91
P32	Surf A	J79	20	93.96
P32	Surf A	J79	20	94.00
P32	Surf A	J79	20	92.91
P32	Surf A	J79	20	93.15
P32	Surf A	J79	21	92.57
P32	Surf A	J79	21	92.97
P32	Surf A	J79	21	92.01
P32	Surf A	J79	21	92.09
P32	Surf A	J79	21	92.69
P32	Surf A	J79	22	93.06
P32	Surf A	J79	22	92.98
P32	Surf A	J79	22	92.91
P32	Surf A	J79	22	92.07
P32	Surf A	J79	22	92.42
P32	Surf A	J79	22	93.34
P32	Surf A	J79	22	93.98
P32	Surf A	J79	23	94.44
P32	Surf A	J79	23	92.80
P32	Surf A	J79	23	94.16
P32	Surf A	J79	23	93.36
P32	Surf A	J79	23	93.36
P32	Surf A	J79	23	92.56
P32	Surf A	J79	23	91.32
P32	Surf A	J79	23	91.56
P32	Surf A	J79	24	92.76
P32	Surf A	J79	24	91.48
P32	Surf A	J79	24	90.00
P32	Surf A	J79	24	91.88
P32	Surf A	J79	24	92.96
P32	Surf A	J79	24	93.20
P32	Surf A	J79	25	91.79
P32	Surf A	J79	25	94.47
P32	Surf A	J79	25	93.31
P32	Surf B	J72	1	91.84
P32	Surf B	J72	1	92.69

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P32	Surf B	J72	1	93.17
P32	Surf B	J72	1	93.69
P32	Surf B	J72	1	92.04
P32	Surf B	J72	1	93.89
P32	Surf B	J72	1	92.33
P32	Surf B	J72	1	93.65
P32	Surf B	J72	1	93.01
P32	Surf B	J72	1	93.09
P32	Surf B	J72	1	93.01
P32	Surf B	J72	1	94.13
P32	Surf B	J72	2	93.44
P32	Surf B	J72	2	93.00
P32	Surf B	J72	2	94.37
P32	Surf B	J72	2	92.72
P32	Surf B	J72	2	93.08
P32	Surf B	J72	2	91.91
P32	Surf B	J72	2	92.52
P32	Surf B	J72	2	92.24
P32	Surf B	J72	2	93.52
P32	Surf B	J72	2	92.36
P32	Surf B	J72	2	93.24
P32	Surf B	J72	2	92.40
P32	Surf B	J72	2	92.52
P32	Surf B	J72	2	93.16
P32	Surf B	J72	3	92.72
P32	Surf B	J72	3	91.92
P32	Surf B	J72	3	93.29
P32	Surf B	J72	3	91.23
P32	Surf B	J72	3	92.36
P32	Surf B	J72	4	93.29
P32	Surf B	J72	4	92.01
P32	Surf B	J72	4	93.09
P32	Surf B	J72	4	95.54
P32	Surf B	J72	4	93.05
P32	Surf B	J72	5	92.21
P32	Surf B	J72	5	92.97
P32	Surf B	J72	5	92.73
P32	Surf B	J72	5	93.25
P32	Surf B	J72	5	94.34
P32	Surf B	J72	5	95.18
P32	Surf B	J72	5	91.40
P32	Surf B	J72	5	95.54
P32	Surf B	J72	5	92.77
P32	Surf B	J72	5	92.93
P32	Surf B	J72	6	93.26
P32	Surf B	J72	6	93.62
P32	Surf B	J72	6	93.86
P32	Surf B	J72	6	93.10
P32	Surf B	J72	6	94.41
P32	Surf B	J72	6	92.65

Table A.1. Density Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P32	Surf B	J72	6	93.90
P32	Surf B	J72	6	93.90
P32	Surf B	J72	6	93.78
P32	Surf B	J72	7	93.29
P32	Surf B	J72	7	92.52
P32	Surf B	J72	7	93.45
P32	Surf B	J72	7	93.41
P32	Surf B	J72	7	91.92
P32	Surf B	J72	7	93.49
P32	Surf B	J72	8	93.18
P32	Surf B	J72	8	93.98
P32	Surf B	J72	8	92.50
P32	Surf B	J72	8	92.98
P32	Surf B	J72	8	93.38
P32	Surf B	J72	8	92.58
P32	Surf B	J72	8	92.22
P32	Surf B	J72	8	93.06
P32	Surf B	J72	8	91.86
P33	Interm B	J73	1	93.30
P33	Interm B	J73	1	94.14
P33	Interm B	J73	1	96.81
P33	Interm B	J73	1	90.67
P33	Interm B	J73	1	93.02
P33	Interm B	J73	2	95.05
P33	Interm B	J73	2	94.73
P33	Interm B	J73	2	93.11
P33	Interm B	J73	2	92.36
P33	Interm B	J73	2	94.22
P33	Interm B	J73	2	88.84
P33	Interm B	J73	2	94.02
P33	Interm B	J73	3	92.76
P33	Interm B	J73	3	92.29
P33	Interm B	J73	3	93.76
P33	Interm B	J73	3	93.56
P33	Interm B	J73	3	91.53
P33	Interm B	J73	4	93.83
P33	Interm B	J73	4	92.56
P33	Interm B	J73	4	94.82
P33	Interm B	J73	4	93.51
P33	Interm B	J73	4	93.15
P33	Interm B	J73	4	93.91
P33	Interm B	J73	4	91.44
P33	Interm B	J73	4	93.31
P33	Interm B	J73	4	93.95
P33	Interm B	J73	4	94.39
P33	Interm B	J73	5	93.13
P33	Interm B	J73	5	93.65
P33	Interm B	J73	5	93.13
P33	Interm B	J73	5	94.12
P33	Interm B	J73	5	91.62
P33	Interm B	J73	5	92.46
P33	Interm B	J73	5	94.60
P33	Interm B	J73	6	92.55
P33	Interm B	J73	6	92.39
P33	Interm B	J73	6	92.03
P33	Interm B	J73	6	91.24
P33	Interm B	J73	6	94.17
P33	Interm B	J73	6	94.65
P33	Interm B	J73	6	94.69
P33	Interm B	J73	6	91.71
P33	Interm B	J73	6	91.83
P33	Interm B	J73	7	95.91
P33	Interm B	J73	7	93.61
P33	Interm B	J73	7	92.46
P33	Interm B	J73	7	93.29
P33	Interm B	J73	7	93.49
P33	Interm B	J73	7	94.33
P33	Interm B	J73	7	91.59
P33	Interm B	J73	8	92.86
P33	Interm B	J73	8	94.05
P33	Interm B	J73	8	91.48
P33	Interm B	J73	8	91.04
P33	Interm B	J73	8	93.46
P33	Interm B	J73	8	93.58
P33	Surf A	J77	1	90.95
P33	Surf A	J77	1	92.38
P33	Surf A	J77	1	92.90
P33	Surf A	J77	1	91.43
P33	Surf A	J77	1	92.15
P33	Surf A	J77	1	91.43
P33	Surf A	J77	1	90.71
P33	Surf A	J77	1	91.75
P33	Surf A	J77	2	92.30
P33	Surf A	J77	2	92.26
P33	Surf A	J77	2	94.50
P33	Surf A	J77	2	94.10
P33	Surf A	J77	2	93.86
P33	Surf A	J77	2	95.29
P33	Surf A	J77	2	92.30
P33	Surf A	J77	2	93.74
P33	Surf A	J77	3	92.70
P33	Surf A	J77	3	93.50
P33	Surf A	J77	3	94.31
P33	Surf A	J77	3	94.23
P33	Surf A	J77	3	94.27
P33	Surf A	J77	3	93.46
P33	Surf A	J77	3	93.99
P33	Surf A	J77	4	91.52
P33	Surf A	J77	4	91.20
P33	Surf A	J77	4	90.08

Table A.1. Density Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	Density
P33	Surf A	J77	4	93.16
P33	Surf A	J77	4	93.40
P33	Surf A	J77	4	93.92
P33	Surf A	J77	4	88.48
P33	Surf A	J77	5	94.13
P33	Surf A	J77	5	91.17
P33	Surf A	J77	5	92.37
P33	Surf A	J77	5	92.85
P33	Surf A	J77	5	89.90
P33	Surf A	J77	5	91.73
P33	Surf A	J77	6	94.64
P33	Surf A	J77	6	93.00
P33	Surf A	J77	6	93.08
P33	Surf A	J77	6	93.48
P34	Surf A	J62	1	94.25
P34	Surf A	J62	1	95.41
P34	Surf A	J62	1	92.60
P34	Surf A	J62	1	93.96
P34	Surf A	J62	1	93.92
P34	Surf A	J62	2	92.78
P34	Surf A	J62	2	92.25
P34	Surf A	J62	2	93.50
P34	Surf A	J62	2	90.52
P34	Surf A	J62	2	93.87
P34	Surf A	J62	3	90.43
P34	Surf A	J62	3	91.52
P34	Surf A	J62	3	90.43
P34	Surf A	J62	3	92.24
P34	Surf A	J62	3	94.57
P34	Surf A	J62	3	92.68
P34	Surf A	J62	3	90.80
P34	Surf A	J62	3	89.11
P34	Surf A	J62	3	89.99
P34	Surf A	J62	3	94.90
P34	Surf A	J62	4	95.87
P34	Surf A	J62	4	92.46
P34	Surf A	J62	4	94.63
P34	Surf A	J62	4	92.66
P34	Surf A	J62	4	93.10
P36	Interm B	J09	4	92.86
P36	Interm B	J09	4	93.43
P36	Interm B	J09	4	92.90
P36	Interm B	J09	10	91.60
P36	Interm B	J09	10	94.02
P36	Interm B	J09	10	93.90
P36	Interm B	J09	16	91.65
P36	Interm B	J09	16	93.55
P36	Interm B	J09	16	93.47
P36	Interm B	J09	16	92.30
P36	Interm B	J09	16	89.74
P36	Interm B	J09	16	92.95
P36	Interm B	J09	16	93.88
P36	Interm B	J09	17	95.49
P36	Interm B	J09	17	92.57
P36	Interm B	J09	17	91.15
P36	Interm B	J09	17	91.64
P36	Interm B	J09	21	95.49
P36	Interm B	J09	21	92.57
P36	Interm B	J09	21	91.15
P36	Interm B	J09	21	91.64

Table A.2. Plant Test Results Data

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P01	AABC 1	J01	1	0.04		
P01	AABC 1	J01	1	-0.16		
P01	AABC 1	J01	1	0.03		
P01	AABC 1	J01	1	-0.32		
P01	AABC 1	J01	1	0.30		
P01	AABC 1	J01	1	-0.03		
P01	AABC 1	J01	2	0.44		
P01	AABC 1	J01	2	0.05		
P01	AABC 1	J01	2	0.33		
P01	AABC 1	J01	2	-0.04		
P01	AABC 1	J01	3	0.10		
P01	AABC 1	J01	3	-0.04		
P01	AABC 1	J01	3	0.52		
P01	AABC 1	J01	4	0.35		
P01	AABC 1	J01	4	0.21		
P01	AABC 1	J01	4	0.08		
P01	AABC 1	J01	5	-0.36		
P01	AABC 1	J01	6	-0.07		
P01	AABC 1	J01	6	-0.15		
P01	AABC 1	J01	7	0.22		
P01	AABC 1	J01	8	0.07		
P01	AABC 1	J01	8	-0.09		
P01	AABC 1	J06	1	0.38		
P01	AABC 1	J06	1	0.09		
P01	AABC 1	J06	1	0.19		
P01	AABC 1	J06	2	-0.16		
P01	AABC 1	J06	2	0.39		
P01	AABC 1	J06	2	0.01		
P01	AABC 1	J06	2	-0.05		
P01	AABC 1	J06	3	0.20		
P01	AABC 1	J06	3	-0.17		
P01	Base A	J18	1	0.02		
P01	Base A	J18	1	0.19		
P01	Base A	J18	1	-0.37		
P01	Base A	J18	1	-0.25		
P01	Base A	J18	3	0.00		
P01	Base A	J18	3	0.02		
P01	Base A	J18	3	-0.05		
P01	Base A	J18	4	0.39		
P01	Base A	J18	4	-0.08		
P01	Base A	J18	4	-0.06		
P01	Base A	J18	4	-0.07		
P01	Base A	J18	5	-0.05		
P01	Base A	J18	5	0.08		
P01	Base A	J18	5	0.00		
P01	Base A	J18	5	0.01		
P01	Base A	J18	6	-0.08		
P01	Base A	J18	6	0.11		
P01	Base A	J18	6	-0.15		
P01	Base A	J18	7	-0.09		

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P01	Base A	J18	7	0.44		
P01	Base A	J18	7	0.02		
P01	Base A	J18	8	0.64		
P01	Base A	J18	8	-0.34		
P01	Base A	J18	8	0.02		
P01	Base A	J18	10	-0.27		
P01	Base A	J18	10	0.04		
P01	Base A	J18	10	-0.11		
P01	Base A	J18	10	-0.13		
P01	Base A	J18	11	0.16		
P01	Base A	J18	11	-0.42		
P01	Base A	J18	12	-0.16		
P01	Base A	J18	15	-0.06		
P01	Base A	J18	15	-0.32		
P01	Base A	J18	15	0.14		
P01	Base A	J18	15	0.40		
P01	Base A	J18	17	-0.52		
P01	Base A	J18	18	0.17		
P01	Base A	J18	18	-0.24		
P01	Base A	J18	19	0.30		
P01	Base A	J18	19	0.93		
P01	Base A	J18	20	0.19		
P01	Base A	J18	21	-0.28		
P01	Base A	J18	22	-0.09		
P01	Base A	J18	23	-0.04		
P01	Base A	J18	23	-0.43		
P01	Base A	J18	23	-0.46		
P01	Base A	J18	23	-0.49		
P01	Base A	J18	31	0.13		
P01	Base A	J18	31	-0.02		
P01	Base A	J18	31	-0.11		
P01	Base A	J18	32	0.08		
P01	Base A	J18	32	0.06		
P01	Base A	J18	33	-0.15		
P01	Base A	J18	33	-0.39		
P01	Base A	J18	34	-0.11		
P01	Base A	J18	35	0.03		
P01	Base A	J18	35	-0.12		
P01	Base A	J18	36	0.09		
P01	Base A	J18	36	0.23		
P01	Base A	J18	37	0.04		
P01	Base A	J18	37	-0.21		
P01	Base A	J18	37	-0.31		
P01	Base A	J18	39	-0.07		
P01	Base A	J18	39	0.17		
P01	Base A	J18	39	-0.27		
P01	Base A	J18	39	-0.13		
P01	Base A	J18	40	0.16		
P01	Base A	J18	40	-0.16		
P01	Base A	J18	40	-0.06		

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P01	Base A	J18	41	-0.13		
P01	Base A	J18	41	0.18		
P01	Base A	J18	43	-0.17		
P01	Base A	J18	43	-0.37		
P01	Base A	J18	44	-0.17		
P01	Base A	J18	44	-0.19		
P01	Base A	J18	45	-0.04		
P01	Base A	J18	45	-0.24		
P01	Base A	J18	46	-0.15		
P01	Base A	J18	46	0.04		
P01	Base A	J18	60	-0.31		
P01	Base A	J18	60	0.06		
P01	Base A	J18	60	0.01		
P01	Base A	J21	1	0.32		
P01	Base A	J21	2	0.17		
P01	Base A	J21	3	0.10		
P01	Base A	J21	3	0.04		
P01	Base A	J21	3	0.27		
P01	Base A	J21	4	-0.19		
P01	Base A	J21	4	-0.06		
P01	Base A	J21	4	0.26		
P01	Base A	J21	5	0.37		
P01	Base A	J21	6	0.30		
P01	Base A	J21	6	0.11		
P01	Base A	J21	6	-0.36		
P01	Base A	J21	8	0.59		
P01	Base A	J21	8	-0.17		
P01	Base A	J21	8	0.30		
P01	Base A	J21	9	0.06		
P01	Base A	J21	10	0.00		
P01	Base A	J21	11	-0.45		
P01	Base A	J21	11	0.49		
P01	Base A	J21	12	0.36		
P01	Base A	J21	13	-0.05		
P01	Base A	J21	14	0.32		
P01	Base A	J21	15	-0.14		
P01	Base A	J21	15	0.34		
P01	Base A	J21	15	0.13		
P01	Base A	J21	16	-0.07		
P01	Base A	J21	16	-0.11		
P01	Binder 1	J02	1	0.00		
P01	Binder 1	J02	1	0.10		
P01	Binder 1	J02	1	0.05		
P01	Binder 1	J02	1	0.00		
P01	Binder 1	J02	1	-0.13	-0.10	-0.46
P01	Binder 1	J02	1	0.38	-0.31	0.50
P01	Binder 1	J02	2	0.11	-0.62	-0.31
P01	Binder 1	J02	2	0.40	-1.10	-0.13
P01	Binder 1	J02	2	0.25	0.82	1.12
P01	Binder 1	J02	3	0.03	-0.44	-0.39
P01	Binder 1	J02	3	0.29	-0.57	0.06
P01	Binder 1	J02	4	-0.02	-0.09	-0.22
P01	Interm B	J10	1	0.25	-0.80	-0.17
P01	Interm B	J10	1	0.02	-1.02	-0.82
P01	Interm B	J10	1	0.08	-1.03	-0.74
P01	Interm B	J10	2	0.29	-1.11	-0.32
P01	Interm B	J10	3	-0.44	-1.12	-2.00
P01	Interm B	J10	4	-0.41	0.53	-0.37
P01	Interm B	J10	4	0.17	-1.10	-0.54
P01	Interm B	J10	4	-0.02	-0.03	-0.02
P01	Interm B	J10	4	0.17	-0.55	-0.04
P01	Interm B	J10	5	-0.10	-0.77	-0.90
P01	Interm B	J10	5	-0.04	-0.19	-0.19
P01	Interm B	J10	5	0.10	-0.63	-0.33
P01	Interm B	J10	6	0.14	-0.44	-0.02
P01	Interm B	J10	7	-0.09	-0.52	-0.64
P01	Interm B	J10	7	-0.24	-0.20	-0.73
P01	Interm B	J10	7	-0.24	0.26	-0.33
P01	Interm B	J10	8	0.18	-0.63	-0.13
P01	Interm B	J10	9	0.13	-0.13	0.20
P01	Interm B	J10	10	-0.07	-0.20	-0.35
P01	Interm B	J10	11	0.05	-0.66	-0.43
P01	Interm B	J10	11	0.43	-0.14	0.86
P01	Interm B	J10	12	0.10	-0.33	-0.06
P01	Interm B	J10	12	0.05	-0.36	-0.18
P01	Interm B	J10	13	0.15	-0.96	-0.46
P01	Interm B	J10	13	0.06	-0.57	-0.37
P01	Interm B	J10	13	-0.04	-0.08	-0.16
P01	Interm B	J10	13	0.00	-0.02	-0.02
P01	Interm B	J10	14	0.13	-0.99	-0.52
P01	Interm B	J10	14	0.23	-0.79	-0.10
P01	Interm B	J10	17	-0.06	-0.13	-0.23
P01	Interm B	J10	17	0.13	-0.43	-0.06
P01	Interm B	J10	18	0.24	0.26	0.82
P01	Interm B	J10	18	0.11	0.06	0.29
P01	Interm B	J10	18	-0.20	0.38	-0.12
P01	Interm B	J10	19	-0.27	0.43	-0.26
P01	Interm B	J10	19	-0.20	0.38	-0.12
P01	Interm B	J10	20	-0.37	-0.09	-0.83
P01	Interm B	J10	20	-0.05	-0.56	-0.57
P01	Interm B	J10	20	-0.23	0.40	-0.12
P01	Interm B	J23	1	0.37	-0.55	0.36
P01	Interm B	J23	1	0.55	-0.92	0.43
P01	Interm B	J23	1	0.18	-0.28	0.19
P01	Interm B	J23	1	0.04	-0.37	-0.23
P01	Interm B	J23	2	-0.27	-0.21	-0.76
P01	Interm B	J23	2	0.40	-0.30	0.64
P01	Interm B	J23	2	-0.38	0.36	-0.53
P01	Interm B	J23	3	-0.06	0.19	0.08
P01	Interm B	J23	4	0.31	-0.60	0.22

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P01	Interm B	J23	4	-0.29	-0.21	-0.80
P01	Interm B	J23	5	0.33	-0.55	0.34
P01	Interm B	J23	6	0.08	-0.50	-0.24
P01	Surf 1C	J07	8	-0.04	0.12	0.00
P01	Surf 1C	J07	8	0.26	-0.38	0.23
P01	Surf 1C	J07	8	0.00	-0.28	-0.26
P01	Surf 1C	J07	9	-0.18	0.89	0.40
P01	Surf 1C	J07	10	-0.21	-0.54	-0.93
P01	Surf 1C	J07	10	0.18	-0.64	-0.12
P01	Surf 1C	J07	10	0.04	-0.23	-0.11
P01	Surf 1C	J07	11	-0.34	0.39	-0.41
P01	Surf 1C	J07	11	-0.25	0.54	-0.10
P01	Surf 1C	J07	11	-0.29	0.87	0.14
P01	Surf 1C	J07	11	-0.10	0.76	0.46
P01	Surf 1C	J07	11	-0.06	0.60	0.38
P01	Surf 1C	J07	12	0.20	-0.63	-0.11
P01	Surf 1C	J07	12	0.05	0.61	0.62
P01	Surf 1C	J07	12	-0.17	0.70	0.22
P01	Surf 1C	J07	12	-0.07	0.83	0.55
P01	Surf B	J07	4	-0.04	0.79	0.63
P01	Surf B	J07	4	0.33	-0.27	0.53
P01	Surf B	J07	4	0.07	0.49	0.61
P01	Surf B	J07	5	-0.14	-0.41	-0.69
P01	Surf B	J07	5	0.03	0.51	0.55
P01	Surf B	J07	5	0.15	0.77	1.04
P01	Surf B	J07	6	-0.43	0.49	-0.54
P01	Surf B	J07	6	-0.11	1.04	0.67
P01	Surf B	J07	6	0.18	0.20	0.59
P01	Surf B	J07	6	0.01	0.51	0.49
P01	Surf B	J07	6	0.09	0.45	0.63
P01	Surf B	J07	7	-0.05	0.50	0.34
P01	Surf B	J07	7	0.02	0.61	0.61
P01	Surf B	J07	7	0.14	0.62	0.87
P01	Surf C	J19	2	0.02	-0.67	-0.42
P01	Surf C	J19	3	0.26	0.25	0.86
P01	Surf C	J19	4	-0.06	-0.92	-0.80
P01	Surf C	J19	4	0.00	-0.26	-0.12
P01	Surf C	J19	5	-0.04	-0.77	-0.66
P01	Surf C	J19	5	-0.15	-0.07	-0.27
P01	Surf C	J19	6	0.02	-1.03	-0.70
P01	Surf C	J19	7	0.14	-0.29	0.28
P01	Surf C	J19	8	0.14	0.76	1.13
P01	Surf C	J19	9	0.22	0.59	1.13
P01	Surf C	J19	11	0.21	-0.48	0.16
P01	Surf C	J19	11	-0.01	0.19	0.24
P01	Surf C	J19	12	0.02	-0.95	-0.60
P01	Surf C	J19	13	0.01	-0.05	0.20
P01	Surf C	J19	16	-0.03	-1.05	-0.81
P01	Surf C	J19	16	0.24	-0.71	0.10
P01	Surf C	J19	17	0.41	-1.07	0.17

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P01	Surf C	J19	18	0.09	-1.00	-0.54
P02	Base A	J17	1	0.15		
P02	Base A	J17	1	-0.19		
P02	Base A	J17	1	-0.17		
P02	Base A	J17	2	0.60		
P02	Base A	J17	2	0.13		
P02	Base A	J17	2	-0.32		
P02	Base A	J17	2	-0.29		
P02	Base A	J17	3	0.45		
P02	Base A	J17	3	-0.16		
P02	Base A	J17	3	0.04		
P02	Base A	J17	4	-0.18		
P02	Base A	J17	4	-0.31		
P02	Base A	J17	4	-0.11		
P02	Base A	J17	5	0.30		
P02	Base A	J17	5	0.13		
P02	Base A	J17	5	-0.48		
P02	Base A	J17	6	0.16		
P02	Base A	J28	1	0.05		
P02	Base A	J28	1	-0.15		
P02	Base A	J28	1	0.26		
P02	Base A	J28	2	0.10		
P02	Base A	J28	2	0.02		
P02	Base A	J28	2	0.09		
P02	Base A	J28	3	0.03		
P02	Base A	J28	4	0.00		
P02	Base A	J28	5	-0.37		
P02	Base A	J28	5	0.08		
P02	Base A	J28	6	0.32		
P02	Base A	J28	6	-0.23		
P02	Base A	J28	6	-0.32		
P02	Base A	J28	6	0.30		
P02	Base A	J28	7	0.27		
P02	Base A	J28	7	0.24		
P02	Base A	J28	7	-0.01		
P02	Base A	J28	8	0.00		
P02	Base A	J28	8	-0.05		
P02	Base A	J28	8	0.11		
P02	Base A	J28	8	0.31		
P02	Base A	J28	9	0.13		
P02	Base A	J28	9	0.14		
P02	Base A	J28	9	0.08		
P02	Base A	J28	10	-0.07		
P02	Base A	J28	11	-0.18		
P02	Base A	J28	11	-0.22		
P02	Base A	J28	11	-0.16		
P02	Base A	J28	13	0.79		
P02	Base A	J28	14	-0.41		
P02	Interm B	J04	1	0.17	0.12	0.59
P02	Interm B	J04	1	0.16	0.11	0.58

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P02	Interm B	J04	1	0.03	-0.03	0.11
P02	Interm B	J04	1	0.38	-0.34	0.66
P02	Interm B	J04	2	0.25	0.20	0.84
P02	Interm B	J04	3	0.00	-0.44	-0.32
P02	Interm B	J04	3	0.06	-0.48	-0.21
P02	Interm B	J04	4	0.38	-0.32	0.68
P02	Interm B	J04	4	0.12	-0.52	-0.11
P02	Interm B	J04	5	0.25	-0.59	0.04
P02	Interm B	J04	5	-0.05	-0.61	-0.67
P02	Interm B	J04	5	0.27	-0.80	-0.08
P02	Interm B	J04	5	-0.02	-0.75	-0.69
P02	Interm B	J04	6	0.78	-1.02	0.99
P02	Interm B	J04	7	-0.14	-0.35	-0.53
P02	Interm B	J04	7	0.00	-0.87	-0.81
P02	Interm B	J04	7	0.30	-0.83	-0.06
P02	Interm B	J04	7	-0.01	-0.76	-0.71
P02	Interm B	J04	8	0.36	0.05	0.95
P02	Interm B	J04	9	0.38	0.06	1.10
P02	Interm B	J04	10	0.22	-0.15	0.49
P02	Interm B	J04	10	-0.16	0.26	-0.04
P02	Interm B	J04	11	0.38	-0.72	0.17
P02	Interm B	J04	11	-0.15	0.40	0.11
P02	Interm B	J04	11	0.03	-0.32	-0.19
P02	Interm B	J04	12	0.21	0.26	0.82
P02	Interm B	J04	13	-0.09	0.83	0.62
P02	Interm B	J04	14	0.06	0.57	0.77
P02	Interm B	J04	14	-0.32	1.04	0.30
P02	Interm B	J04	14	0.02	1.12	1.14
P02	Interm B	J09	1	0.22	-0.20	0.40
P02	Interm B	J09	2	-0.02	0.72	0.79
P02	Interm B	J09	2	0.08	0.13	0.40
P02	Interm B	J09	3	0.43	-0.84	0.15
P02	Interm B	J09	4	0.54	-0.39	0.92
P02	Interm B	J09	4	-0.12	0.06	-0.14
P02	Interm B	J09	4	0.45	-1.09	0.14
P02	Interm B	J09	5	0.11	-0.35	-0.03
P02	Interm B	J09	5	-0.29	0.12	-0.52
P02	Interm B	J09	6	0.24	-0.17	0.44
P02	Interm B	J09	6	0.06	0.54	0.66
P02	Interm B	J09	7	-0.45	-0.39	-1.35
P02	Interm B	J09	8	0.10	0.14	0.44
P02	Interm B	J09	9	-0.07	-0.81	-0.80
P02	Interm B	J09	9	-0.18	-0.81	-1.00
P02	Interm B	J09	10	0.31	0.17	0.96
P02	Interm B	J09	10	0.10	-0.36	-0.01
P02	Interm B	J09	10	0.31	-0.81	0.10
P02	Interm B	J09	13	-0.15	-0.31	-0.52
P02	Interm B	J09	13	-0.13	0.28	0.08
P02	Interm B	J09	14	-0.34	-0.34	-0.97
P02	Interm B	J09	14	0.02	0.32	0.47

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P02	Interm B	J09	15	0.21	0.40	0.96
P02	Interm B	J09	16	0.04	0.13	0.32
P02	Interm B	J09	16	-0.18	0.32	-0.09
P02	Interm B	J09	16	0.03	-0.74	-0.55
P02	Interm B	J09	16	0.33	-0.08	0.75
P02	Interm B	J09	17	-0.27	0.01	-0.57
P02	Interm B	J09	17	-0.19	-0.60	-0.92
P02	Interm B	J09	18	-0.18	0.03	-0.34
P02	Interm B	J09	19	0.02	0.06	0.18
P02	Interm B	J09	19	-0.12	-0.08	-0.32
P02	Interm B	J09	20	0.18	0.78	1.10
P02	Interm B	J09	20	-0.35	1.06	0.24
P02	Surf B	J15	2	0.32	0.42	1.12
P02	Surf B	J15	3	0.16	0.31	0.67
P02	Surf B	J15	3	-0.03	0.93	0.67
P02	Surf B	J15	3	-0.07	0.73	0.44
P02	Surf B	J15	3	-0.06	0.78	0.53
P02	Surf B	J15	4	-0.08	0.30	0.04
P02	Surf B	J15	4	-0.13	1.03	0.54
P02	Surf B	J15	4	-0.26	1.08	0.30
P02	Surf B	J15	4	-0.19	0.72	0.14
P02	Surf B	J15	5	-0.08	0.70	0.31
P02	Surf B	J15	5	-0.21	0.66	0.07
P02	Surf B	J15	5	-0.12	0.99	0.60
P02	Surf B	J15	5	0.14	0.84	1.04
P02	Surf B	J15	5	0.48	0.67	1.63
P02	Surf B	J15	6	-0.26	-0.46	-1.03
P02	Surf B	J15	6	-0.10	0.86	0.52
P02	Surf B	J15	6	0.07	0.09	0.21
P02	Surf B	J15	7	0.20	-1.07	-0.52
P02	Surf C	J05	1	0.01	0.67	0.66
P02	Surf C	J05	1	-0.02	0.32	0.29
P02	Surf C	J05	2	-0.07	0.63	0.45
P02	Surf C	J05	3	-0.04	0.06	0.01
P02	Surf C	J05	3	0.11	-0.48	-0.09
P02	Surf C	J05	4	-0.12	0.45	0.22
P02	Surf C	J05	5	-0.19	0.87	0.45
P02	Surf C	J05	6	0.28	0.13	0.83
P02	Surf C	J13	1	0.19	0.33	0.66
P02	Surf C	J13	2	-0.02	-0.08	-0.23
P02	Surf C	J13	3	0.21	0.81	1.15
P02	Surf C	J13	3	0.22	0.58	0.97
P02	Surf C	J13	5	0.18	0.88	1.06
P02	Surf C	J13	6	-0.18	0.90	0.28
P02	Surf C	J13	7	0.39	-0.43	0.39
P02	Surf C	J13	8	-0.25	0.98	0.19
P02	Surf C	J13	8	-0.41	0.53	-0.40
P02	Surf C	J13	9	-0.35	0.35	-0.60
P02	Surf C	J13	11	-0.33	-0.11	-0.76
P02	Surf C	J13	12	-0.17	0.67	0.18

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P02	Surf C	J13	13	0.00	0.55	0.38
P02	Surf C	J13	14	-0.36	0.74	-0.18
P02	Surf C	J13	14	-0.58	0.66	-0.69
P02	Surf C	J13	15	0.06	0.60	0.64
P02	Surf C	J13	15	-0.06	1.14	0.97
P02	Surf C	J13	16	0.43	-0.87	0.18
P04	Binder 1	J08	11	0.11		
P04	Binder 1	J08	11	0.01		
P04	Binder 1	J08	12	-0.05		
P04	Binder 1	J08	12	0.42		
P04	Binder 1	J08	13	0.53		
P04	Binder 1	J08	14	-0.04		
P04	Binder 1	J08	14	-0.08		
P04	Binder 1	J08	15	-0.43		
P04	Binder 1	J08	15	0.22		
P04	Binder 1	J08	16	0.22		
P04	Binder 1	J08	16	0.42		
P04	Binder 1	J08	17	-0.50	0.16	-1.11
P04	Binder 1	J08	17	0.39	-0.20	0.65
P04	Binder 1	J08	18	0.38	-0.65	0.28
P04	Binder 1	J08	18	0.36	0.43	1.13
P04	Binder 1	J08	19	0.14	0.31	0.52
P04	Binder 1	J08	19	0.50	0.11	1.20
P04	Binder 1	J08	20	0.74	-0.14	1.52
P04	Binder 1	J08	20	0.19	0.35	0.65
P04	Binder 1	J08	21	0.12	-0.04	0.15
P04	Binder 1	J08	21	0.13	1.00	1.08
P04	Surf 1R	J14	1	-0.28	0.61	0.00
P04	Surf 1R	J14	1	0.02	0.66	0.78
P04	Surf 1R	J14	1	-0.11	0.59	0.35
P04	Surf 1R	J14	2	0.32	-0.69	0.13
P04	Surf 1R	J14	2	0.01	-0.35	-0.38
P04	Surf 1R	J14	2	0.03	0.61	0.89
P04	Surf 1R	J14	2	-0.05	-0.12	-0.36
P04	Surf 1R	J14	3	0.32	0.46	1.10
P04	Surf 1R	J14	3	-0.24	0.68	0.06
P04	Surf 1R	J14	3	0.19	0.68	1.00
P04	Surf 1R	J14	3	0.17	0.73	1.01
P04	Surf 1R	J14	4	-0.14	0.98	0.53
P04	Surf 1R	J14	4	0.31	-0.02	0.64
P04	Surf 1R	J14	4	0.05	0.04	0.06
P04	Surf 1R	J14	5	0.09	-0.69	-0.41
P04	Surf 1R	J14	5	0.31	-0.02	0.64
P04	Surf 1R	J14	5	0.05	0.00	0.02
P05	Interm C	J27	8	0.06	0.06	0.31
P05	Interm C	J27	8	-0.32	0.32	-0.28
P05	Interm C	J27	9	-0.02	0.59	0.63
P05	Interm C	J27	9	-0.05	0.03	0.06
P05	Interm C	J27	10	0.07	0.48	0.72
P05	Interm C	J27	10	-0.15	0.28	0.02
P05	Interm C	J27	11	-0.22	0.52	0.13
P05	Interm C	J27	11	-0.16	0.46	0.17
P05	Interm C	J27	12	-0.16	-0.22	-0.47
P05	Interm C	J27	12	-0.02	-0.75	-0.71
P05	Interm C	J27	13	-0.06	0.06	0.02
P05	Interm C	J27	13	-0.12	0.22	0.02
P05	Interm C	J27	14	-0.14	0.12	-0.11
P05	Interm C	J27	15	-0.10	0.89	0.67
P05	Interm C	J27	15	-0.39	0.43	-0.41
P05	Surf D	J25	1	-0.41	-0.68	-1.40
P05	Surf D	J25	2	-0.02	0.05	0.03
P05	Surf D	J25	3	-0.11	-0.07	-0.27
P05	Surf D	J25	4	-0.11	-0.85	-0.99
P05	Surf D	J25	5	-0.25	0.10	-0.37
P05	Surf D	J25	6	0.21	0.58	1.00
P05	Surf D	J25	8	-0.13	0.46	0.14
P05	Surf D	J25	9	-0.23	0.50	0.09
P05	Surf E	J40	2	-0.20		
P05	Surf E	J40	2	-0.43		
P05	Surf E	J40	2	0.04		
P05	Surf E	J40	3	-0.19		
P05	Surf E	J40	3	-0.10		
P05	Surf E	J40	3	-0.05		
P05	Surf E	J40	4	-0.32		
P05	Surf E	J40	5	-0.07		
P05	Surf E	J40	6	0.11		
P06	Surf 1D	J24	1	-0.09	0.09	-0.02
P06	Surf 1D	J24	1	-0.18	-0.40	-0.66
P06	Surf 1D	J24	1	-0.19	-0.46	-0.80
P06	Surf 1D	J24	2	0.00	-0.84	-0.79
P06	Surf 1D	J24	2	-0.01	-0.09	-0.13
P06	Surf 1D	J24	2	0.39	-0.55	0.36
P06	Surf 1D	J24	3	0.03	-0.18	-0.08
P06	Surf 1D	J24	3	0.21	-0.77	-0.20
P06	Surf 1D	J24	3	0.17	-0.53	-0.14
P06	Surf 1D	J24	4	0.17	0.35	0.97
P06	Surf 1D	J24	4	0.08	-1.03	-0.73
P06	Surf 1D	J24	4	0.11	0.31	-0.08
P06	Surf 1D	J24	5	0.28	-0.81	-0.06
P06	Surf 1D	J24	5	0.14	-0.27	0.09
P06	Surf 1D	J24	5	-0.14	-0.68	-0.88
P07	Surf 3	J30	1	-0.04	0.57	0.46
P07	Surf 3	J30	1	-0.06	0.28	0.23
P07	Surf 3	J30	1	-0.12	0.57	0.40
P07	Surf 3	J30	2	-0.06	0.28	0.23
P07	Surf 3	J30	3	-0.17	0.24	0.02
P07	Surf 3	J30	4	-0.12	0.76	0.59
P07	Surf 3	J30	5	-0.06	-0.37	-0.27
P07	Surf 3	J30	5	0.54	-0.49	0.92
P07	Surf 3	J30	5	-0.30	0.50	-0.05

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P07	Surf 3	J30	5	0.08	-0.12	0.25
P07	Surf 3	J30	6	-0.03	0.07	0.14
P07	Surf 3	J30	6	-0.09	0.39	0.31
P07	Surf 3	J30	7	0.00	-1.06	-0.75
P07	Surf 3	J30	7	-0.02	-0.24	-0.09
P07	Surf 3	J30	8	-0.15	0.23	0.07
P07	Surf 3	J30	9	-0.20	0.32	0.01
P07	Surf 3	J30	9	-0.13	0.24	0.09
P07	Surf 3	J30	9	-0.05	-0.47	-0.34
P07	Surf 3	J30	10	-0.17	-0.91	-1.01
P07	Surf 3	J30	10	-0.11	-0.23	-0.26
P07	Surf 3	J30	10	0.08	-0.16	0.20
P07	Surf 3	J30	11	-0.09	0.05	-0.08
P07	Surf 3	J30	11	-0.09	0.28	0.16
P07	Surf 3	J30	11	0.10	0.60	0.90
P07	Surf 3	J30	12	-0.19	-0.65	-0.83
P07	Surf 3	J30	12	-0.12	0.45	0.29
P07	Surf 3	J30	12	-0.24	0.74	0.26
P07	Surf 3	J30	13	-0.13	-0.34	-0.43
P07	Surf 3	J30	13	-0.01	-0.85	-0.60
P07	Surf 3	J30	14	-0.14	-0.74	-0.76
P07	Surf 3	J30	14	-0.28	0.58	0.07
P07	Surf 3	J30	14	-0.21	-0.13	-0.39
P07	Surf 3	J30	15	-0.22	-0.19	-0.49
P07	Surf 3	J30	15	-0.23	-0.06	-0.34
P07	Surf 3	J30	15	-0.19	-0.21	-0.43
P07	Surf 3	J30	16	-0.08	0.36	0.32
P07	Surf 3	J30	17	-0.11	-0.78	-0.73
P07	Surf 3	J30	17	-0.23	0.47	0.06
P07	Surf 3	J30	18	-0.25	0.79	0.30
P07	Surf 3	J30	19	0.13	0.00	0.42
P09	Surf CM	J35	1	0.12	1.04	1.17
P09	Surf CM	J35	1	-0.13	0.59	0.25
P09	Surf CM	J35	1	-0.33	0.55	-0.18
P09	Surf CM	J35	2	0.08	-0.41	-0.19
P09	Surf CM	J35	2	0.02	-0.04	0.01
P09	Surf CM	J35	2	0.04	-0.13	0.01
P09	Surf CM	J35	3	0.04	0.56	0.57
P09	Surf CM	J35	3	0.10	-0.18	0.06
P09	Surf CM	J35	3	-0.10	0.66	0.37
P09	Surf CM	J83	1	-0.10	-0.17	-0.30
P09	Surf CM	J83	1	-0.40	0.40	-0.45
P09	Surf CM	J83	1	0.18	0.39	0.71
P09	Surf CM	J83	2	-0.04	0.17	0.10
P09	Surf CM	J83	2	0.15	-0.85	-0.40
P09	Surf CM	J83	2	-0.18	-0.84	-1.09
P09	Surf CM	J83	3	0.00	-1.04	-0.90
P09	Surf CM	J83	3	0.06	-0.54	-0.32
P10	Interm C	J31	2	-0.18	-0.80	-1.09
P10	Interm C	J31	2	0.11	-0.68	-0.37

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P10	Interm C	J31	3	0.52	-0.21	1.01
P10	Interm C	J31	3	0.08	0.50	0.77
P10	Interm C	J31	5	0.19	0.34	0.77
P10	Interm C	J31	5	-0.28	0.49	-0.16
P10	Interm C	J31	6	-0.08	0.45	0.32
P10	Interm C	J31	6	-0.50	0.75	-0.38
P10	Interm C	J31	7	-0.03	1.02	1.00
P10	Interm C	J31	8	0.05	0.74	0.90
P10	Interm C	J31	8	-0.31	0.64	-0.05
P10	Interm C	J31	9	0.15	-0.23	0.21
P10	Interm C	J31	9	0.00	0.28	0.34
P10	Interm C	J31	10	0.41	-0.07	0.90
P10	Interm C	J31	11	0.27	-0.54	0.18
P10	Interm C	J31	11	-0.07	0.78	0.64
P10	Interm C	J31	12	-0.40	0.98	0.11
P10	Interm C	J31	12	-0.37	0.94	0.14
P10	Interm C	J31	13	0.01	0.70	0.68
P10	Interm C	J31	13	-0.02	0.95	0.90
P10	Interm C	J31	14	0.13	1.06	1.27
P10	Interm C	J31	14	0.06	0.41	0.56
P10	Interm C	J31	15	0.14	0.38	0.71
P10	Interm C	J31	15	0.22	0.41	0.92
P10	Interm C	J31	16	0.33	0.25	1.00
P10	Interm C	J31	16	-0.24	0.47	-0.07
P10	Interm C	J31	17	0.29	0.47	1.10
P10	Interm C	J31	17	-0.39	1.12	0.19
P10	Interm C	J31	18	-0.14	0.86	0.53
P10	Interm C	J31	18	-0.17	0.92	0.55
P10	Interm C	J31	19	0.03	0.03	0.12
P10	Interm C	J31	19	0.48	-0.07	1.06
P10	Interm C	J31	28	0.29	0.27	1.03
P10	Interm C	J31	28	-0.37	0.17	-0.68
P10	Interm C	J31	29	-0.14	-0.07	-0.37
P10	Interm C	J31	29	-0.11	0.64	0.40
P10	Interm C	J31	30	-0.08	0.90	0.69
P10	Interm C	J31	30	0.02	0.53	0.57
P10	Interm C	J31	31	0.41	-0.02	0.96
P10	Interm C	J31	31	-0.29	-0.20	-0.82
P10	Interm C	J31	32	0.34	-0.14	0.65
P10	Interm C	J31	33	0.43	-0.24	0.70
P10	Interm C	J31	33	-0.31	0.39	-0.38
P10	Interm C	J31	34	-0.15	-0.36	-0.70
P10	Interm C	J31	34	0.15	-1.07	-0.74
P10	Interm C	J31	35	0.09	-0.62	-0.37
P10	Interm C	J31	35	-0.42	-0.15	-1.09
P10	Interm C	J31	36	-0.05	0.45	0.34
P10	Interm C	J31	36	0.16	-0.38	0.02
P10	Interm C	J31	37	0.07	-0.64	-0.42
P10	Interm C	J31	38	-0.43	0.15	-0.80
P10	Interm C	J31	38	-0.02	-1.04	-1.02

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P10	Interm C	J31	39	0.17	-0.65	-0.17
P10	Interm C	J31	39	-0.19	-0.63	-1.05
P10	Interm C	J31	40	0.00	0.49	0.50
P10	Interm C	J31	40	0.16	-0.06	0.29
P10	Interm C	J31	41	-0.52	1.09	-0.03
P10	Interm C	J31	41	0.06	0.05	0.23
P10	Interm C	J31	42	0.03	1.03	1.13
P10	Interm C	J31	42	0.09	-0.05	0.18
P10	Interm C	J31	43	0.10	0.67	0.97
P10	Interm C	J31	43	-0.12	-0.35	-0.57
P10	Interm C	J31	44	0.27	0.38	0.98
P10	Interm C	J31	44	0.02	-0.22	-0.17
P10	Interm C	J31	45	0.23	0.50	0.97
P10	Interm C	J31	45	0.13	0.32	0.58
P10	Interm C	J31	46	0.10	-0.36	-0.10
P10	Interm C	J31	46	0.35	-0.67	0.16
P10	Interm C	J31	47	0.01	-0.26	-0.18
P10	Interm C	J31	47	-0.51	0.28	-0.88
P10	Interm C	J31	48	0.14	-0.81	-0.40
P10	Interm C	J31	48	0.40	-0.10	0.94
P10	Interm C	J31	49	0.36	-0.93	0.03
P10	Interm C	J31	49	-0.40	0.42	-0.47
P10	Interm C	J31	50	0.36	-0.24	0.61
P10	Interm C	J31	50	-0.17	-0.12	-0.46
P10	Interm C	J31	51	0.04	0.32	0.37
P10	Interm C	J37	1	0.14	0.85	0.87
P10	Interm C	J37	2	-0.01	0.14	-0.12
P10	Interm C	J37	2	-0.02	-0.11	-0.39
P10	Interm C	J37	3	0.22	-0.54	-0.24
P10	Interm C	J37	3	0.03	0.00	-0.11
P10	Interm C	J37	4	-0.30	0.62	-0.31
P10	Interm C	J37	4	0.01	0.62	0.35
P10	Interm C	J37	5	0.15	0.80	0.87
P10	Interm C	J37	5	-0.29	0.41	-0.49
P10	Interm C	J37	6	0.26	0.32	0.65
P10	Interm C	J37	7	0.05	0.83	0.64
P10	Interm C	J37	7	0.31	0.42	0.87
P10	Interm C	J37	8	0.38	0.18	2.80
P10	Interm C	J37	8	-0.01	0.55	0.26
P10	Interm C	J37	9	0.17	0.85	0.90
P10	Interm C	J37	9	0.00	0.73	0.41
P10	Interm C	J37	10	-0.21	0.92	0.11
P10	Interm C	J37	10	-0.25	0.79	-0.11
P10	Interm C	J37	11	0.15	0.87	0.87
P10	Interm C	J37	11	0.22	0.68	0.88
P10	Interm C	J37	12	-0.17	0.85	0.13
P10	Interm C	J37	12	-0.28	0.94	0.00
P10	Interm C	J82	1	-0.25	0.14	-0.36
P10	Interm C	J82	1	-0.29	0.38	-0.34
P10	Interm C	J82	2	-0.07	1.05	0.83

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P10	Interm C	J82	2	-0.22	0.44	-0.08
P10	Interm C	J82	3	0.00	0.95	0.86
P10	Interm C	J82	3	0.25	0.79	1.30
P10	Interm C	J82	4	0.11	1.05	1.24
P10	Interm C	J82	4	-0.06	1.17	1.01
P10	Interm C	J82	5	-0.21	0.92	0.26
P10	Interm C	J82	5	0.00	0.59	0.50
P10	Interm C	J82	6	0.09	0.82	1.01
P10	Interm C	J82	7	0.23	0.73	1.14
P10	Interm C	J82	7	0.29	0.82	1.39
P10	Interm C	J82	14	-0.24	0.86	0.25
P10	Interm C	J82	14	-0.10	1.06	0.75
P10	Surf 4	J12	1	0.54	-0.37	0.71
P10	Surf 4	J12	2	0.03	0.55	0.69
P10	Surf 4	J12	3	0.33	0.29	0.94
P10	Surf 4	J12	4	0.30	0.53	1.05
P10	Surf 4	J12	4	0.15	0.88	1.09
P10	Surf 4	J12	5	-0.32	0.96	0.16
P10	Surf 4	J12	6	-0.29	1.04	0.32
P10	Surf 4	J12	7	-0.23	0.01	-0.47
P10	Surf 4	J12	9	-0.32	-0.14	-0.75
P10	Surf 4	J12	10	-0.21	2.41	1.63
P10	Surf 4	J12	10	0.35	0.21	1.03
P10	Surf 4	J12	11	0.05	0.22	0.22
P10	Surf 4	J12	11	-0.01	0.01	-0.09
P10	Surf 4	J12	12	-0.25	0.41	-0.27
P10	Surf 4	J12	12	-0.17	0.46	-0.07
P10	Surf 4	J12	13	-0.22	0.41	-0.20
P10	Surf 4	J12	13	-0.28	0.06	-0.64
P10	Surf 4	J12	16	-0.33	0.30	-0.55
P10	Surf 4	J12	16	0.17	-0.35	-0.07
P11	Surf C	J41	1	-0.25	0.99	0.29
P11	Surf C	J41	1	-0.13	0.23	-0.04
P11	Surf C	J41	1	0.06	0.50	0.62
P11	Surf C	J41	2	0.03	0.19	0.29
P11	Surf C	J41	3	0.20	-0.55	-0.04
P11	Surf C	J41	3	0.26	-0.09	0.54
P11	Surf C	J41	4	0.26	-0.09	0.54
P11	Surf C	J41	4	0.03	0.01	0.16
P11	Surf C	J41	4	0.21	-0.12	0.49
P11	Surf C	J41	4	0.04	-0.01	0.18
P12	Surf C	J38	1	-0.29	-0.22	-0.87
P12	Surf C	J38	1	-0.01	-0.45	-0.50
P12	Surf C	J38	1	-0.11	-0.84	-1.00
P12	Surf C	J38	1	0.18	-0.90	-0.41
P12	Surf C	J38	2	0.32	-2.28	-1.38
P12	Surf C	J38	2	0.22	-1.44	-0.79
P12	Surf C	J38	3	0.20	-1.42	-0.81
P12	Surf C	J38	4	-0.13	-0.56	-0.77
P12	Surf C	J38	5	-0.05	-0.48	-0.53

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P12	Surf C	J38	5	0.01	-0.04	0.05
P12	Surf C	J38	5	0.17	-0.13	0.30
P12	Surf C	J38	8	0.28	0.58	1.13
P12	Surf C	J38	8	0.04	-1.03	-0.82
P12	Surf C	J38	8	-0.08	0.21	0.05
P13	Surf C	J03	2	-0.17	-0.54	-0.74
P13	Surf C	J03	2	0.10	-1.09	-0.56
P13	Surf C	J03	2	0.16	-1.01	-0.36
P13	Surf C	J03	3	0.01	0.21	0.34
P13	Surf C	J03	3	-0.58	0.95	-0.31
P13	Surf C	J03	3	0.18	-0.84	-0.18
P13	Surf C	J03	4	-0.43	0.72	-0.16
P13	Surf C	J03	6	-0.06	-0.18	-0.17
P13	Surf C	J03	6	0.02	-0.56	-0.29
P13	Surf C	J03	6	0.60	-1.04	0.42
P13	Surf C	J03	7	-0.06	-0.18	-0.17
P13	Surf C	J03	8	0.02	-0.56	-0.29
P13	Surf C	J03	10	0.26	-0.62	0.14
P13	Surf C	J03	10	-0.03	0.13	0.12
P13	Surf C	J03	10	-0.18	0.09	-0.22
P13	Surf C	J03	11	0.00	1.13	1.01
P13	Surf C	J43	12	0.17	-0.81	-0.26
P13	Surf C	J43	12	0.31	-0.36	0.48
P13	Surf C	J43	13	0.06	-1.12	-0.79
P13	Surf C	J43	13	-0.02	0.38	0.35
P13	Surf C	J43	14	-0.05	-0.66	-0.59
P13	Surf C	J43	14	0.07	-0.63	-0.32
P13	Surf C	J43	15	0.00	0.16	0.24
P13	Surf C	J43	15	-0.24	1.07	0.51
P13	Surf C	J43	16	0.00	0.92	0.90
P13	Surf C	J43	16	0.06	-0.80	-0.46
P13	Surf C	J43	16	0.30	-0.69	0.17
P13	Surf C	J43	17	0.03	-0.47	-0.27
P13	Surf C	J43	17	-0.20	0.78	0.31
P13	Surf C	J43	17	0.10	-0.74	-0.30
P13	Surf C	J43	17	-0.10	0.75	0.59
P13	Surf C	J43	18	-0.21	-0.08	-0.38
P13	Surf C	J43	18	-0.09	1.12	0.84
P13	Surf C	J43	18	-0.10	0.75	0.59
P13	Surf C	J43	20	-0.11	1.71	1.33
P14	Surf C	J16	2	-0.45	0.50	-0.42
P14	Surf C	J16	3	-0.16	-0.03	-0.27
P14	Surf C	J16	3	-0.27	-0.24	-0.68
P14	Surf C	J16	4	-0.55	-0.74	-1.78
P14	Surf C	J16	4	-0.20	-0.95	-1.22
P14	Surf C	J16	4	-0.04	-0.78	-0.68
P14	Surf C	J16	5	0.12	0.29	0.60
P14	Surf C	J16	5	-0.11	0.15	-0.05
P14	Surf C	J16	6	-0.06	-0.30	-0.32
P14	Surf C	J16	7	-0.05	-0.89	-0.82

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P14	Surf C	J16	7	0.13	-0.59	-0.14
P14	Surf C	J16	7	-0.03	-1.22	-1.04
P14	Surf C	J16	7	-0.22	0.64	0.17
P14	Surf C	J16	8	0.05	-0.95	-0.66
P14	Surf C	J16	8	-0.05	-0.87	-0.80
P14	Surf C	J16	8	-0.07	-0.62	-0.64
P14	Surf C	J16	10	-0.16	-2.21	-2.25
P14	Surf C	J16	10	-0.30	-0.25	-0.79
P14	Surf C	J16	10	-0.58	0.67	-0.63
P14	Surf C	J16	10	-0.28	0.07	-0.45
P14	Surf C	J16	11	-0.76	1.67	-0.08
P14	Surf C	J16	11	0.09	-1.34	-0.97
P14	Surf C	J16	11	-0.16	-1.14	-1.28
P14	Surf C	J16	11	-0.08	-1.07	-1.05
P14	Surf C	J16	12	-0.13	-0.46	-0.59
P14	Surf C	J16	12	-0.42	0.15	-0.75
P14	Surf C	J16	13	-0.29	-0.80	-1.25
P14	Surf C	J16	14	-0.07	-0.84	-0.79
P14	Surf C	J16	14	0.11	-0.91	-0.56
P14	Surf C	J16	15	-0.26	-0.26	-0.80
P14	Surf C	J16	15	-0.12	-0.47	-0.67
P14	Surf C	J16	15	-0.29	-0.50	-0.95
P16	Surf C	J20	1	-0.36	-0.06	-0.81
P16	Surf C	J20	1	-0.35	0.12	-0.64
P16	Surf C	J20	1	-0.18	1.08	0.60
P16	Surf C	J20	2	-0.47	0.97	-0.13
P16	Surf C	J20	2	-0.39	1.18	0.24
P16	Surf C	J20	2	0.11	-0.77	-0.47
P16	Surf C	J20	3	-0.16	0.11	-0.24
P16	Surf C	J20	3	0.06	-0.38	-0.19
P16	Surf C	J20	3	0.11	-0.77	-0.47
P17	Interm C	J22	5	0.18	-0.88	-0.47
P17	Interm C	J22	5	0.23	-0.86	-0.39
P17	Interm C	J22	6	-0.01	-0.98	-1.07
P17	Interm C	J22	6	-0.10	-0.55	-0.79
P17	Interm C	J22	7	0.11	-0.90	-0.65
P17	Interm C	J22	7	0.07	0.14	0.22
P17	Interm C	J22	8	-0.25	0.01	-0.70
P17	Interm C	J22	9	-0.13	-0.84	-1.15
P17	Interm C	J22	9	0.03	0.16	0.16
P17	Interm C	J22	10	-0.53	0.67	-0.64
P17	Interm C	J22	10	0.44	-0.63	0.33
P18	Surf C	J48	1	0.52	-1.50	-0.11
P18	Surf C	J48	2	0.11	-1.11	-0.62
P18	Surf C	J48	2	0.06	-0.48	-0.21
P18	Surf C	J48	2	0.20	-1.15	-0.51
P18	Surf C	J48	3	-0.05	-1.07	-0.93
P18	Surf C	J48	4	0.25	-0.60	0.10
P18	Surf C	J48	4	0.16	-0.25	0.19
P18	Surf C	J48	5	-0.31	-0.21	-0.79

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P18	Surf C	J48	5	0.13	-0.13	0.30
P18	Surf C	J48	5	0.29	-0.03	0.69
P18	Surf C	J48	6	0.08	-0.45	-0.13
P18	Surf C	J48	7	-0.10	1.68	1.33
P19	Surf D	J49	3	-0.12	0.37	0.04
P19	Surf D	J49	3	-0.01	-0.03	-0.07
P19	Surf D	J49	4	-0.13	0.04	-0.21
P19	Surf D	J49	5	-0.06	-0.96	-0.93
P19	Surf D	J49	5	-0.13	-0.53	-0.77
P19	Surf D	J49	5	0.26	-1.06	-0.35
P19	Surf D	J49	6	0.03	-0.49	-0.36
P19	Surf D	J49	6	0.07	-1.06	-0.78
P19	Surf D	J49	6	0.03	-0.40	-0.21
P19	Surf D	J49	6	0.21	-0.88	-0.31
P19	Surf D	J49	7	0.01	-0.57	-0.44
P19	Surf D	J49	7	-0.44	0.32	-0.64
P19	Surf D	J49	7	-0.88	-0.46	-2.29
P19	Surf D	J49	7	0.09	-1.27	-0.85
P19	Surf D	J49	8	0.15	0.34	0.67
P19	Surf D	J49	8	0.02	-1.49	-1.27
P19	Surf D	J49	8	-0.06	-1.07	-0.89
P19	Surf D	J49	9	0.01	-1.01	-0.84
P19	Surf D	J49	9	-0.40	0.10	-0.76
P19	Surf D	J49	9	-0.20	-0.17	-0.54
P20	Surf C	J50	1	0.38	-1.54	-0.51
P20	Surf C	J50	2	0.02	-0.90	-0.71
P20	Surf C	J50	2	0.04	-0.79	-0.56
P20	Surf C	J50	2	-0.05	-0.70	-0.67
P20	Surf C	J50	2	-0.19	-0.40	-0.71
P20	Surf C	J50	2	-0.41	-0.15	-0.97
P20	Surf C	J50	3	0.04	-0.79	-0.56
P20	Surf C	J50	3	-0.49	0.10	-0.91
P20	Surf C	J50	4	-0.07	0.46	0.22
P20	Surf C	J50	4	-0.16	0.48	0.03
P20	Surf C	J50	4	-0.04	0.08	-0.07
P20	Surf C	J50	4	-0.10	0.23	-0.08
P20	Surf C	J50	5	0.03	0.21	0.19
P20	Surf C	J50	6	0.09	0.16	0.31
P20	Surf C	J50	6	0.18	0.24	0.51
P20	Surf C	J50	7	0.30	-0.36	0.27
P20	Surf C	J50	7	0.25	-0.05	0.43
P20	Surf C	J50	7	0.00	0.20	0.14
P20	Surf C	J50	7	0.14	-0.36	-0.07
P20	Surf C	J50	7	0.02	-0.45	-0.41
P20	Surf C	J50	8	0.10	-0.66	-0.37
P20	Surf C	J50	8	0.22	-0.34	0.14
P20	Surf C	J50	8	-0.12	-0.10	-0.36
P20	Surf C	J50	9	0.34	-0.77	0.02
P20	Surf C	J50	10	-0.12	-0.10	-0.36
P20	Surf C	J50	11	0.15	-0.48	-0.10
P20	Surf C	J50	11	-0.10	-0.75	-0.89
P20	Surf C	J50	11	0.29	-1.02	-0.31
P20	Surf C	J50	11	0.10	0.35	0.47
P20	Surf C	J50	11	-0.08	0.12	-0.11
P20	Surf C	J50	12	-0.10	-0.75	-0.89
P20	Surf C	J50	13	0.29	-1.02	-0.31
P20	Surf C	J50	13	0.10	0.35	0.47
P20	Surf C	J50	14	0.07	-0.58	-0.38
P20	Surf C	J50	14	-0.03	-0.62	-0.63
P20	Surf C	J50	14	0.11	-0.78	-0.47
P20	Surf C	J50	14	-0.01	0.26	0.17
P20	Surf C	J50	15	0.12	-0.61	-0.32
P20	Surf C	J50	15	-0.24	1.36	0.64
P20	Surf C	J50	15	-0.21	-0.17	-0.65
P20	Surf C	J50	15	-0.26	0.25	-0.39
P20	Surf C	J50	15	-0.12	0.22	-0.11
P20	Surf C	J50	16	0.15	-0.76	-0.37
P20	Surf C	J50	16	0.36	-1.01	-0.19
P20	Surf C	J50	17	-0.07	0.11	-0.07
P20	Surf C	J50	17	0.01	0.02	0.01
P21	Interm C	J34	3	0.33	-0.28	0.46
P21	Interm C	J34	3	0.37	-0.74	0.16
P21	Interm C	J34	3	0.14	0.27	0.53
P21	Interm C	J34	3	0.12	-0.09	0.18
P21	Interm C	J34	5	-0.06	0.23	0.09
P21	Interm C	J34	5	-0.10	0.31	0.12
P21	Interm C	J34	5	0.10	-0.09	0.18
P21	Interm C	J34	6	-0.08	0.31	0.12
P21	Surf C	J39	1	0.09	-0.84	-0.51
P21	Surf C	J39	2	0.06	-0.80	-0.55
P21	Surf C	J39	2	0.11	-0.99	-0.61
P21	Surf C	J39	2	0.06	-0.82	-0.56
P21	Surf C	J39	2	0.06	-0.80	-0.55
P21	Surf C	J39	3	0.11	-0.99	-0.61
P21	Surf C	J39	3	0.06	-0.82	-0.56
P21	Surf C	J39	4	-0.13	-0.89	-1.02
P21	Surf C	J39	4	0.06	-0.99	-0.70
P21	Surf C	J39	4	0.08	-0.74	-0.46
P21	Surf C	J39	4	-0.13	-0.89	-1.02
P21	Surf C	J39	5	0.13	-0.98	-0.57
P21	Surf C	J39	5	-0.28	-0.61	-1.11
P21	Surf C	J39	5	-0.13	-0.89	-1.02
P21	Surf C	J39	6	-0.14	-0.46	-0.68
P22	Surf D	J54	1	0.00	-1.18	-1.07
P22	Surf D	J54	1	0.02	-1.15	-1.02
P22	Surf D	J54	1	0.21	0.34	0.70
P22	Surf D	J54	1	0.09	-0.42	-0.21
P22	Surf D	J54	1	0.17	-0.44	0.55
P22	Surf D	J54	1	-0.07	1.96	1.52
P22	Surf D	J54	2	0.00	0.95	0.81

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P22	Surf D	J54	2	0.01	0.13	0.09
P22	Surf D	J54	2	0.01	0.42	0.38
P22	Surf D	J54	2	-0.01	0.25	0.19
P22	Surf D	J54	2	0.01	-0.06	-0.07
P22	Surf D	J54	3	0.12	0.54	0.73
P24	Base C	J57	1	0.03		
P24	Base C	J57	1	0.10		
P24	Base C	J57	2	0.09		
P24	Base C	J57	2	0.18		
P24	Base C	J57	3	0.08		
P24	Base C	J57	3	-0.03		
P24	Base C	J57	4	0.08		
P24	Base C	J57	4	0.06		
P24	Base C	J57	5	0.26		
P24	Base C	J57	5	0.20		
P24	Base C	J57	6	0.30		
P24	Base C	J57	6	0.30		
P24	Interm C	J51	1	-0.04		
P24	Interm C	J51	3	0.18		
P24	Interm C	J51	3	0.02		
P24	Interm C	J51	4	0.29		
P24	Interm C	J51	5	0.39		
P24	Interm C	J51	6	-0.26		
P24	Interm C	J51	6	0.05		
P24	Interm C	J51	7	0.06		
P24	Interm C	J51	8	-0.03		
P24	Interm C	J51	8	-0.04		
P24	Interm C	J51	9	-0.06		
P24	Interm C	J51	9	0.37		
P24	Interm C	J51	10	-0.06		
P24	Interm C	J51	10	-0.13		
P24	Interm C	J51	11	0.02		
P24	Interm C	J51	12	-0.11		
P24	Interm C	J51	12	0.04		
P24	Interm C	J51	13	-0.17		
P24	Interm C	J51	13	0.11		
P24	Interm C	J51	14	0.01		
P24	Interm C	J51	15	0.13		
P24	Interm C	J51	15	-0.09		
P24	Interm C	J51	16	-0.02		
P24	Surf C	J56	1	-0.36	1.10	0.24
P24	Surf C	J56	2	-0.04	0.85	0.72
P24	Surf C	J56	2	-0.10	0.30	0.09
P24	Surf C	J56	2	-0.04	-0.73	-0.66
P24	Surf C	J56	2	-0.14	-0.49	-0.66
P24	Surf C	J56	2	0.11	-1.10	-0.65
P24	Surf C	J56	3	-0.01	-0.25	-0.13
P24	Surf C	J56	4	0.20	-0.94	-0.34
P24	Surf C	J56	4	0.09	-0.70	-0.36
P24	Surf C	J56	4	-0.11	-0.34	-0.42
P24	Surf C	J56	5	-1.02	1.43	-0.80
P24	Surf C	J56	6	-0.18	0.14	-0.20
P24	Surf C	J56	6	0.00	-0.27	-0.18
P24	Surf C	J56	6	-0.06	-0.24	-0.28
P24	Surf C	J56	7	0.18	-0.83	-0.18
P24	Surf C	J56	8	0.23	-1.04	-0.37
P24	Surf C	J56	9	0.17	-1.32	-0.70
P24	Surf C	J56	9	0.17	-0.50	0.00
P24	Surf C	J56	9	-0.21	0.26	-0.22
P24	Surf C	J56	10	0.14	-0.98	-0.46
P24	Surf C	J56	11	0.07	0.07	0.26
P24	Surf C	J56	11	0.03	-0.46	-0.29
P24	Surf C	J56	11	-0.16	0.38	0.01
P24	Surf C	J56	11	0.73	-2.50	-0.54
P24	Surf C	J56	12	0.04	0.32	0.42
P24	Surf C	J56	12	0.05	0.46	0.62
P24	Surf C	J56	13	0.08	1.30	1.42
P24	Surf C	J56	14	-0.03	-0.54	-0.48
P24	Surf C	J56	14	-0.31	1.06	0.28
P24	Surf C	J56	14	-0.06	-0.72	-0.80
P24	Surf C	J56	15	0.01	-0.48	-0.33
P24	Surf C	J56	16	-0.13	-0.08	-0.33
P24	Surf C	J56	16	0.22	-1.00	-0.28
P24	Surf C	J56	17	0.12	-0.78	-0.38
P24	Surf C	J56	17	0.19	-1.11	-0.49
P24	Surf C	J56	17	0.04	-1.13	-0.86
P24	Surf C	J56	17	-0.07	-0.90	-0.92
P24	Surf C	J56	18	-0.12	0.70	0.42
P24	Surf C	J56	18	0.30	0.02	-1.27
P24	Surf C	J56	18	0.02	0.52	0.51
P24	Surf C	J67	1	1.67	0.03	-0.04
P24	Surf C	J67	2	-0.51	1.17	0.03
P24	Surf C	J67	3	0.05	-1.13	-0.81
P24	Surf C	J67	4	-0.14	-0.66	-0.85
P24	Surf C	J67	4	0.02	-0.66	-0.47
P24	Surf C	J67	5	-0.32	-0.07	-0.72
P24	Surf C	J67	5	-0.14	-0.36	-0.54
P24	Surf C	J67	5	-0.14	0.53	0.24
P24	Surf C	J67	7	0.03	0.18	0.29
P24	Surf C	J67	7	0.07	-0.95	-0.67
P24	Surf D	J64	1	0.16	0.00	0.00
P24	Surf D	J64	2	0.26	-0.48	0.28
P24	Surf D	J64	2	0.17	-0.78	-0.26
P24	Surf D	J64	3	0.13	-0.82	-0.39
P24	Surf D	J64	3	0.21	-1.05	-0.36
P24	Surf D	J64	4	0.13	-0.59	-0.12
P24	Surf D	J64	4	0.18	-0.24	0.23
P24	Surf D	J64	5	0.08	-0.82	-0.53
P24	Surf D	J64	5	0.04	-0.73	-0.52
P24	Surf D	J64	6	0.10	-0.62	-0.28

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P24	Surf D	J64	6	0.14	-0.52	-0.09
P24	Surf D	J64	7	0.14	-0.73	-0.27
P24	Surf D	J64	7	0.12	-0.97	-0.45
P25	Interm C	J29	1	-0.19	0.15	-0.10
P25	Interm C	J29	1	0.21	0.44	0.99
P25	Interm C	J29	2	-0.52	1.68	0.56
P25	Interm C	J29	2	-0.13	0.94	0.73
P25	Interm C	J29	3	-0.15	0.58	0.40
P25	Interm C	J29	3	0.10	0.67	1.08
P25	Interm C	J29	4	-0.34	0.58	-0.04
P25	Interm C	J29	4	-0.38	0.80	0.06
P25	Interm C	J29	5	-0.12	-0.38	-0.44
P25	Interm C	J29	6	-0.11	0.56	0.58
P25	Interm C	J29	6	0.01	0.56	0.81
P25	Interm C	J29	8	-0.26	1.05	0.62
P25	Surf D	J36	1	0.12	0.48	0.87
P25	Surf D	J36	2	-0.12	-1.13	-0.97
P25	Surf D	J36	2	-0.01	0.15	0.33
P25	Surf D	J36	3	-0.04	0.18	0.40
P25	Surf D	J36	3	0.42	0.64	1.65
P25	Surf D	J36	3	-0.08	0.50	0.52
P25	Surf D	J36	4	-0.10	1.13	1.08
P25	Surf D	J36	4	0.42	0.64	1.65
P25	Surf D	J36	5	0.00	0.31	0.51
P25	Surf D	J36	6	-0.04	0.85	0.96
P26	Base A	J45	1	-0.03		
P26	Base A	J45	1	-0.46		
P26	Base A	J45	1	0.86		
P26	Base A	J45	1	0.08		
P26	Base A	J45	2	0.43		
P26	Base A	J45	2	0.04		
P26	Base A	J45	2	-0.10		
P26	Base A	J45	3	-0.12		
P26	Base A	J45	3	-0.14		
P26	Base A	J45	5	-0.38		
P26	Base A	J45	5	0.34		
P26	Base A	J45	5	0.23		
P26	OGFC	J68	1	-1.03		
P26	OGFC	J68	1	-0.12		
P26	OGFC	J68	1	0.30		
P26	OGFC	J68	2	-0.23		
P26	OGFC	J68	2	-0.19		
P26	OGFC	J68	2	-0.24		
P26	OGFC	J68	2	-0.16		
P26	OGFC	J68	3	-0.19		
P26	OGFC	J68	3	-0.04		
P26	OGFC	J68	3	0.06		
P26	OGFC	J68	4	0.03		
P26	OGFC	J68	4	0.89		
P26	OGFC	J68	4	-0.34		

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P26	Surf A	J62	1	0.06	-0.51	-0.36
P26	Surf A	J62	1	0.18	0.14	0.53
P26	Surf A	J62	1	0.24	-1.10	-0.44
P26	Surf A	J62	1	0.16	-0.47	-0.11
P26	Surf A	J62	2	0.15	0.95	1.19
P26	Surf A	J62	2	-0.18	0.87	0.37
P26	Surf A	J62	2	0.04	0.21	0.24
P26	Surf A	J62	2	0.04	0.64	0.64
P26	Surf A	J62	3	-0.23	0.66	0.05
P26	Surf A	J62	3	0.03	0.53	0.51
P26	Surf A	J62	3	-0.12	0.47	0.15
P26	Surf A	J62	4	-0.21	0.23	-0.28
P26	Surf A	J62	4	-0.03	0.80	0.63
P26	Surf A	J62	4	-0.27	1.68	0.92
P26	Surf A	J62	5	0.18	0.41	0.72
P26	Surf A	J62	5	-0.12	0.78	0.40
P26	Surf A	J62	5	-0.10	1.06	0.70
P26	Surf A	J62	6	-0.06	0.21	1.01
P26	Surf A	J62	6	-0.09	0.53	0.23
P26	Surf A	J62	6	0.10	0.70	0.84
P26	Surf A	J62	7	0.08	-0.03	0.11
P26	Surf A	J62	7	-0.06	-0.52	-0.69
P26	Surf A	J62	7	0.00	0.53	0.43
P26	Surf A	J62	7	0.15	-0.15	0.42
P26	Surf A	J62	8	0.16	0.02	0.37
P26	Surf A	J62	8	-0.17	1.16	0.62
P26	Surf A	J62	8	0.47	-0.51	0.55
P26	Surf A	J62	9	0.12	0.16	0.39
P26	Surf A	J62	9	-0.32	0.92	0.11
P26	Surf A	J62	9	0.29	-0.13	0.49
P26	Surf A	J62	9	-0.04	0.13	-0.02
P26	Surf A	J69	1	0.21	-0.35	0.13
P26	Surf A	J69	1	0.36	0.32	1.02
P26	Surf A	J69	1	0.27	-0.06	0.53
P26	Surf A	J69	1	0.23	-0.58	0.07
P26	Surf A	J69	2	0.15	-0.61	-0.16
P26	Surf A	J69	2	-0.24	0.44	-0.06
P26	Surf A	J69	2	-0.03	-0.19	-0.19
P26	Surf A	J69	3	0.04	-0.29	-0.13
P26	Surf A	J69	3	-0.22	0.34	-0.15
P26	Surf A	J69	3	-0.26	-0.25	-0.80
P26	Surf A	J69	4	-0.01	-0.53	-0.47
P26	Surf A	J69	4	0.10	-0.01	0.26
P26	Surf A	J69	4	0.01	0.21	0.26
P26	Surf A	J69	5	0.13	-0.26	0.09
P26	Surf A	J69	5	0.22	-0.34	0.21
P26	Surf A	J69	5	-0.04	0.09	0.02
P26	Surf A	J69	6	0.18	-0.16	0.27
P26	Surf A	J69	6	-0.04	0.11	0.04
P26	Surf A	J69	6	0.10	-0.94	-0.61

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P26	Surf A	J69	7	0.27	-1.00	-0.28
P26	Surf A	J69	7	-0.10	0.19	-0.02
P26	Surf A	J69	7	0.11	-0.62	-0.29
P26	Surf A	J69	8	-0.23	0.67	0.11
P26	Surf A	J69	8	-0.07	0.34	0.14
P26	Surf A	J69	8	0.03	0.13	0.24
P26	Surf A	J69	9	-0.15	0.42	0.08
P26	Surf A	J69	9	-0.05	0.24	0.11
P26	Surf A	J69	9	-0.09	-0.52	-0.68
P26	Surf A	J69	10	-0.14	0.80	0.45
P26	Surf A	J69	10	0.27	-0.04	0.58
P26	Surf A	J69	10	0.13	0.18	0.48
P26	Surf A	J69	10	0.11	-0.12	0.18
P26	Surf A	J69	11	-0.10	1.03	0.72
P26	Surf A	J69	11	0.30	0.67	1.31
P26	Surf A	J69	11	-0.03	1.55	1.34
P26	Surf A	J69	12	-0.14	0.63	0.28
P26	Surf A	J69	12	0.02	0.61	0.62
P26	Surf A	J69	12	-0.13	0.75	0.40
P26	Surf A	J69	12	0.00	1.12	1.10
P26	Surf A	J69	13	-0.40	0.80	-0.15
P26	Surf A	J69	13	-0.21	0.38	-0.10
P26	Surf A	J69	13	0.02	-0.12	-0.06
P26	Surf A	J69	14	-0.27	0.73	0.07
P26	Surf A	J69	14	-0.35	0.43	-0.39
P26	Surf A	J69	14	-0.09	0.29	0.04
P26	Surf A	J69	15	0.09	-0.33	-0.11
P26	Surf A	J69	15	0.16	-0.41	-0.03
P26	Surf A	J69	15	0.33	-0.56	0.20
P26	Surf A	J69	16	0.13	0.14	0.42
P26	Surf A	J69	16	-0.12	0.91	0.57
P26	Surf A	J69	16	0.16	-0.41	-0.03
P26	Surf A	J69	17	-0.53	1.91	0.60
P26	Surf A	J69	18	0.06	1.01	1.08
P26	Surf C	J58	1	-0.19	-0.05	-0.42
P26	Surf C	J58	2	0.13	-0.63	-0.24
P26	Surf C	J58	3	-0.01	0.37	0.37
P26	Surf C	J58	4	-0.25	0.94	0.38
P26	Surf C	J58	5	-0.12	-0.30	-0.47
P26	Surf C	J58	6	0.23	-0.30	0.32
P26	Surf C	J58	7	0.05	0.27	0.40
P26	Surf C	J58	8	-0.03	0.12	0.05
P26	Surf C	J58	9	0.17	-0.35	0.12
P26	Surf C	J58	10	-0.06	0.21	0.08
P26	Surf C	J58	11	0.04	1.58	1.49
P26	Surf C	J58	11	-0.24	1.35	0.72
P26	Surf C	J58	12	0.24	0.44	0.95
P26	Surf E	J52	1	-0.15		
P26	Surf E	J52	2	-0.10		
P26	Surf E	J52	2	-0.12		

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P26	Surf E	J52	2	0.06		
P26	Surf E	J52	3	-0.30		
P26	Surf E	J52	3	-0.17		
P26	Surf E	J52	4	-0.12		
P26	Surf E	J52	4	0.17		
P26	Surf E	J52	5	-0.09		
P26	Surf E	J52	5	-0.10		
P26	Surf E	J52	6	-0.12		
P26	Surf E	J52	6	0.13		
P26	Surf E	J52	7	0.03		
P26	Surf E	J52	8	-0.12		
P26	Surf E	J52	8	-0.02		
P26	Surf E	J52	9	0.00		
P26	Surf E	J52	9	0.12		
P26	Surf E	J52	10	0.02		
P26	Surf E	J52	10	-0.12		
P26	Surf E	J52	11	-0.04		
P26	Surf E	J52	11	-0.09		
P26	Surf E	J52	12	-0.10		
P26	Surf E	J52	12	-0.06		
P26	Surf E	J52	13	0.27		
P26	Surf E	J52	14	-0.08		
P26	Surf E	J52	14	0.05		
P26	Surf E	J52	15	-0.15		
P26	Surf E	J52	15	0.18		
P26	Surf E	J52	15	0.22		
P26	Surf E	J52	16	-0.18		
P26	Surf E	J52	16	-0.25		
P26	Surf E	J52	17	-0.26		
P26	Surf E	J52	18	-0.20		
P26	Surf E	J52	18	-0.35		
P26	Surf E	J52	18	-0.33		
P26	Surf E	J52	19	-0.10		
P26	Surf E	J52	19	-0.16		
P26	Surf E	J52	20	-0.10		
P26	Surf E	J52	21	0.05		
P26	Surf E	J52	21	0.01		
P26	Surf E	J52	21	0.16		
P26	Surf E	J52	22	-0.14		
P26	Surf E	J52	22	0.03		
P26	Surf E	J52	22	0.06		
P26	Surf E	J52	23	-0.21		
P26	Surf E	J52	23	0.01		
P26	Surf E	J52	23	0.02		
P26	Surf E	J52	24	-0.02		
P26	Surf E	J52	24	-0.26		
P26	Surf E	J52	24	-0.28		
P26	Surf E	J52	25	0.11		
P26	Surf E	J52	26	-0.19		
P26	Surf E	J52	26	-0.30		

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P26	Surf E	J52	26	0.11		
P26	Surf E	J52	27	-0.07		
P26	Surf E	J52	28	0.12		
P26	Surf E	J52	29	-0.09		
P26	Surf E	J52	30	0.01		
P27	Base A	J66	1	0.02		
P27	Base A	J66	2	-0.15		
P27	Base A	J66	3	0.01		
P27	Base A	J66	4	0.13		
P27	Base A	J66	5	-0.10		
P27	Base A	J66	6	-0.24		
P27	Base A	J66	7	0.31		
P27	Base A	J66	8	0.19		
P27	Base A	J66	9	0.37		
P27	Base A	J66	10	-0.16		
P27	Base A	J66	11	0.12		
P27	Interm B	J60	1	0.12	0.86	1.05
P27	Interm B	J60	2	0.43	0.11	1.11
P27	Interm B	J60	3	0.35	0.06	0.85
P27	Interm B	J60	4	-0.10	1.09	0.74
P27	Interm B	J60	5	0.26	-0.39	0.27
P27	Interm B	J60	6	0.41	-0.21	0.76
P27	Interm B	J60	7	0.16	-0.45	-0.01
P27	Interm B	J60	8	0.55	0.50	1.75
P27	Interm B	J60	9	0.43	-0.86	0.20
P27	Interm B	J60	10	0.40	0.11	0.98
P27	Interm B	J60	11	-0.19	0.45	-0.01
P27	Interm B	J60	12	0.25	0.22	0.79
P27	Interm B	J60	13	-0.12	0.47	0.18
P27	Interm B	J60	14	0.42	-1.08	-0.02
P27	Interm B	J60	15	0.55	-0.76	0.52
P27	Interm C	J53	1	0.02	-0.84	-0.71
P27	Interm C	J53	1	-0.25		
P27	Interm C	J53	2	-0.21		
P27	Interm C	J53	2	-0.15		
P27	Interm C	J53	3	-0.22		
P27	Interm C	J53	4	-0.20	0.30	-0.10
P27	Interm C	J53	5	-0.25	-0.24	-0.73
P27	Interm C	J53	6	-0.26	0.22	-0.35
P27	Interm C	J53	7	0.32	-0.75	0.12
P27	Interm C	J53	8	0.18	-0.15	0.37
P27	Interm C	J53	8	-0.02	-0.20	-0.17
P27	Interm C	J53	9	0.07	-0.27	0.02
P27	Interm C	J53	10	0.01	-0.02	0.12
P27	Interm C	J53	11	0.13	-0.28	0.13
P27	Interm C	J53	12	-0.07	0.09	0.01
P27	Interm C	J53	13	0.10	-0.22	0.11
P27	Interm C	J53	14	0.39	-1.05	0.02
P27	Interm C	J53	15	0.22	0.07	0.61
P27	Interm C	J53	16	0.19	0.63	1.07

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P27	Surf B	J55	1	0.64	-0.58	0.96
P27	Surf B	J55	1	-0.11	0.03	-0.19
P27	Surf B	J55	1	0.11	-0.24	0.10
P27	Surf B	J55	2	0.02	-0.16	-0.05
P27	Surf B	J55	2	0.11	0.06	0.36
P27	Surf B	J55	2	0.23	0.28	0.80
P27	Surf B	J55	3	0.30	-0.31	0.44
P27	Surf B	J55	3	0.04	0.61	0.67
P27	Surf B	J55	3	0.05	0.60	0.66
P27	Surf B	J55	4	-0.15	0.82	0.45
P27	Surf B	J55	4	0.26	0.01	0.65
P27	Surf B	J55	4	0.23	-0.51	0.10
P27	Surf B	J55	5	0.04	0.28	0.45
P27	Surf B	J55	5	0.01	0.59	0.63
P27	Surf B	J55	5	0.15	0.52	0.91
P27	Surf B	J71	1	-0.28	1.01	0.26
P27	Surf B	J71	1	0.14	0.00	0.32
P27	Surf B	J71	1	0.25	0.22	0.78
P27	Surf B	J71	2	0.10	-0.02	0.20
P27	Surf B	J71	2	0.20	-0.24	0.24
P27	Surf B	J71	2	-0.14	0.53	0.17
P27	Surf B	J71	2	0.13	0.53	0.79
P27	Surf B	J71	4	-0.23	-0.15	-0.64
P27	Surf B	J71	4	-0.24	0.35	-0.23
P27	Surf B	J71	4	0.18	0.24	0.62
P27	Surf B	J71	5	0.16	0.90	1.13
P27	Surf B	J71	5	-0.05	0.10	-0.03
P27	Surf B	J71	6	0.14	-0.06	0.28
P27	Surf B	J71	7	0.03	-0.04	0.03
P27	Surf B	J71	7	0.19	0.59	0.94
P27	Surf B	J71	7	-0.25	1.05	0.40
P27	Surf B	J71	8	0.28	-1.03	-0.30
P27	Surf B	J71	8	0.03	0.25	0.31
P27	Surf B	J71	8	0.22	-0.29	0.23
P27	Surf B	J71	9	0.00	0.18	0.16
P27	Surf B	J71	9	0.15	-0.66	-0.30
P27	Surf B	J71	9	0.17	-0.23	0.16
P27	Surf B	J71	9	0.01	0.55	0.48
P27	Surf B	J71	9	0.07	0.75	0.81
P27	Surf B	J71	10	0.17	-0.26	0.15
P27	Surf B	J71	10	0.01	0.55	0.48
P27	Surf B	J71	10	0.07	0.74	0.81
P27	Surf CM	J61	1	0.00	0.31	0.41
P27	Surf CM	J61	2	-0.05	-0.06	-0.07
P27	Surf CM	J61	3	-0.30	-0.93	-1.26
P27	Surf CM	J61	4	0.05	-0.31	0.08
P27	Surf CM	J61	5	0.08	-0.80	-0.38
P27	Surf CM	J61	6	-0.06	0.40	0.37
P27	Surf CM	J61	7	0.02	-0.90	-0.55
P27	Surf CM	J61	8	-0.05	-0.81	-0.66

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P27	Surf CM	J61	9	-0.22	-0.18	-0.51
P28	Base B	J47	1	0.05		
P28	Base B	J47	2	0.01		
P28	Base B	J47	2	-0.10		
P28	Base B	J47	3	-0.29		
P28	Base B	J47	4	-0.36		
P28	Base B	J47	5	0.06		
P28	Base B	J47	6	-0.24		
P28	Base B	J47	7	-0.05		
P28	Base B	J47	7	-0.27		
P28	Base B	J47	8	0.44		
P28	Base B	J47	8	-0.16		
P28	Base B	J47	9	0.13		
P28	Base B	J47	9	0.07		
P28	Base B	J47	10	0.36		
P28	Interm C	J42	1	-0.08	-0.71	-0.82
P28	Interm C	J42	1	0.03	0.35	0.37
P28	Interm C	J42	2	-0.03	0.83	0.68
P28	Interm C	J42	3	-0.29	0.01	-0.62
P28	Interm C	J42	4	-0.16	0.82	0.39
P28	Interm C	J42	5	-0.06	-0.04	-0.17
P28	Interm C	J42	6	0.09	-0.36	-0.14
P28	Interm C	J42	7	0.37	0.01	0.94
P28	Interm C	J42	8	0.37	0.01	0.94
P28	Interm C	J42	9	0.07	0.00	0.16
P28	Interm C	J42	9	0.24	-0.28	0.26
P28	Interm C	J42	10	0.12	0.03	0.27
P28	Interm C	J42	11	0.18	-0.01	0.37
P28	Interm C	J42	12	0.11	-0.55	-0.26
P28	Interm C	J42	13	0.31	-0.55	0.16
P28	Surf C	J39	1	0.31	-1.13	-0.29
P28	Surf C	J39	1	0.25	-0.86	-0.20
P28	Surf C	J39	1	-0.15	-0.59	-0.77
P28	Surf C	J39	3	-0.03	-0.90	-0.84
P28	Surf C	J39	4	0.00	-0.28	-0.23
P28	Surf C	J39	4	0.20	-0.96	-0.41
P28	Surf C	J39	4	0.11	-0.61	-0.30
P28	Surf C	J39	4	0.23	-0.95	-0.36
P28	Surf C	J39	5	-0.22	-0.67	-1.01
P28	Surf C	J39	5	0.19	-0.82	-0.30
P28	Surf C	J39	5	0.02	-0.59	-0.47
P28	Surf C	J39	5	-0.11	-0.73	-0.50
P28	Surf C	J39	5	0.09	-0.56	-0.31
P28	Surf C	J39	6	-0.11	-0.29	-0.47
P28	Surf C	J39	6	-0.11	-0.32	-0.47
P28	Surf C	J39	6	0.21	-0.89	-0.34
P28	Surf C	J39	6	0.06	-0.46	-0.28
P28	Surf C	J39	6	0.06	-0.40	-0.22
P28	Surf C	J39	7	0.09	-0.40	-0.17
P28	Surf C	J39	8	0.06	-0.51	-0.31
P28	Surf C	J39	8	0.11	-0.61	-0.30
P28	Surf C	J39	8	0.06	-0.40	-0.22
P28	Surf C	J39	9	0.00	-0.53	-0.45
P28	Surf C	J39	10	-0.29	0.15	-0.45
P29	Surf C	J59	1	-0.11	-0.03	-0.21
P29	Surf C	J59	2	0.19	-0.36	0.17
P29	Surf C	J59	2	0.20	-0.31	0.22
P29	Surf C	J59	2	0.05	0.13	0.28
P29	Surf C	J59	3	0.04	0.43	0.52
P29	Surf C	J59	3	0.13	0.03	0.44
P29	Surf C	J59	3	-0.25	0.39	-0.14
P29	Surf C	J59	4	-0.16	-0.01	-0.26
P29	Surf C	J59	4	-0.02	-0.35	-0.29
P29	Surf C	J59	4	0.03	-0.18	0.02
P29	Surf C	J59	5	-0.18	0.86	0.45
P29	Surf C	J59	5	-0.19	0.10	-0.25
P29	Surf C	J59	5	0.14	0.29	0.64
P29	Surf C	J59	6	-0.02	-0.23	-0.19
P29	Surf C	J59	6	0.07	-0.23	0.05
P29	Surf C	J59	6	-0.05	0.14	0.08
P29	Surf C	J59	7	0.22	-0.11	0.49
P29	Surf C	J59	7	-0.13	0.07	-0.11
P29	Surf C	J59	7	-0.27	0.10	-0.41
P29	Surf C	J59	7	-0.13	-0.24	-0.42
P29	Surf C	J59	8	-0.04	-0.23	-0.16
P29	Surf C	J59	8	-0.15	-0.08	-0.27
P29	Surf C	J59	8	-0.15	0.04	-0.17
P29	Surf C	J59	9	-0.11	-0.36	-0.47
P29	Surf C	J59	9	-0.15	-0.08	-0.27
P29	Surf C	J59	9	-0.15	0.04	-0.17
P30	Surf B	J65	1	-0.15	1.09	0.71
P30	Surf B	J65	1	-0.07	0.41	0.27
P30	Surf B	J65	1	0.04	0.42	0.50
P30	Surf B	J65	2	0.09	0.45	0.63
P30	Surf B	J65	2	-0.07	0.41	0.27
P30	Surf B	J65	2	0.04	0.42	0.50
P30	Surf B	J65	3	0.09	0.45	0.63
P30	Surf B	J65	4	-0.05	0.43	0.33
P32	Interm B	J76	2	-0.08	-0.82	-0.64
P32	Interm B	J76	2	-0.05	-0.52	-0.41
P32	Interm B	J76	2	0.28	-0.34	0.63
P32	Interm B	J76	2	0.25	-0.96	0.04
P32	Interm B	J76	3	-0.16	-0.72	-0.74
P32	Interm B	J76	3	-0.14	-0.71	-0.63
P32	Interm B	J76	3	-0.15	-0.18	-0.17
P32	Interm B	J76	4	0.31	-0.48	0.57
P32	Interm B	J76	4	0.47	-1.02	0.48
P32	Interm B	J76	4	0.05	0.09	0.49
P32	Interm B	J76	4	0.08	-0.58	-0.06
P32	Interm B	J76	4	-0.31	-0.63	-0.99

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P32	Interm B	J76	5	0.15	0.40	0.47
P32	Interm B	J76	5	0.03	-0.66	-0.25
P32	Interm B	J76	5	-0.01	-0.54	-0.24
P32	Interm B	J76	5	0.14	-0.92	-0.22
P32	Interm B	J76	6	0.17	-0.72	0.02
P32	Interm B	J76	6	0.23	-0.33	0.55
P32	Interm B	J76	6	0.17	-0.49	0.21
P32	Interm B	J76	7	-0.20	-0.38	-0.55
P32	Interm B	J76	7	-0.35	-0.40	-0.91
P32	Interm B	J76	7	0.23	-0.65	0.20
P32	Interm B	J76	9	0.06	-0.47	-0.03
P32	Interm B	J76	9	0.02	-0.52	-0.13
P32	Interm B	J76	9	0.00	-0.70	-0.36
P32	Interm B	J76	10	-0.15	0.21	0.13
P32	Interm B	J76	10	0.32	-0.79	0.36
P32	Interm B	J76	10	0.19	-0.84	-0.01
P32	Interm B	J76	10	0.23	-0.78	0.14
P32	Interm B	J76	11	-0.11	-0.54	-0.45
P32	Interm B	J76	11	-0.08	-0.98	-0.79
P32	Interm B	J76	11	0.05	-0.90	-0.41
P32	Interm B	J76	11	0.07	-0.94	-0.39
P32	Interm B	J76	12	0.02	-0.48	-0.10
P32	Interm B	J76	12	0.23	-0.96	-0.04
P32	Interm B	J76	12	0.43	-0.84	0.53
P32	Interm B	J76	12	0.08	-0.90	-0.33
P32	Interm B	J76	13	0.52	-1.06	0.56
P32	Interm B	J76	13	-0.02	-0.82	-0.51
P32	Interm B	J76	13	0.15	-0.76	-0.06
P32	Interm B	J76	14	0.11	-0.08	0.47
P32	Interm B	J76	14	0.56	-0.58	-0.24
P32	Interm B	J76	14	0.23	-0.54	0.33
P32	Surf A	J79	2	0.16	0.34	0.67
P32	Surf A	J79	2	0.25	0.03	0.57
P32	Surf A	J79	2	0.17	-0.78	-0.28
P32	Surf A	J79	2	0.28	-1.12	-0.32
P32	Surf A	J79	2	0.33	-0.58	0.26
P32	Surf A	J79	2	0.16	-0.37	0.07
P32	Surf A	J79	3	0.29	0.04	0.77
P32	Surf A	J79	3	0.19	-0.09	0.38
P32	Surf A	J79	3	0.20	0.05	0.54
P32	Surf A	J79	3	0.30	-0.60	0.19
P32	Surf A	J79	3	0.34	-0.51	0.40
P32	Surf A	J79	4	0.22	0.13	0.66
P32	Surf A	J79	4	0.23	0.18	0.75
P32	Surf A	J79	4	0.01	-0.07	0.00
P32	Surf A	J79	4	0.31	-0.74	0.08
P32	Surf A	J79	5	0.11	-0.83	-0.43
P32	Surf A	J79	5	0.36	-1.10	-0.13
P32	Surf A	J79	5	0.19	-0.09	0.38
P32	Surf A	J79	6	-0.23	-0.23	-0.71
P32	Surf A	J79	6	-0.09	0.13	-0.05
P32	Surf A	J79	6	0.11	-0.12	0.21
P32	Surf A	J79	6	0.13	-0.27	0.09
P32	Surf A	J79	7	0.11	-0.26	0.09
P32	Surf A	J79	7	0.08	-0.45	-0.16
P32	Surf A	J79	7	0.22	-0.29	0.30
P32	Surf A	J79	8	0.06	0.54	0.67
P32	Surf A	J79	8	0.09	0.29	0.51
P32	Surf A	J79	8	0.18	-0.78	-0.26
P32	Surf A	J79	9	0.28	0.49	1.11
P32	Surf A	J79	9	0.20	0.01	0.50
P32	Surf A	J79	9	0.17	0.16	0.53
P32	Surf A	J79	10	0.22	-0.19	0.39
P32	Surf A	J79	10	0.18	0.19	0.63
P32	Surf A	J79	10	0.35	0.27	1.09
P32	Surf A	J79	10	0.10	-0.30	-0.02
P32	Surf A	J79	11	0.01	0.34	0.34
P32	Surf A	J79	11	0.07	0.94	1.10
P32	Surf A	J79	11	0.31	-0.43	0.33
P32	Surf A	J79	11	-0.07	-0.58	-0.68
P32	Surf A	J79	11	0.37	-0.64	0.29
P32	Surf A	J79	12	0.13	0.01	0.34
P32	Surf A	J79	12	-0.14	-0.47	-0.72
P32	Surf A	J79	12	0.20	0.16	-2.33
P32	Surf A	J79	12	0.15	-0.40	0.00
P32	Surf A	J79	13	0.02	0.02	0.12
P32	Surf A	J79	13	-0.36	0.28	-0.53
P32	Surf A	J79	13	-0.31	0.37	-0.31
P32	Surf A	J79	13	-0.07	-0.49	-0.55
P32	Surf A	J79	13	-0.10	0.13	-0.08
P32	Surf A	J79	14	-0.19	0.48	0.04
P32	Surf A	J79	14	-0.03	0.01	0.03
P32	Surf A	J79	14	-0.23	0.46	-0.02
P32	Surf A	J79	15	0.08	-0.43	-0.14
P32	Surf A	J79	15	0.08	-0.32	-0.03
P32	Surf A	J79	15	0.28	0.03	0.79
P32	Surf A	J79	15	0.19	-0.90	-0.36
P32	Surf A	J79	15	0.25	-0.95	-0.21
P32	Surf A	J79	16	0.34	-1.20	-0.26
P32	Surf A	J79	16	0.10	-0.95	-0.59
P32	Surf A	J79	16	0.04	-0.24	-0.03
P32	Surf A	J79	16	0.06	-0.28	-0.03
P32	Surf A	J79	16	0.10	0.31	0.61
P32	Surf A	J79	17	0.20	-0.86	-0.35
P32	Surf A	J79	17	0.03	-1.05	-0.80
P32	Surf A	J79	17	0.10	-0.67	-0.32
P32	Surf A	J79	17	-0.11	-0.87	-0.98
P32	Surf A	J79	17	-0.34	-0.27	-0.95
P32	Surf A	J79	18	0.11	-0.54	-0.14
P32	Surf A	J79	18	0.32	-0.24	0.62

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P32	Surf A	J79	18	0.08	-0.20	0.09
P32	Surf A	J79	18	0.11	-0.12	0.21
P32	Surf A	J79	18	0.12	-0.02	0.31
P32	Surf A	J79	19	0.17	0.29	0.74
P32	Surf A	J79	19	0.32	-0.25	0.55
P32	Surf A	J79	19	0.22	-0.95	-0.29
P32	Surf A	J79	20	0.16	-0.24	0.18
P32	Surf A	J79	20	0.38	0.16	1.03
P32	Surf A	J79	20	0.36	-0.23	0.69
P32	Surf A	J79	20	0.22	-0.47	0.13
P32	Surf A	J79	20	-0.14	0.23	-0.09
P32	Surf A	J79	21	0.07	0.84	0.96
P32	Surf A	J79	21	-0.06	-0.23	-0.29
P32	Surf A	J79	21	-0.07	0.33	0.17
P32	Surf A	J79	22	0.25	0.08	0.72
P32	Surf A	J79	22	0.02	0.27	0.37
P32	Surf A	J79	22	0.06	-0.42	-0.17
P32	Surf A	J79	23	0.18	-1.10	-0.63
P32	Surf A	J79	23	-0.02	0.00	0.01
P32	Surf A	J79	23	0.06	-0.09	0.11
P32	Surf A	J79	23	0.17	-0.99	-0.42
P32	Surf A	J79	24	0.14	-1.09	-0.57
P32	Surf A	J79	24	0.08	-0.51	-0.22
P32	Surf A	J79	24	0.07	-0.70	-0.45
P32	Surf A	J79	25	0.17	-1.45	-0.86
P32	Surf A	J79	25	-0.11	-0.63	-0.78
P32	Surf A	J79	25	0.07	-0.70	-0.45
P32	Surf B	J72	1	-0.04	0.50	0.35
P32	Surf B	J72	1	-0.19	0.07	-0.36
P32	Surf B	J72	1	0.14	0.24	0.53
P32	Surf B	J72	1	0.05	0.40	0.48
P32	Surf B	J72	1	0.17	0.35	0.72
P32	Surf B	J72	2	0.06	1.01	0.99
P32	Surf B	J72	2	0.22	0.18	0.66
P32	Surf B	J72	2	-0.15	1.03	0.56
P32	Surf B	J72	2	0.11	0.74	0.87
P32	Surf B	J72	2	-0.06	0.32	0.16
P32	Surf B	J72	2	-0.14	0.25	-0.09
P32	Surf B	J72	3	-0.10	0.36	0.08
P32	Surf B	J72	3	0.22	0.48	0.93
P32	Surf B	J72	3	-0.22	0.50	-0.06
P32	Surf B	J72	4	0.13	-0.27	0.08
P32	Surf B	J72	4	0.29	-0.38	0.35
P32	Surf B	J72	4	0.22	-0.25	0.32
P32	Surf B	J72	5	0.08	-0.39	-0.12
P32	Surf B	J72	5	-0.05	-0.37	-0.43
P32	Surf B	J72	5	0.18	-0.44	0.01
P32	Surf B	J72	5	-0.14	-0.41	-0.67
P32	Surf B	J72	5	0.32	-0.06	0.70
P32	Surf B	J72	6	0.17	-0.49	0.00

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P32	Surf B	J72	6	0.19	-0.19	0.29
P32	Surf B	J72	6	-0.04	-0.81	-0.80
P32	Surf B	J72	6	0.17	-0.54	-0.08
P32	Surf B	J72	6	0.19	-0.47	0.05
P32	Surf B	J72	7	0.31	-0.82	0.00
P32	Surf B	J72	7	0.06	-0.33	-0.14
P32	Surf B	J72	7	0.07	-0.42	-0.21
P32	Surf B	J72	8	0.38	-0.79	0.24
P32	Surf B	J72	8	-0.36	0.26	-0.55
P32	Surf B	J72	8	0.16	-0.31	0.12
P32	Surf B	J72	8	0.00	-0.22	-0.19
P32	Surf E	J46	1	0.22		
P32	Surf E	J46	2	0.06		
P32	Surf E	J46	3	-0.25		
P32	Surf E	J46	5	-0.12		
P32	Surf E	J46	6	-0.36		
P32	Surf E	J46	7	-0.29		
P32	Surf E	J46	7	0.06		
P32	Surf E	J46	8	-0.08		
P32	Surf E	J46	8	0.12		
P32	Surf E	J46	9	0.12		
P32	Surf E	J46	9	-0.08		
P32	Surf E	J46	10	-0.32		
P32	Surf E	J46	10	0.01		
P32	Surf E	J46	10	0.31		
P32	Surf E	J46	11	-0.08		
P32	Surf E	J46	12	0.31		
P32	Surf E	J46	14	0.15		
P32	Surf E	J46	18	-0.03		
P32	Surf E	J46	19	0.12		
P32	Surf E	J46	21	0.08		
P32	Surf E	J46	22	-0.04		
P32	Surf E	J46	24	0.18		
P32	Surf E	J46	25	0.04		
P32	Surf E	J46	26	-0.06		
P32	Surf E	J46	27	0.11		
P32	Surf E	J46	28	-0.07		
P32	Surf E	J46	30	-0.04		
P32	Surf E	J46	30	0.02		
P32	Surf E	J46	31	0.19		
P32	Surf E	J46	31	-0.05		
P32	Surf E	J46	32	-0.16		
P32	Surf E	J46	32	-0.17		
P32	Surf E	J46	33	-0.41		
P32	Surf E	J46	35	-0.07		
P32	Surf E	J46	36	-0.24		
P32	Surf E	J46	37	0.34		
P32	Surf E	J46	38	-0.05		
P32	Surf E	J46	38	-0.21		
P32	Surf E	J46	38	-0.09		

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P32	Surf E	J46	41	-0.02		
P32	Surf E	J46	45	-0.05		
P33	Interm B	J73	1	0.32	-0.23	0.42
P33	Interm B	J73	2	0.01	0.34	0.27
P33	Interm B	J73	2	-0.16	0.55	0.06
P33	Interm B	J73	2	0.30	-0.09	0.50
P33	Interm B	J73	3	-0.22	-0.37	-0.92
P33	Interm B	J73	3	-0.31	-0.01	-0.82
P33	Interm B	J73	3	0.60	-1.46	-0.03
P33	Interm B	J73	4	-0.05	0.14	-0.05
P33	Interm B	J73	4	-0.12	0.58	0.11
P33	Interm B	J73	4	0.34	-0.57	0.14
P33	Interm B	J73	4	-0.12	0.69	0.25
P33	Interm B	J73	4	0.21	-0.50	-0.10
P33	Interm B	J73	5	0.15	0.37	0.63
P33	Interm B	J73	5	-0.31	0.38	-0.49
P33	Interm B	J73	5	-0.04	0.66	0.42
P33	Interm B	J73	5	0.03	0.55	0.47
P33	Interm B	J73	6	0.04	0.06	0.09
P33	Interm B	J73	6	0.16	-0.26	0.05
P33	Interm B	J73	6	-0.03	0.30	0.14
P33	Interm B	J73	7	0.43	-0.24	0.68
P33	Interm B	J73	7	0.04	0.92	0.84
P33	Interm B	J73	7	-0.01	0.55	0.42
P33	Interm B	J73	8	-0.12	0.35	-0.05
P33	Interm B	J73	8	0.17	-0.11	0.22
P33	Interm B	J73	8	-0.01	0.55	0.42
P33	OGFC	J78	1	-0.07		
P33	OGFC	J78	1	0.74		
P33	OGFC	J78	1	-0.40		
P33	OGFC	J78	1	0.28		
P33	OGFC	J78	2	-0.01		
P33	OGFC	J78	2	0.15		
P33	OGFC	J78	2	0.50		
P33	OGFC	J78	3	-0.50		
P33	OGFC	J78	3	0.10		
P33	OGFC	J78	3	-0.21		
P33	OGFC	J78	4	0.02		
P33	OGFC	J78	4	0.25		
P33	OGFC	J78	4	-0.21		
P33	Surf A	J77	1	0.00	1.43	0.34
P33	Surf A	J77	1	-0.38	1.55	-0.44
P33	Surf A	J77	1	0.13	0.76	0.03
P33	Surf A	J77	1	-0.23	0.80	-0.77
P33	Surf A	J77	2	0.00	0.04	-0.92
P33	Surf A	J77	2	0.39	0.22	0.11
P33	Surf A	J77	2	0.12	0.37	-0.30
P33	Surf A	J77	2	0.01	0.81	-0.18
P33	Surf A	J77	3	0.24	-0.05	-0.46
P33	Surf A	J77	3	0.45	-0.37	-0.33

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P33	Surf A	J77	3	0.29	-0.31	-0.58
P33	Surf A	J77	3	0.32	-0.50	-0.70
P33	Surf A	J77	4	-0.01	1.14	1.04
P33	Surf A	J77	4	0.20	0.74	1.12
P33	Surf A	J77	4	-0.24	0.60	0.02
P33	Surf A	J77	4	0.16	0.10	0.46
P33	Surf A	J77	5	-0.28	0.96	0.25
P33	Surf A	J77	5	0.11	0.79	0.99
P33	Surf A	J77	5	0.09	0.96	1.11
P33	Surf A	J77	6	-0.09	0.78	0.58
P33	Surf A	J77	6	0.30	0.18	0.86
P33	Surf A	J77	6	0.56	-0.84	0.55
P33	Surf E	J75	1	-0.10		
P33	Surf E	J75	2	-0.15		
P33	Surf E	J75	3	0.05		
P33	Surf E	J75	4	-0.16		
P33	Surf E	J75	5	-0.03		
P33	Surf E	J75	6	0.37		
P33	Surf E	J75	7	-0.17		
P33	Surf E	J75	8	-0.10		
P33	Surf E	J75	9	-0.10		
P33	Surf E	J75	10	0.24		
P34	Surf A	J62	1	0.26	-0.58	0.08
P34	Surf A	J62	1	0.08	0.02	0.22
P34	Surf A	J62	1	-0.27	0.46	-0.15
P34	Surf A	J62	1	-0.09	0.79	0.53
P34	Surf A	J62	2	0.21	-0.45	0.10
P34	Surf A	J62	2	0.24	-0.72	-0.10
P34	Surf A	J62	2	0.11	-0.59	-0.26
P34	Surf A	J62	2	0.26	-0.62	0.05
P34	Surf A	J62	3	0.02	0.09	0.17
P34	Surf A	J62	3	0.00	0.23	0.29
P34	Surf A	J62	3	-0.09	0.35	0.13
P34	Surf A	J62	3	-0.09	0.65	0.41
P34	Surf A	J62	3	-0.32	0.09	-0.67
P34	Surf A	J62	3	-0.12	0.76	0.37
P34	Surf A	J62	4	-0.01	-0.39	-0.35
P34	Surf A	J62	4	-0.20	0.82	0.35
P34	Surf A	J62	4	-0.18	1.59	1.10
P34	Surf A	J62	4	-0.10	0.96	0.70
P34	Surf A	J62	5	-0.36	0.94	0.08
P34	Surf A	J62	5	0.11	0.23	0.49
P34	Surf A	J62	5	0.21	-1.19	-0.58
P34	Surf A	J62	5	-0.55	1.23	-0.08
P34	Surf A	J62	6	0.23	-0.74	-0.23
P34	Surf A	J62	6	0.06	0.68	0.67
P34	Surf A	J62	6	0.06	0.13	0.20
P34	Surf A	J62	6	0.06	-0.23	-0.14
P34	Surf A	J62	7	-0.08	-0.21	-0.43
P34	Surf A	J62	7	-0.10	-0.04	-0.30

Table A.2. Plant Test Results Data (*continued*)

Proj. No.	Mix Type	JMF No.	Lot No.	AC	AV	VMA
P34	Surf C	J81	1	-0.06	1.06	0.82
P34	Surf C	J81	1	-0.11	1.12	0.78
P34	Surf C	J81	2	0.13	0.46	0.76
P34	Surf C	J81	2	-0.13	0.28	0.03
P34	Surf C	J81	3	0.16	0.29	0.65
P34	Surf C	J81	4	-0.08	0.08	-0.07
P34	Surf C	J81	4	0.40	-0.75	0.30
P34	Surf C	J81	5	-0.03	-0.18	-0.24
P34	Surf C	J81	5	0.42	-0.62	0.44
P34	Surf C	J81	6	-0.03	-0.20	-0.26
P34	Surf C	J81	6	0.06	-0.13	0.04
P34	Surf C	J81	7	0.02	-0.46	-0.39
P34	Surf C	J81	7	0.45	0.03	0.95
P34	Surf E	J80	1	-0.09		
P34	Surf E	J80	1	0.00		
P34	Surf E	J80	2	0.03		
P34	Surf E	J80	2	0.13		
P34	Surf E	J80	3	0.12		
P34	Surf E	J80	3	-0.04		
P34	Surf E	J80	3	0.10		
P34	Surf E	J80	4	-0.01		
P34	Surf E	J80	5	0.03		
P34	Surf E	J80	5	-0.06		
P34	Surf E	J80	5	-0.05		
P34	Surf E	J80	6	-0.23		
P35	Surf C	J32	2	0.20	-1.07	-0.53
P35	Surf C	J32	2	-0.18	0.97	0.49
P35	Surf C	J32	2	-0.18	0.17	-0.27
P35	Surf C	J32	4	-0.18	0.17	-0.27
P35	Surf C	J32	5	-0.11	0.48	0.16
P35	Surf C	J32	5	0.04	0.04	0.12
P35	Surf C	J32	5	0.02	0.60	0.56
P35	Surf C	J32	6	-0.09	0.53	0.26
P35	Surf C	J32	6	-0.24	0.42	-0.14
P35	Surf C	J32	6	-0.08	0.10	-0.08
P35	Surf C	J32	7	0.04	0.85	0.81
P35	Surf C	J32	7	-0.12	0.92	0.56
P35	Surf C	J32	7	-0.10	0.90	0.58
P35	Surf C	J32	8	0.27	0.51	1.01
P35	Surf C	J38	7	-0.20	-0.05	-0.46
P35	Surf C	J38	7	-0.06	-0.36	-0.43
P35	Surf C	J38	8	0.10	-0.08	0.14
P35	Surf C	J38	8	0.02	-0.53	-0.41
P35	Surf C	J38	9	0.26	-0.30	0.35
P35	Surf C	J38	10	0.13	0.72	0.93
P35	Surf C	J38	10	0.02	-0.36	-0.26
P35	Surf C	J38	11	0.04	0.22	0.30
P35	Surf C	J38	11	0.10	0.20	0.40
P35	Surf C	J38	12	0.16	0.04	0.19
P35	Surf C	J38	13	0.14	0.10	0.40
P35	Surf C	J38	13	-0.16	0.10	-0.25
P35	Surf C	J38	14	0.32	-0.39	0.38
P35	Surf C	J38	14	0.25	-0.86	-0.20
P35	Surf C	J38	14	0.18	-0.55	-0.08
P35	Surf C	J38	15	0.08	-0.27	-0.05
P35	Surf C	J38	15	0.18	-0.89	-0.37
P35	Surf C	J38	15	0.02	0.14	0.19
P35	Surf C	J38	15	0.05	0.06	0.17
P35	Surf C	J38	15	0.15	0.21	0.51
P35	Surf C	J38	16	0.02	0.14	0.19
P35	Surf C	J38	16	0.15	0.21	0.51
P35	Surf C	J38	17	-0.03	0.06	0.00
P35	Surf C	J38	17	0.09	0.08	0.26
P35	Surf C	J38	17	0.09	0.14	0.33
P35	Surf C	J38	17	0.09	-0.09	0.13
P35	Surf C	J38	18	-0.03	0.27	0.22
P35	Surf C	J38	18	0.14	0.26	0.57
P35	Surf C	J38	18	-0.09	0.26	0.05
P35	Surf C	J38	19	-0.02	0.03	0.01
P35	Surf C	J38	19	-0.09	0.26	0.05
P35	Surf C	J38	19	0.14	0.26	0.57
P35	Surf C	J38	20	-0.22	0.67	0.15
P35	Surf C	J38	20	0.00	0.52	0.50
P35	Surf C	J38	21	-0.02	0.62	0.55
P35	Surf C	J38	22	-0.07	0.45	0.30

APPENDIX B — CALCULATION OF UNBIASED STANDARD DEVIATION VALUES FOR EACH LOT FOR EACH PROJECT

This appendix includes the calculations involved and lists the unbiased standard deviation for each lot on each project for which density or plant test results were obtained. The following tables also show the average unbiased lot standard deviation for each project. The calculations that are involved are illustrated in Exhibit B.1. The c_4 factors used in the calculations are shown in Table B.1.

Lot No.	Lot Size	Lot Mean	Lot St Dev*	c_4**	Unbiased Lot St Dev***
1	5	92.71	0.546	0.9400	0.581
3	6	91.83	0.863	0.9515	0.907
4	7	92.50	0.504	0.9594	0.525
5	6	92.15	0.489	0.9515	0.514
	Average	**92.3**	**0.601**		**0.632********

***** calculated from $s = \sqrt{\dfrac{\sum_{i=1}^{n}\left(X_i - \overline{X}\right)^2}{n-1}}$

****** obtained from Table B.1 for the sample size, *n*

******* calculated as $\dfrac{s}{c_4}$

******** calculated as $\dfrac{\dfrac{s_1}{c_{4_1}} + \dfrac{s_3}{c_{4_3}} + \dfrac{s_4}{c_{4_4}} + \dfrac{s_5}{c_{4_5}}}{4}$

Exhibit B.1. Example of Calculating Unbiased Std Dev for Project P27, JMF J55

Table B.1. c_4 Factors for Various Sample Sizes, *n*

Sample Size, n	c_4
2	0.7979
3	0.8862
4	0.9213
5	0.9400
6	0.9515
7	0.9594
8	0.9650
9	0.9693
10	0.9727
11	0.9754
12	0.9776
13	0.9794
14	0.9810
15	0.9823
16	0.9835
17	0.9845
18	0.9854
19	0.9862
20	0.9869
21	0.9876
22	0.9882
23	0.9887
24	0.9892
25	0.9896
Over 25	*a*

[a] $(4n-4)/(4n-3)$

Table B.2. Summary of Unbiased Lot Std Dev for Density for Each Interstate Paving Project

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P01	J02	10	94.37	0.821	0.9727	0.844			Interm
P01	J02	1	92.47	–	–	–			Interm
P01	J02	5	93.81	0.746	0.9400	0.794			Interm
P01	J02	6	93.58	0.862	0.9515	0.906	93.56	0.848	Interm
P01	J10	1	92.32	0.101	0.8862	0.114			Interm
P01	J10	4	93.07	0.546	0.9213	0.593			Interm
P01	J10	5	92.54	0.167	0.9213	0.181			Interm
P01	J10	7	93.10	0.977	0.9400	1.039			Interm
P01	J10	13	92.76	0.487	0.8862	0.550			Interm
P01	J10	18	92.95	0.557	0.9400	0.593			Interm
P01	J10	20	93.18	0.508	0.9515	0.534	92.85	0.515	Interm
P23	J33	1	91.96	1.587	0.8862	1.791			Interm
P23	J33	2	91.23	1.572	0.8862	1.774			Interm
P23	J33	3	91.84	1.426	0.9400	1.517			Interm
P23	J33	4	91.48	1.422	0.9400	1.513	91.63	1.649	Interm
P32	J76	2	93.84	0.817	0.9693	0.843			Interm
P32	J76	3	94.23	1.120	0.9515	1.177			Interm
P32	J76	4	92.79	0.548	0.9727	0.563			Interm
P32	J76	5	93.09	0.856	0.9727	0.880			Interm
P32	J76	6	93.02	0.750	0.9727	0.771			Interm
P32	J76	7	92.09	1.437	0.9515	1.510			Interm
P32	J76	8	92.49	0.988	0.9594	1.030			Interm
P32	J76	9	93.33	1.738	0.9515	1.827			Interm
P32	J76	10	93.34	0.964	0.9693	0.995			Interm
P32	J76	11	93.60	0.770	0.9693	0.794			Interm
P32	J76	12	93.69	0.972	0.9727	0.999			Interm
P32	J76	13	93.38	0.781	0.9594	0.814			Interm
P32	J76	14	93.56	1.381	0.9515	1.451	93.27	1.050	Interm
P33	J73	5	93.59	2.214	0.9400	2.355			Interm
P33	J73	7	93.19	2.129	0.9594	2.219			Interm
P33	J73	5	92.78	0.918	0.9400	0.977			Interm
P33	J73	10	93.49	0.960	0.9727	0.987			Interm
P33	J73	7	93.24	1.004	0.9594	1.046			Interm
P33	J73	9	92.81	1.335	0.9693	1.377			Interm
P33	J73	7	93.53	1.371	0.9594	1.429			Interm
P33	J73	6	92.75	1.219	0.9515	1.281	93.17	1.459	Interm
P01	J07	5	92.50	0.217	0.9400	0.231			Surface
P01	J07	4	93.55	0.396	0.9213	0.430			Surface
P01	J07	6	93.19	0.346	0.9515	0.364			Surface
P01	J07	7	93.70	1.101	0.9594	1.148	93.24	0.543	Surface

Table B.2. Summary of Unbiased Lot Std Dev for Density for Each Interstate Paving Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P26	J62	8	93.39	2.154	0.9650	2.232			Surface
P26	J62	4	93.86	0.823	0.9213	0.893			Surface
P26	J62	3	92.48	0.295	0.8862	0.333			Surface
P26	J62	5	91.70	1.538	0.9400	1.636			Surface
P26	J62	5	92.81	1.195	0.9400	1.271			Surface
P26	J62	4	92.99	0.705	0.9213	0.765			Surface
P26	J62	5	93.07	0.878	0.9400	0.934			Surface
P26	J62	3	93.23	0.363	0.8862	0.410			Surface
P26	J62	5	92.05	0.931	0.9400	0.990	92.84	1.052	Surface
P26	J69	5	93.27	1.226	0.9400	1.304			Surface
P26	J69	6	93.00	2.265	0.9515	2.380			Surface
P26	J69	4	92.82	2.080	0.9213	2.258			Surface
P26	J69	5	94.13	0.564	0.9400	0.600			Surface
P26	J69	4	93.83	0.651	0.9213	0.707			Surface
P26	J69	5	94.29	0.664	0.9400	0.706			Surface
P26	J69	6	93.37	0.994	0.9515	1.045			Surface
P26	J69	5	93.10	0.721	0.9400	0.767			Surface
P26	J69	5	93.33	0.967	0.9400	1.029			Surface
P26	J69	5	93.26	1.282	0.9400	1.364			Surface
P26	J69	5	92.78	0.737	0.9400	0.784			Surface
P26	J69	6	92.38	1.020	0.9515	1.072			Surface
P26	J69	6	93.79	0.782	0.9515	0.822			Surface
P26	J69	6	94.38	0.674	0.9515	0.708			Surface
P26	J69	5	93.05	1.633	0.9400	1.737			Surface
P26	J69	3	93.54	0.650	0.8862	0.733	93.40	1.126	Surface
P32	J74	6	93.20	1.348	0.9515	1.417	93.20	1.417	Surface
P32	J79	10	93.03	0.817	0.9727	0.840			Surface
P32	J79	8	92.99	0.655	0.9650	0.679			Surface
P32	J79	10	92.98	1.174	0.9727	1.207			Surface
P32	J79	4	92.80	0.896	0.9213	0.973			Surface
P32	J79	10	92.78	0.706	0.9727	0.726			Surface
P32	J79	4	93.15	0.334	0.9213	0.363			Surface
P32	J79	8	93.03	0.520	0.9650	0.539			Surface
P32	J79	4	93.01	0.311	0.9213	0.338			Surface
P32	J79	9	92.53	1.713	0.9693	1.767			Surface
P32	J79	9	92.93	0.609	0.9693	0.628			Surface
P32	J79	11	92.77	0.489	0.9754	0.501			Surface
P32	J79	5	93.07	0.870	0.9400	0.926			Surface
P32	J79	5	91.26	0.663	0.9400	0.705			Surface
P32	J79	10	92.45	0.985	0.9727	1.013			Surface
P32	J79	6	92.21	1.104	0.9515	1.160			Surface
P32	J79	8	92.61	1.033	0.9650	1.070			Surface
P32	J79	5	92.50	0.479	0.9400	0.510			Surface
P32	J79	4	93.49	0.645	0.9213	0.700			Surface

Table B.2. Summary of Unbiased Lot Std Dev for Density for Each Interstate Paving Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P32	J79	7	93.26	1.135	0.9594	1.183			Surface
P32	J79	5	92.47	0.408	0.9400	0.434			Surface
P32	J79	7	92.97	0.617	0.9594	0.643			Surface
P32	J79	8	92.95	1.120	0.9650	1.161			Surface
P32	J79	6	92.05	1.201	0.9515	1.262			Surface
P32	J79	3	93.19	1.344	0.8862	1.517	92.77	0.868	Surface
P33	J77	8	91.71	0.736	0.9650	0.763			Surface
P33	J77	8	93.54	1.144	0.9650	1.185			Surface
P33	J77	7	93.78	0.594	0.9594	0.619			Surface
P33	J77	7	91.68	1.967	0.9594	2.050			Surface
P33	J77	6	92.03	1.454	0.9515	1.528			Surface
P33	J77	4	93.55	0.756	0.9213	0.821	92.72	1.161	Surface
P34	J62	5	94.03	1.002	0.9400	1.066			Surface
P34	J62	5	92.58	1.314	0.9400	1.398			Surface
P34	J62	10	91.67	1.927	0.9727	1.981			Surface
P34	J62	5	93.74	1.461	0.9400	1.554	93.01	1.500	Surface
P01	J07	5	92.70	0.369	0.9400	0.393			Surface
P01	J07	4	92.99	0.648	0.9213	0.703			Surface
P01	J07	3	92.53	0.217	0.8862	0.245			Surface
P01	J07	5	92.35	0.128	0.9400	0.136			Surface
P01	J07	3	93.28	1.109	0.8862	1.251	92.77	0.546	Surface
P03	J15	4	93.56	0.606	0.9213	0.658			Surface
P03	J15	4	92.49	0.801	0.9213	0.869			Surface
P03	J15	10	92.80	1.583	0.9727	1.627			Surface
P03	J15	4	93.97	0.692	0.9213	0.751			Surface
P03	J15	3	94.25	0.778	0.8862	0.878	93.41	0.957	Surface
P23	J63	3	92.76	0.487	0.8862	0.550			Surface
P23	J63	3	93.10	0.487	0.8862	0.550			Surface
P23	J63	3	92.83	0.487	0.8862	0.550			Surface
P23	J63	3	92.87	0.487	0.8862	0.550			Surface
P23	J63	3	93.40	0.637	0.8862	0.719			Surface
P23	J63	3	93.71	0.643	0.8862	0.726	93.11	0.607	Surface
P32	J72	12	93.05	0.726	0.9776	0.743			Surface
P32	J72	14	92.89	0.641	0.9810	0.653			Surface
P32	J72	5	92.30	0.783	0.9400	0.833			Surface
P32	J72	5	93.40	1.298	0.9400	1.381			Surface
P32	J72	10	93.33	1.303	0.9727	1.340			Surface
P32	J72	9	93.61	0.525	0.9693	0.542			Surface
P32	J72	6	93.01	0.647	0.9515	0.680			Surface
P32	J72	9	92.86	0.642	0.9693	0.662	93.06	0.854	Surface

Table B.3. Summary of Unbiased Lot Std Dev for Density for Each Other Paving Project

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P01	J23	5	93.68	0.970	0.9400	1.032			Interm
P01	J23	3	93.86	1.572	0.8862	1.774	93.77	1.403	Interm
P03	J04	5	93.11	1.170	0.9400	1.245			Interm
P03	J04	4	94.31	1.150	0.9213	1.248			Interm
P03	J04	12	94.61	0.729	0.9776	0.746			Interm
P03	J04	3	93.93	0.615	0.8862	0.694			Interm
P03	J04	6	91.99	1.267	0.9515	1.332	93.59	1.053	Interm
P36	J09	3	93.06	0.318	0.8862	0.359			Interm
P36	J09	3	93.17	1.364	0.8862	1.539			Interm
P36	J09	7	92.51	1.445	0.9594	1.506			Interm
P36	J09	4	92.71	1.943	0.9213	2.109			Interm
P36	J09	4	92.71	1.943	0.9213	2.109	92.83	1.524	Interm
P06	J26	14	90.05	1.159	0.9810	1.181	90.05	1.181	Surface
P06	J24	6	90.44	1.455	0.9515	1.529			Surface
P06	J24	6	89.83	1.669	0.9515	1.754			Surface
P06	J24	5	92.36	0.481	0.9400	0.512			Surface
P06	J24	4	93.37	0.565	0.9213	0.613			Surface
P06	J24	4	92.45	0.522	0.9213	0.567	91.69	0.995	Surface
P04	J14	8	88.73	1.624	0.9650	1.683			Surface
P04	J14	8	90.28	0.605	0.9650	0.627			Surface
P04	J14	6	90.08	1.271	0.9515	1.336			Surface
P04	J14	9	89.95	1.186	0.9693	1.224			Surface
P04	J14	5	89.94	1.356	0.9400	1.443	89.80	1.262	Surface
P08	J11	8	88.65	1.161	0.9650	1.203	88.65	1.203	Surface
P27	J55	5	92.71	0.546	0.9400	0.581			Surface
P27	J55	6	91.83	0.863	0.9515	0.907			Surface
P27	J55	7	92.50	0.504	0.9594	0.525			Surface
P27	J55	6	92.15	0.489	0.9515	0.514	92.30	0.632	Surface
P27	J70	5	93.22	1.498	0.9400	1.594			Surface
P27	J70	7	93.36	0.949	0.9594	0.989			Surface
P27	J70	4	92.32	0.559	0.9213	0.607			Surface
P27	J70	5	92.75	1.001	0.9400	1.065			Surface
P27	J70	3	93.38	0.757	0.8862	0.854			Surface
P27	J70	6	92.70	1.092	0.9515	1.148			Surface
P27	J70	3	92.72	1.222	0.8862	1.379	92.92	1.091	Surface
P30	J65	5	93.57	3.130	0.9400	3.330			Surface
P30	J65	3	94.02	0.575	0.8862	0.649	93.80	1.989	Surface
P31	J71	5	94.06	0.286	0.9400	0.304			Surface
P31	J71	3	94.24	0.822	0.8862	0.928	94.15	0.616	Surface

Table B.3. Summary of Unbiased Lot Std Dev for Density for Each Other Paving Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P13	J03	9	92.01	1.519	0.9693	1.567	92.01	1.567	Surface
P14	J16	6	92.68	1.456	0.9515	1.530			Surface
P14	J16	7	92.92	1.035	0.9594	1.079			Surface
P14	J16	6	92.73	0.722	0.9515	0.759			Surface
P14	J16	10	91.75	1.788	0.9727	1.838			Surface
P14	J16	5	92.12	0.600	0.9400	0.638			Surface
P14	J16	4	93.07	1.135	0.9213	1.232	92.55	1.179	Surface
P15	J44	3	92.75	0.751	0.8862	0.847			Surface
P15	J44	3	92.56	0.751	0.8862	0.847			Surface
P15	J44	4	92.60	1.908	0.9213	2.071			Surface
P15	J44	4	92.90	1.919	0.9213	2.083			Surface
P15	J44	4	92.60	1.908	0.9213	2.071	92.68	1.584	Surface
P16	J20	4	91.38	1.445	0.9213	1.568			Surface
P16	J20	4	91.15	0.527	0.9213	0.572			Surface
P16	J20	4	92.22	0.967	0.9213	1.050	91.58	1.063	Surface
P18	J48	7	91.62	1.883	0.9594	1.963			Surface
P18	J48	3	92.01	1.960	0.8862	2.212			Surface
P18	J48	8	91.31	1.884	0.9650	1.952	91.65	2.042	Surface
P20	J50	11	92.63	0.936	0.9754	0.960			Surface
P20	J50	12	91.85	0.850	0.9776	0.869			Surface
P20	J50	11	92.17	0.916	0.9754	0.939			Surface
P20	J50	7	92.43	0.866	0.9594	0.903			Surface
P20	J50	8	92.72	1.239	0.9650	1.284			Surface
P20	J50	8	92.80	1.000	0.9650	1.036			Surface
P20	J50	10	92.36	0.610	0.9727	0.627	92.42	0.945	Surface
P24	J56	11	92.90	1.636	0.9754	1.677			Surface
P24	J56	4	93.80	0.637	0.9213	0.691			Surface
P24	J56	6	93.54	1.088	0.9515	1.143			Surface
P24	J56	8	92.57	0.825	0.9650	0.855			Surface
P24	J56	9	93.37	0.894	0.9693	0.922			Surface
P24	J56	9	93.15	0.629	0.9693	0.649			Surface
P24	J56	9	93.05	1.037	0.9693	1.070	93.20	1.001	Surface
P26	J59	6	91.69	0.945	0.9515	0.993			Surface
P26	J59	8	92.09	0.961	0.9650	0.996			Surface
P26	J59	7	90.40	1.338	0.9594	1.395			Surface
P26	J59	11	90.59	1.235	0.9754	1.266			Surface
P26	J59	6	91.16	0.706	0.9515	0.742			Surface
P26	J59	7	91.09	0.841	0.9594	0.877			Surface
P26	J59	8	90.06	1.795	0.9650	1.860			Surface
P26	J59	2	92.64	0.983	0.7979	1.232	91.22	1.170	Surface
P28	J39	7	92.98	0.999	0.9594	1.041			Surface
P28	J39	11	93.37	1.278	0.9754	1.310			Surface
P28	J39	7	93.27	1.861	0.9594	1.940			Surface
P28	J39	3	93.49	0.600	0.8862	0.677	93.56	0.848	Surface

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P01	J01	6	-0.023	0.209	0.9515	0.220			Base
P01	J01	4	0.195	0.227	0.9213	0.246			Base
P01	J01	3	0.193	0.291	0.8862	0.329			Base
P01	J01	3	0.213	0.135	0.8862	0.152			Base
P01	J01	1	-0.360	–	–	–			Base
P01	J01	2	-0.110	0.057	0.7979	0.071			Base
P01	J01	1	0.220	–	–	–			Base
P01	J01	2	-0.010	0.113	0.7979	0.142	0.040	0.193	Base
P01	J02	6	0.067	0.172	0.9515	0.180			Interm
P01	J02	3	0.253	0.145	0.8862	0.164			Interm
P01	J02	2	0.160	0.184	0.7979	0.230			Interm
P01	J02	1	-0.020	–	–	–	0.115	0.191	Interm
P01	J06	3	0.220	0.147	0.8862	0.166			Base
P01	J06	4	0.048	0.239	0.9213	0.259			Base
P01	J06	2	0.015	0.262	0.7979	0.328	0.094	0.251	Base
P01	J07	3	0.120	0.190	0.8862	0.214			Surface
P01	J07	3	0.013	0.146	0.8862	0.164			Surface
P01	J07	5	-0.052	0.237	0.9400	0.252			Surface
P01	J07	3	0.037	0.096	0.8862	0.108			Surface
P01	J07	3	0.073	0.163	0.8862	0.184			Surface
P01	J07	1	-0.180	–	–	–			Surface
P01	J07	3	0.003	0.198	0.8862	0.223			Surface
P01	J07	5	-0.208	0.122	0.9400	0.130			Surface
P01	J07	4	0.003	0.159	0.9213	0.173	-0.021	0.181	Surface
P01	J10	3	0.117	0.119	0.8862	0.135			Interm
P01	J10	1	0.290	–	–	–			Interm
P01	J10	1	-0.440	–	–	–			Interm
P01	J10	4	-0.023	0.273	0.9213	0.297			Interm
P01	J10	3	-0.013	0.103	0.8862	0.116			Interm
P01	J10	1	0.140	–	–	–			Interm
P01	J10	3	-0.190	0.087	0.8862	0.098			Interm
P01	J10	1	0.180	–	–	–			Interm
P01	J10	1	0.130	–	–	–			Interm
P01	J10	1	-0.070	–	–	–			Interm
P01	J10	2	0.240	0.269	0.7979	0.337			Interm
P01	J10	2	0.075	0.035	0.7979	0.044			Interm
P01	J10	4	0.043	0.083	0.9213	0.090			Interm
P01	J10	2	0.180	0.071	0.7979	0.089			Interm
P01	J10	2	0.035	0.134	0.7979	0.168			Interm
P01	J10	3	0.050	0.226	0.8862	0.255			Interm
P01	J10	2	-0.235	0.049	0.7979	0.062			Interm
P01	J10	3	-0.217	0.160	0.8862	0.181	0.016	0.156	Interm
P01	J18	4	-0.103	0.254	0.9213	0.276			Base
P01	J18	3	-0.010	0.036	0.8862	0.041			Base
P01	J18	4	0.045	0.230	0.9213	0.250			Base
P01	J18	4	0.010	0.054	0.9213	0.058			Base
P01	J18	3	-0.040	0.135	0.8862	0.152			Base

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P01	J18	3	0.123	0.280	0.8862	0.316			Base
P01	J18	3	0.107	0.496	0.8862	0.559			Base
P01	J18	4	-0.118	0.127	0.9213	0.138			Base
P01	J18	2	-0.130	0.410	0.7979	0.514			Base
P01	J18	1	-0.160	–	–	–			Base
P01	J18	4	0.040	0.305	0.9213	0.331			Base
P01	J18	1	-0.520	–	–	–			Base
P01	J18	2	-0.035	0.290	0.7979	0.363			Base
P01	J18	2	0.615	0.445	0.7979	0.558			Base
P01	J18	1	0.190	–	–	–			Base
P01	J18	1	-0.280	–	–	–			Base
P01	J18	1	-0.090	–	–	–			Base
P01	J18	4	-0.355	0.211	0.9213	0.229			Base
P01	J18	3	0.000	0.121	0.8862	0.137			Base
P01	J18	2	0.070	0.014	0.7979	0.018			Base
P01	J18	2	-0.270	0.170	0.7979	0.213			Base
P01	J18	1	-0.110	–	–	–			Base
P01	J18	2	-0.045	0.106	0.7979	0.133			Base
P01	J18	2	0.160	0.099	0.7979	0.124			Base
P01	J18	3	-0.160	0.180	0.8862	0.203			Base
P01	J18	4	-0.075	0.184	0.9213	0.199			Base
P01	J18	3	-0.020	0.164	0.8862	0.185			Base
P01	J18	2	0.025	0.219	0.7979	0.275			Base
P01	J18	2	-0.270	0.141	0.7979	0.177			Base
P01	J18	2	-0.180	0.014	0.7979	0.018			Base
P01	J18	2	-0.140	0.141	0.7979	0.177			Base
P01	J18	2	-0.055	0.134	0.7979	0.168			Base
P01	J18	3	-0.080	0.201	0.8862	0.227	-0.056	0.224	Base
P01	J19	1	0.020	–	–	–			Surface
P01	J19	1	0.260	–	–	–			Surface
P01	J19	2	-0.030	0.042	0.7979	0.053			Surface
P01	J19	2	-0.095	0.078	0.7979	0.097			Surface
P01	J19	1	0.020	–	–	–			Surface
P01	J19	1	0.140	–	–	–			Surface
P01	J19	1	0.140	–	–	–			Surface
P01	J19	1	0.220	–	–	–			Surface
P01	J19	2	0.100	0.156	0.7979	0.195			Surface
P01	J19	1	0.020	–	–	–			Surface
P01	J19	1	0.010	–	–	–			Surface
P01	J19	2	0.105	0.191	0.7979	0.239			Surface
P01	J19	1	0.410	–	–	–			Surface
P01	J19	1	0.090	–	–	–	0.101	0.146	Surface
P01	J21	1	0.320	–	–	–			Base
P01	J21	1	0.170	–	–	–			Base
P01	J21	3	0.137	0.119	0.8862	0.135			Base
P01	J21	3	0.003	0.232	0.8862	0.261			Base
P01	J21	1	0.370	–	–	–			Base

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P01	J21	3	0.017	0.340	0.8862	0.383			Base
P01	J21	3	0.240	0.384	0.8862	0.433			Base
P01	J21	1	0.060	–	–	–			Base
P01	J21	1	0.000	–	–	–			Base
P01	J21	2	0.020	0.665	0.7979	0.833			Base
P01	J21	1	0.360	–	–	–			Base
P01	J21	1	-0.050	–	–	–			Base
P01	J21	1	0.320	–	–	–			Base
P01	J21	3	0.110	0.241	0.8862	0.272			Base
P01	J21	2	-0.090	0.028	0.7979	0.035	0.132	0.336	Base
P01	J23	4	0.285	0.222	0.9213	0.241			Interm
P01	J23	3	-0.083	0.422	0.8862	0.476			Interm
P01	J23	1	-0.060	–	–	–			Interm
P01	J23	2	0.010	0.424	0.7979	0.532			Interm
P01	J23	1	0.330	–	–	–			Interm
P01	J23	1	0.080	–	–	–	0.094	0.417	Interm
P02	J04	4	0.185	0.145	0.9213	0.157			Interm
P02	J04	1	0.250	–	–	–			Interm
P02	J04	2	0.030	0.042	0.7979	0.053			Interm
P02	J04	2	0.250	0.184	0.7979	0.230			Interm
P02	J04	4	0.113	0.171	0.9213	0.186			Interm
P02	J04	1	0.780	–	–	–			Interm
P02	J04	4	0.038	0.186	0.9213	0.202			Interm
P02	J04	1	0.360	–	–	–			Interm
P02	J04	1	0.380	–	–	–			Interm
P02	J04	2	0.030	0.269	0.7979	0.337			Interm
P02	J04	3	0.087	0.270	0.8862	0.304			Interm
P02	J04	1	0.210	–	–	–			Interm
P02	J04	1	-0.090	–	–	–			Interm
P02	J04	3	-0.080	0.209	0.8862	0.236	0.182	0.213	Interm
P02	J05	2	-0.005	0.021	0.7979	0.027			Surface
P02	J05	1	-0.070	–	–	–			Surface
P02	J05	2	0.035	0.106	0.7979	0.133			Surface
P02	J05	1	-0.120	–	–	–			Surface
P02	J05	1	-0.190	–	–	–			Surface
P02	J05	1	0.280	–	–	–	-0.012	0.080	Surface
P02	J09	1	0.220	–	–	–			Interm
P02	J09	2	0.030	0.071	0.7979	0.089			Interm
P02	J09	1	0.430	–	–	–			Interm
P02	J09	3	0.290	0.358	0.8862	0.404			Interm
P02	J09	2	-0.090	0.283	0.7979	0.354			Interm
P02	J09	2	0.150	0.127	0.7979	0.160			Interm
P02	J09	1	-0.450	–	–	–			Interm
P02	J09	1	0.100	–	–	–			Interm
P02	J09	2	-0.125	0.078	0.7979	0.097			Interm
P02	J09	3	0.240	0.121	0.8862	0.137			Interm
P02	J09	2	-0.140	0.014	0.7979	0.018			Interm

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P02	J09	2	-0.160	0.255	0.7979	0.319			Interm
P02	J09	1	0.210	–	–	–			Interm
P02	J09	4	0.055	0.210	0.9213	0.227			Interm
P02	J09	2	-0.230	0.057	0.7979	0.071			Interm
P02	J09	1	-0.180	–	–	–			Interm
P02	J09	2	-0.050	0.099	0.7979	0.124			Interm
P02	J09	2	-0.085	0.375	0.7979	0.470	0.012	0.206	Interm
P02	J13	1	0.190	–	–	–			Surface
P02	J13	1	-0.020	–	–	–			Surface
P02	J13	2	0.215	0.007	0.7979	0.009			Surface
P02	J13	1	0.180	–	–	–			Surface
P02	J13	1	-0.180	–	–	–			Surface
P02	J13	1	0.390	–	–	–			Surface
P02	J13	2	-0.330	0.113	0.7979	0.142			Surface
P02	J13	1	-0.350	–	–	–			Surface
P02	J13	1	-0.330	–	–	–			Surface
P02	J13	1	-0.170	–	–	–			Surface
P02	J13	1	0.000	–	–	–			Surface
P02	J13	2	-0.470	0.156	0.7979	0.195			Surface
P02	J13	2	0.000	0.085	0.7979	0.106			Surface
P02	J13	1	0.430	–	–	–	-0.032	0.113	Surface
P02	J15	1	0.320	–	–	–			Surface
P02	J15	4	0.000	0.108	0.9213	0.117			Surface
P02	J15	4	-0.165	0.078	0.9213	0.084			Surface
P02	J15	5	0.042	0.277	0.9400	0.294			Surface
P02	J15	3	-0.097	0.165	0.8862	0.186			Surface
P02	J15	1	0.200	–	–	–	0.050	0.171	Surface
P02	J17	3	-0.070	0.191	0.8862	0.215			Base
P02	J17	4	0.030	0.432	0.9213	0.469			Base
P02	J17	3	0.110	0.311	0.8862	0.351			Base
P02	J17	3	-0.200	0.101	0.8862	0.115			Base
P02	J17	3	-0.017	0.410	0.8862	0.463			Base
P02	J17	1	0.160	–	–	–	0.002	0.322	Base
P02	J28	3	0.053	0.205	0.8862	0.231			Base
P02	J28	3	0.070	0.044	0.8862	0.049			Base
P02	J28	1	0.030	–	–	–			Base
P02	J28	1	0.000	–	–	–			Base
P02	J28	2	-0.145	0.318	0.7979	0.399			Base
P02	J28	4	0.018	0.340	0.9213	0.369			Base
P02	J28	3	0.167	0.154	0.8862	0.173			Base
P02	J28	4	0.093	0.160	0.9213	0.173			Base
P02	J28	3	0.117	0.032	0.8862	0.036			Base
P02	J28	1	-0.070	–	–	–			Base
P02	J28	3	-0.187	0.031	0.8862	0.034			Base
P02	J28	1	0.790	–	–	–			Base
P02	J28	1	-0.410	–	–	–	0.040	0.183	Base
P04	J08	2	0.060	0.071	0.7979	0.089			Interm

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P04	J08	2	0.185	0.332	0.7979	0.417			Interm
P04	J08	1	0.530	–	–	–			Interm
P04	J08	2	-0.060	0.028	0.7979	0.035			Interm
P04	J08	2	-0.105	0.460	0.7979	0.576			Interm
P04	J08	2	0.320	0.141	0.7979	0.177			Interm
P04	J08	2	-0.055	0.629	0.7979	0.789			Interm
P04	J08	2	0.370	0.014	0.7979	0.018			Interm
P04	J08	2	0.320	0.255	0.7979	0.319			Interm
P04	J08	2	0.465	0.389	0.7979	0.487			Interm
P04	J08	2	0.125	0.007	0.7979	0.009	0.196	0.292	Interm
P04	J14	3	-0.123	0.150	0.8862	0.170			Surface
P04	J14	4	0.078	0.165	0.9213	0.179			Surface
P04	J14	4	0.110	0.243	0.9213	0.263			Surface
P04	J14	3	0.073	0.226	0.8862	0.255			Surface
P04	J14	3	0.150	0.140	0.8862	0.158	0.058	0.205	Surface
P05	J25	1	-0.410	–	–	–			Surface
P05	J25	1	-0.020	–	–	–			Surface
P05	J25	1	-0.110	–	–	–			Surface
P05	J25	1	-0.110	–	–	–			Surface
P05	J25	1	-0.250	–	–	–			Surface
P05	J25	1	0.210	–	–	–			Surface
P05	J25	1	-0.130	–	–	–			Surface
P05	J25	1	-0.230	–	–	–	-0.131	–	Surface
P05	J27	2	-0.130	0.269	0.7979	0.337			Interm
P05	J27	2	-0.035	0.021	0.7979	0.027			Interm
P05	J27	2	-0.040	0.156	0.7979	0.195			Interm
P05	J27	2	-0.190	0.042	0.7979	0.053			Interm
P05	J27	2	-0.090	0.099	0.7979	0.124			Interm
P05	J27	2	-0.090	0.042	0.7979	0.053			Interm
P05	J27	1	-0.140	–	–	–			Interm
P05	J27	2	-0.245	0.205	0.7979	0.257	-0.120	0.149	Interm
P05	J40	3	-0.197	0.235	0.8862	0.265			Surface
P05	J40	3	-0.113	0.071	0.8862	0.080			Surface
P05	J40	1	-0.320	–	–	–			Surface
P05	J40	1	-0.070	–	–	–			Surface
P05	J40	1	0.110	–	–	–	-0.118	0.173	Surface
P06	J24	3	-0.153	0.055	0.8862	0.062			Surface
P06	J24	3	0.127	0.228	0.8862	0.257			Surface
P06	J24	3	0.137	0.095	0.8862	0.107			Surface
P06	J24	3	0.120	0.046	0.8862	0.052			Surface
P06	J24	3	0.093	0.214	0.8862	0.241	0.065	0.144	Surface
P07	J30	3	-0.073	0.042	0.8862	0.047			Surface
P07	J30	1	-0.060	–	–	–			Surface
P07	J30	1	-0.170	–	–	–			Surface
P07	J30	1	-0.120	–	–	–			Surface
P07	J30	4	0.065	0.353	0.9213	0.384			Surface
P07	J30	2	-0.060	0.042	0.7979	0.053			Surface

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P07	J30	2	-0.010	0.014	0.7979	0.018			Surface
P07	J30	1	-0.150	–	–	–			Surface
P07	J30	3	-0.127	0.075	0.8862	0.085			Surface
P07	J30	3	-0.067	0.131	0.8862	0.147			Surface
P07	J30	3	-0.027	0.110	0.8862	0.124			Surface
P07	J30	3	-0.183	0.060	0.8862	0.068			Surface
P07	J30	2	-0.070	0.085	0.7979	0.106			Surface
P07	J30	3	-0.210	0.070	0.8862	0.079			Surface
P07	J30	3	-0.213	0.021	0.8862	0.023			Surface
P07	J30	1	-0.080	–	–	–			Surface
P07	J30	2	-0.170	0.085	0.7979	0.106			Surface
P07	J30	1	-0.250	–	–	–			Surface
P07	J30	1	0.130	–	–	–	-0.097	0.103	Surface
P09	J35	3	-0.113	0.225	0.8862	0.254			Surface
P09	J35	3	0.047	0.031	0.8862	0.034			Surface
P09	J35	3	0.013	0.103	0.8862	0.116	-0.018	0.135	Surface
P09	J83	3	-0.107	0.290	0.8862	0.327			Surface
P09	J83	3	-0.023	0.166	0.8862	0.187			Surface
P09	J83	2	0.030	0.042	0.7979	0.053	-0.033	0.189	Surface
P10	J12	1	0.540	–	–	–			Surface
P10	J12	1	0.030	–	–	–			Surface
P10	J12	1	0.330	–	–	–			Surface
P10	J12	2	0.225	0.106	0.7979	0.133			Surface
P10	J12	1	-0.320	–	–	–			Surface
P10	J12	1	-0.290	–	–	–			Surface
P10	J12	1	-0.230	–	–	–			Surface
P10	J12	1	-0.320	–	–	–			Surface
P10	J12	2	0.070	0.396	0.7979	0.496			Surface
P10	J12	2	0.020	0.042	0.7979	0.053			Surface
P10	J12	2	-0.210	0.057	0.7979	0.071			Surface
P10	J12	2	-0.250	0.042	0.7979	0.053			Surface
P10	J12	2	-0.080	0.354	0.7979	0.443	-0.037	0.208	Surface
P10	J31	2	-0.035	0.205	0.7979	0.257			Interm
P10	J31	2	0.300	0.311	0.7979	0.390			Interm
P10	J31	2	-0.045	0.332	0.7979	0.417			Interm
P10	J31	2	-0.290	0.297	0.7979	0.372			Interm
P10	J31	1	-0.030	–	–	–			Interm
P10	J31	2	-0.130	0.255	0.7979	0.319			Interm
P10	J31	2	0.075	0.106	0.7979	0.133			Interm
P10	J31	1	0.410	–	–	–			Interm
P10	J31	2	0.100	0.240	0.7979	0.301			Interm
P10	J31	2	-0.385	0.021	0.7979	0.027			Interm
P10	J31	2	-0.005	0.021	0.7979	0.027			Interm
P10	J31	2	0.095	0.049	0.7979	0.062			Interm
P10	J31	2	0.180	0.057	0.7979	0.071			Interm
P10	J31	2	0.045	0.403	0.7979	0.505			Interm
P10	J31	2	-0.050	0.481	0.7979	0.603			Interm

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P10	J31	2	-0.155	0.021	0.7979	0.027			Interm
P10	J31	2	0.255	0.318	0.7979	0.399			Interm
P10	J31	2	-0.040	0.467	0.7979	0.585			Interm
P10	J31	2	-0.125	0.021	0.7979	0.027			Interm
P10	J31	2	-0.030	0.071	0.7979	0.089			Interm
P10	J31	2	0.060	0.495	0.7979	0.620			Interm
P10	J31	1	0.340	–	–	–			Interm
P10	J31	2	0.060	0.523	0.7979	0.656			Interm
P10	J31	2	0.000	0.212	0.7979	0.266			Interm
P10	J31	2	-0.165	0.361	0.7979	0.452			Interm
P10	J31	2	0.055	0.148	0.7979	0.186			Interm
P10	J31	1	0.070	–	–	–			Interm
P10	J31	2	-0.225	0.290	0.7979	0.363			Interm
P10	J31	2	-0.010	0.255	0.7979	0.319			Interm
P10	J31	2	0.080	0.113	0.7979	0.142			Interm
P10	J31	2	-0.230	0.410	0.7979	0.514			Interm
P10	J31	2	0.060	0.042	0.7979	0.053			Interm
P10	J31	2	-0.010	0.156	0.7979	0.195			Interm
P10	J31	2	0.145	0.177	0.7979	0.222			Interm
P10	J31	2	0.180	0.071	0.7979	0.089			Interm
P10	J31	2	0.225	0.177	0.7979	0.222			Interm
P10	J31	2	-0.250	0.368	0.7979	0.461			Interm
P10	J31	2	0.270	0.184	0.7979	0.230			Interm
P10	J31	2	-0.020	0.537	0.7979	0.674			Interm
P10	J31	2	0.095	0.375	0.7979	0.470			Interm
P10	J31	1	0.040	–	–	–	0.022	0.298	Interm
P10	J37	1	0.140	–	–	–			Interm
P10	J37	2	-0.015	0.007	0.7979	0.009			Interm
P10	J37	2	0.125	0.134	0.7979	0.168			Interm
P10	J37	2	-0.145	0.219	0.7979	0.275			Interm
P10	J37	2	-0.070	0.311	0.7979	0.390			Interm
P10	J37	1	0.260	–	–	–			Interm
P10	J37	2	0.180	0.184	0.7979	0.230			Interm
P10	J37	2	0.185	0.276	0.7979	0.346			Interm
P10	J37	2	0.085	0.120	0.7979	0.151			Interm
P10	J37	2	-0.230	0.028	0.7979	0.035			Interm
P10	J37	2	0.185	0.049	0.7979	0.062			Interm
P10	J37	2	-0.225	0.078	0.7979	0.097	0.040	0.176	Interm
P10	J82	2	-0.270	0.028	0.7979	0.035			Interm
P10	J82	2	-0.145	0.106	0.7979	0.133			Interm
P10	J82	2	0.125	0.177	0.7979	0.222			Interm
P10	J82	2	0.025	0.120	0.7979	0.151			Interm
P10	J82	2	-0.105	0.148	0.7979	0.186			Interm
P10	J82	1	0.090	–	–	–			Interm
P10	J82	2	0.260	0.042	0.7979	0.053			Interm
P10	J82	2	-0.170	0.099	0.7979	0.124	-0.024	0.129	Interm
P11	J41	3	-0.107	0.156	0.8862	0.176			Surface

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P11	J41	1	0.030	–	–	–			Surface
P11	J41	2	0.230	0.042	0.7979	0.053			Surface
P11	J41	4	0.135	0.117	0.9213	0.127	0.072	0.119	Surface
P12	J38	4	-0.058	0.196	0.9213	0.213			Surface
P12	J38	2	0.270	0.071	0.7979	0.089			Surface
P12	J38	1	0.200	–	–	–			Surface
P12	J38	1	-0.130	–	–	–			Surface
P12	J38	3	0.043	0.114	0.8862	0.128			Surface
P12	J38	3	0.080	0.183	0.8862	0.207	0.068	0.159	Surface
P13	J03	3	0.030	0.176	0.8862	0.198			Surface
P13	J03	3	-0.130	0.399	0.8862	0.450			Surface
P13	J03	1	-0.430	–	–	–			Surface
P13	J03	3	0.187	0.360	0.8862	0.406			Surface
P13	J03	1	-0.060	–	–	–			Surface
P13	J03	1	0.020	–	–	–			Surface
P13	J03	3	0.017	0.224	0.8862	0.252			Surface
P13	J03	1	0.000	–	–	–	-0.046	0.327	Surface
P13	J43	2	0.240	0.099	0.7979	0.124			Surface
P13	J43	2	0.020	0.057	0.7979	0.071			Surface
P13	J43	2	0.010	0.085	0.7979	0.106			Surface
P13	J43	2	-0.120	0.170	0.7979	0.213			Surface
P13	J43	3	0.120	0.159	0.8862	0.179			Surface
P13	J43	4	-0.043	0.134	0.9213	0.145			Surface
P13	J43	3	-0.133	0.067	0.8862	0.075			Surface
P13	J43	1	-0.110	–	–	–	-0.002	0.130	Surface
P14	J16	1	-0.450	–	–	–			Surface
P14	J16	2	-0.215	0.078	0.7979	0.097			Surface
P14	J16	3	-0.263	0.261	0.8862	0.294			Surface
P14	J16	2	0.005	0.163	0.7979	0.204			Surface
P14	J16	1	-0.060	–	–	–			Surface
P14	J16	4	-0.043	0.143	0.9213	0.155			Surface
P14	J16	3	-0.023	0.064	0.8862	0.073			Surface
P14	J16	4	-0.330	0.178	0.9213	0.193			Surface
P14	J16	4	-0.228	0.370	0.9213	0.402			Surface
P14	J16	2	-0.275	0.205	0.7979	0.257			Surface
P14	J16	1	-0.290	–	–	–			Surface
P14	J16	2	0.020	0.127	0.7979	0.160			Surface
P14	J16	3	-0.223	0.091	0.8862	0.102	-0.183	0.194	Surface
P16	J20	3	-0.297	0.101	0.8862	0.114			Surface
P16	J20	3	-0.250	0.314	0.8862	0.355			Surface
P16	J20	3	0.003	0.144	0.8862	0.162	-0.181	0.210	Surface
P17	J22	2	0.205	0.035	0.7979	0.044			Interm
P17	J22	2	-0.055	0.064	0.7979	0.080			Interm
P17	J22	2	0.090	0.028	0.7979	0.035			Interm
P17	J22	1	-0.250	–	–	–			Interm
P17	J22	2	-0.050	0.113	0.7979	0.142			Interm
P17	J22	2	-0.045	0.686	0.7979	0.860	-0.018	0.232	Interm

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P18	J48	1	0.520	–	–	–			Surface
P18	J48	3	0.123	0.071	0.8862	0.080			Surface
P18	J48	1	-0.050	–	–	–			Surface
P18	J48	2	0.205	0.064	0.7979	0.080			Surface
P18	J48	3	0.037	0.311	0.8862	0.351			Surface
P18	J48	1	0.080	–	–	–			Surface
P18	J48	1	-0.100	–	–	–	0.116	0.170	Surface
P19	J49	2	-0.065	0.078	0.7979	0.097			Surface
P19	J49	1	-0.130	–	–	–			Surface
P19	J49	3	0.023	0.208	0.8862	0.235			Surface
P19	J49	4	0.085	0.085	0.9213	0.093			Surface
P19	J49	4	-0.305	0.449	0.9213	0.487			Surface
P19	J49	3	0.037	0.106	0.8862	0.120			Surface
P19	J49	3	-0.197	0.205	0.8862	0.231	-0.079	0.210	Surface
P20	J50	1	0.380	–	–	–			Surface
P20	J50	5	-0.118	0.186	0.9400	0.198			Surface
P20	J50	2	-0.225	0.375	0.7979	0.470			Surface
P20	J50	4	-0.093	0.051	0.9213	0.056			Surface
P20	J50	1	0.030	–	–	–			Surface
P20	J50	2	0.135	0.064	0.7979	0.080			Surface
P20	J50	5	0.142	0.134	0.9400	0.142			Surface
P20	J50	3	0.067	0.172	0.8862	0.195			Surface
P20	J50	1	0.340	–	–	–			Surface
P20	J50	1	-0.120	–	–	–			Surface
P20	J50	5	0.072	0.164	0.9400	0.174			Surface
P20	J50	1	-0.100	–	–	–			Surface
P20	J50	2	0.195	0.134	0.7979	0.168			Surface
P20	J50	4	0.035	0.066	0.9213	0.072			Surface
P20	J50	5	-0.142	0.156	0.9400	0.166			Surface
P20	J50	2	0.255	0.148	0.7979	0.186			Surface
P20	J50	2	-0.030	0.057	0.7979	0.071	0.048	0.165	Surface
P21	J34	4	0.240	0.128	0.9213	0.139			Interm
P21	J34	3	-0.020	0.106	0.8862	0.119			Interm
P21	J34	1	-0.080	–	–	–	0.047	0.129	Interm
P21	J39	1	0.090	–	–	–			Surface
P21	J39	4	0.073	0.025	0.9213	0.027			Surface
P21	J39	2	0.085	0.035	0.7979	0.044			Surface
P21	J39	4	-0.030	0.116	0.9213	0.126			Surface
P21	J39	3	-0.093	0.207	0.8862	0.234			Surface
P21	J39	1	-0.140	–	–	–	-0.003	0.108	Surface
P22	J54	6	0.070	0.107	0.9515	0.112			Surface
P22	J54	5	0.004	0.009	0.9400	0.010			Surface
P22	J54	1	0.120	–	–	–	0.065	0.061	Surface
P24	J51	1	-0.040	–	–	–			Interm
P24	J51	2	0.100	0.113	0.7979	0.142			Interm
P24	J51	1	0.290	–	–	–			Interm
P24	J51	1	0.390	–	–	–			Interm

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P24	J51	2	-0.105	0.219	0.7979	0.275			Interm
P24	J51	1	0.060	–	–	–			Interm
P24	J51	2	-0.035	0.007	0.7979	0.009			Interm
P24	J51	2	0.155	0.304	0.7979	0.381			Interm
P24	J51	2	-0.095	0.049	0.7979	0.062			Interm
P24	J51	1	0.020	–	–	–			Interm
P24	J51	2	-0.035	0.106	0.7979	0.133			Interm
P24	J51	2	-0.030	0.198	0.7979	0.248			Interm
P24	J51	1	0.010	–	–	–			Interm
P24	J51	2	0.020	0.156	0.7979	0.195			Interm
P24	J51	1	-0.020	–	–	–	0.046	0.181	Interm
P24	J56	1	-0.360	–	–	–			Surface
P24	J56	5	-0.042	0.095	0.9400	0.101			Surface
P24	J56	1	-0.010	–	–	–			Surface
P24	J56	3	0.060	0.157	0.8862	0.177			Surface
P24	J56	1	-1.020	–	–	–			Surface
P24	J56	3	1.793	0.318	0.8862	0.359			Surface
P24	J56	1	0.180	–	–	–			Surface
P24	J56	1	0.230	–	–	–			Surface
P24	J56	3	0.043	0.219	0.8862	0.248			Surface
P24	J56	1	0.140	–	–	–			Surface
P24	J56	4	0.168	0.388	0.9213	0.421			Surface
P24	J56	2	0.045	0.007	0.7979	0.009			Surface
P24	J56	1	0.080	–	–	–			Surface
P24	J56	3	-0.133	0.154	0.8862	0.173			Surface
P24	J56	1	0.010	–	–	–			Surface
P24	J56	2	0.045	0.247	0.7979	0.310			Surface
P24	J56	4	0.070	0.112	0.9213	0.121			Surface
P24	J56	3	0.067	0.214	0.8862	0.241	0.076	0.216	Surface
P24	J57	2	0.065	0.049	0.7979	0.062			Base
P24	J57	2	0.135	0.064	0.7979	0.080			Base
P24	J57	2	0.025	0.078	0.7979	0.097			Base
P24	J57	2	0.070	0.014	0.7979	0.018			Base
P24	J57	2	0.230	0.042	0.7979	0.053			Base
P24	J57	2	0.300	0.000	0.7979	0.000	0.138	0.052	Base
P24	J64	1	0.160	–	–	–			Surface
P24	J64	2	0.215	0.064	0.7979	0.080			Surface
P24	J64	2	0.170	0.057	0.7979	0.071			Surface
P24	J64	2	0.155	0.035	0.7979	0.044			Surface
P24	J64	2	0.060	0.028	0.7979	0.035			Surface
P24	J64	2	0.120	0.028	0.7979	0.035			Surface
P24	J64	2	0.130	0.014	0.7979	0.018	0.144	0.047	Surface
P24	J67	1	1.670	–	–	–			Surface
P24	J67	1	-0.510	–	–	–			Surface
P24	J67	1	0.050	–	–	–			Surface
P24	J67	2	-0.060	0.113	0.7979	0.142			Surface
P24	J67	3	-0.200	0.104	0.8862	0.117			Surface

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P24	J67	2	0.050	0.028	0.7979	0.035	0.167	0.098	Surface
P25	J29	2	0.010	0.283	0.7979	0.354			Interm
P25	J29	2	-0.325	0.276	0.7979	0.346			Interm
P25	J29	2	-0.025	0.177	0.7979	0.222			Interm
P25	J29	2	-0.360	0.028	0.7979	0.035			Interm
P25	J29	1	-0.120	–	–	–			Interm
P25	J29	2	-0.050	0.085	0.7979	0.106			Interm
P25	J29	1	-0.260	0.325	–	–	-0.161	0.213	Interm
P25	J36	1	0.120	–	–	–			Surface
P25	J36	2	-0.065	0.078	0.7979	0.097			Surface
P25	J36	3	0.100	0.278	0.8862	0.314			Surface
P25	J36	2	0.160	0.368	0.7979	0.461			Surface
P25	J36	1	0.000	–	–	–			Surface
P25	J36	1	-0.040	–	–	–	0.046	0.291	Surface
P26	J45	4	0.113	0.550	0.9213	0.597			Base
P26	J45	3	0.123	0.275	0.8862	0.310			Base
P26	J45	2	-0.130	0.014	0.7979	0.018			Base
P26	J45	3	0.063	0.388	0.8862	0.438	0.042	0.341	Base
P26	J52	1	-0.150	–	–	–			Surface
P26	J52	3	-0.053	0.099	0.8862	0.111			Surface
P26	J52	2	-0.235	0.092	0.7979	0.115			Surface
P26	J52	2	0.025	0.205	0.7979	0.257			Surface
P26	J52	2	-0.095	0.007	0.7979	0.009			Surface
P26	J52	2	0.005	0.177	0.7979	0.222			Surface
P26	J52	1	0.030	–	–	–			Surface
P26	J52	2	-0.070	0.071	0.7979	0.089			Surface
P26	J52	2	0.060	0.085	0.7979	0.106			Surface
P26	J52	2	-0.050	0.099	0.7979	0.124			Surface
P26	J52	2	-0.065	0.035	0.7979	0.044			Surface
P26	J52	2	-0.080	0.028	0.7979	0.035			Surface
P26	J52	1	0.270	–	–	–			Surface
P26	J52	2	-0.015	0.092	0.7979	0.115			Surface
P26	J52	3	0.083	0.203	0.8862	0.229			Surface
P26	J52	2	-0.215	0.049	0.7979	0.062			Surface
P26	J52	1	-0.260	–	–	–			Surface
P26	J52	3	-0.293	0.081	0.8862	0.092			Surface
P26	J52	2	-0.130	0.042	0.7979	0.053			Surface
P26	J52	1	-0.100	–	–	–			Surface
P26	J52	3	0.073	0.078	0.8862	0.088			Surface
P26	J52	3	-0.017	0.108	0.8862	0.122			Surface
P26	J52	3	-0.060	0.130	0.8862	0.147			Surface
P26	J52	3	-0.187	0.145	0.8862	0.163			Surface
P26	J52	1	0.110	–	–	–			Surface
P26	J52	3	-0.127	0.212	0.8862	0.239			Surface
P26	J52	1	-0.070	–	–	–			Surface
P26	J52	1	0.120	–	–	–			Surface
P26	J52	1	-0.090	–	–	–			Surface

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P26	J52	1	0.010	–	–	–	-0.053	0.121	Surface
P26	J58	1	-0.190	–	–	–			Surface
P26	J58	1	0.130	0.042	–	–			Surface
P26	J58	1	-0.010	0.007	–	–			Surface
P26	J58	1	-0.250	0.177	–	–			Surface
P26	J58	1	-0.120	0.085	–	–			Surface
P26	J58	1	0.230	0.163	–	–			Surface
P26	J58	1	0.050	0.035	–	–			Surface
P26	J58	1	-0.030	0.021	–	–			Surface
P26	J58	1	0.170	0.035	–	–			Surface
P26	J58	1	-0.060	–	–	–			Surface
P26	J58	2	-0.100	0.198	0.7979	0.248			Surface
P26	J58	1	0.240	–	–	–	0.005	0.248	Surface
P26	J62	4	0.160	0.075	0.9213	0.081			Surface
P26	J62	4	0.013	0.138	0.9213	0.150			Surface
P26	J62	3	-0.107	0.131	0.8862	0.147			Surface
P26	J62	3	-0.170	0.125	0.8862	0.141			Surface
P26	J62	3	-0.013	0.168	0.8862	0.189			Surface
P26	J62	3	-0.017	0.102	0.8862	0.115			Surface
P26	J62	4	0.043	0.092	0.9213	0.100			Surface
P26	J62	3	0.153	0.320	0.8862	0.361			Surface
P26	J62	4	0.013	0.259	0.9213	0.282	0.008	0.174	Surface
P26	J68	3	-0.283	0.680	0.8862	0.767			Surface
P26	J68	4	-0.205	0.037	0.9213	0.040			Surface
P26	J68	3	-0.057	0.126	0.8862	0.142			Surface
P26	J68	3	0.193	0.631	0.8862	0.712	-0.088	0.415	Surface
P26	J69	4	0.268	0.067	0.9213	0.072			Surface
P26	J69	3	-0.040	0.195	0.8862	0.220			Surface
P26	J69	3	-0.147	0.163	0.8862	0.184			Surface
P26	J69	3	0.033	0.059	0.8862	0.066			Surface
P26	J69	3	0.103	0.132	0.8862	0.149			Surface
P26	J69	3	0.080	0.111	0.8862	0.126			Surface
P26	J69	3	0.093	0.186	0.8862	0.209			Surface
P26	J69	3	-0.090	0.131	0.8862	0.148			Surface
P26	J69	3	-0.097	0.050	0.8862	0.057			Surface
P26	J69	4	0.093	0.171	0.9213	0.185			Surface
P26	J69	3	0.057	0.214	0.8862	0.241			Surface
P26	J69	4	-0.063	0.084	0.9213	0.091			Surface
P26	J69	3	-0.197	0.210	0.8862	0.237			Surface
P26	J69	3	-0.237	0.133	0.8862	0.150			Surface
P26	J69	3	0.193	0.123	0.8862	0.139			Surface
P26	J69	3	0.057	0.154	0.8862	0.173			Surface
P26	J69	1	-0.530	–	–	–			Surface
P26	J69	1	0.060	–	–	–	-0.020	0.153	Surface
P27	J53	2	-0.115	0.191	0.7979	0.239			Interm
P27	J53	2	-0.180	0.042	0.7979	0.053			Interm
P27	J53	1	-0.220	–	–	–			Interm

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P27	J53	1	-0.200	–	–	–			Interm
P27	J53	1	-0.250	–	–	–			Interm
P27	J53	1	-0.260	–	–	–			Interm
P27	J53	1	0.320	–	–	–			Interm
P27	J53	2	0.080	0.141	0.7979	0.177			Interm
P27	J53	1	0.070	–	–	–			Interm
P27	J53	1	0.010	–	–	–			Interm
P27	J53	1	0.130	–	–	–			Interm
P27	J53	1	-0.070	–	–	–			Interm
P27	J53	1	0.100	–	–	–			Interm
P27	J53	1	0.390	–	–	–			Interm
P27	J53	1	0.220	–	–	–			Interm
P27	J53	1	0.190	–	–	–	0.013	0.157	Interm
P27	J55	3	0.213	0.386	0.8862	0.435			Surface
P27	J55	3	0.120	0.105	0.8862	0.119			Surface
P27	J55	3	0.130	0.147	0.8862	0.166			Surface
P27	J55	3	0.113	0.229	0.8862	0.258			Surface
P27	J55	3	0.067	0.074	0.8862	0.083	0.129	0.212	Surface
P27	J60	1	0.120	–	–	–			Interm
P27	J60	1	0.430	–	–	–			Interm
P27	J60	1	0.350	–	–	–			Interm
P27	J60	1	-0.100	–	–	–			Interm
P27	J60	1	0.260	–	–	–			Interm
P27	J60	1	0.410	–	–	–			Interm
P27	J60	1	0.160	–	–	–			Interm
P27	J60	1	0.550	–	–	–			Interm
P27	J60	1	0.430	–	–	–			Interm
P27	J60	1	0.400	–	–	–			Interm
P27	J60	1	-0.190	–	–	–			Interm
P27	J60	1	0.250	–	–	–			Interm
P27	J60	1	-0.120	–	–	–			Interm
P27	J60	1	0.420	–	–	–			Interm
P27	J60	1	0.550	–	–	–	0.261	–	Interm
P27	J61	1	0.000	–	–	–			Surface
P27	J61	1	-0.050	–	–	–			Surface
P27	J61	1	-0.300	–	–	–			Surface
P27	J61	1	0.050	–	–	–			Surface
P27	J61	1	0.080	–	–	–			Surface
P27	J61	1	-0.060	–	–	–			Surface
P27	J61	1	0.020	–	–	–			Surface
P27	J61	1	-0.050	–	–	–			Surface
P27	J61	1	-0.220	–	–	–	-0.059	–	Surface
P27	J66	1	0.020	–	–	–			Base
P27	J66	1	-0.150	–	–	–			Base
P27	J66	1	0.010	–	–	–			Base
P27	J66	1	0.130	–	–	–			Base
P27	J66	1	-0.100	–	–	–			Base

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P27	J66	1	-0.240	–	–	–			Base
P27	J66	1	0.310	–	–	–			Base
P27	J66	1	0.190	–	–	–			Base
P27	J66	1	0.370	–	–	–			Base
P27	J66	1	-0.160	–	–	–			Base
P27	J66	1	0.120	–	–	–	0.045	–	Base
P27	J71	3	0.037	0.280	0.8862	0.316			Surface
P27	J71	4	0.073	0.148	0.9213	0.160			Surface
P27	J71	3	-0.097	0.240	0.8862	0.270			Surface
P27	J71	2	0.055	0.148	0.7979	0.186			Surface
P27	J71	1	0.140	–	–	–			Surface
P27	J71	3	-0.010	0.223	0.8862	0.251			Surface
P27	J71	3	0.177	0.131	0.8862	0.147			Surface
P27	J71	5	0.080	0.078	0.9400	0.083			Surface
P27	J71	3	0.083	0.081	0.8862	0.091	0.060	0.188	Surface
P28	J39	3	0.137	0.250	0.8862	0.282			Surface
P28	J39	1	-0.030	–	–	–			Surface
P28	J39	4	0.135	0.103	0.9213	0.112			Surface
P28	J39	5	-0.006	0.162	0.9400	0.172			Surface
P28	J39	5	0.022	0.135	0.9400	0.144			Surface
P28	J39	1	0.090	–	–	–			Surface
P28	J39	3	0.077	0.029	0.8862	0.033			Surface
P28	J39	1	0.000	–	–	–			Surface
P28	J39	1	-0.290	–	–	–	0.015	0.149	Surface
P28	J42	2	-0.025	0.078	0.7979	0.097			Interm
P28	J42	1	-0.030	–	–	–			Interm
P28	J42	1	-0.290	–	–	–			Interm
P28	J42	1	-0.160	–	–	–			Interm
P28	J42	1	-0.060	–	–	–			Interm
P28	J42	1	0.090	–	–	–			Interm
P28	J42	1	0.370	–	–	–			Interm
P28	J42	1	0.370	–	–	–			Interm
P28	J42	2	0.155	0.120	0.7979	0.151			Interm
P28	J42	1	0.120	–	–	–			Interm
P28	J42	1	0.180	–	–	–			Interm
P28	J42	1	0.110	–	–	–			Interm
P28	J42	1	0.310	–	–	–	0.088	0.124	Interm
P28	J47	1	0.050	–	–	–			Base
P28	J47	2	-0.045	0.078	0.7979	0.097			Base
P28	J47	1	-0.290	–	–	–			Base
P28	J47	1	-0.360	–	–	–			Base
P28	J47	1	0.060	–	–	–			Base
P28	J47	1	-0.240	–	–	–			Base
P28	J47	2	-0.160	0.156	0.7979	0.195			Base
P28	J47	2	0.140	0.424	0.7979	0.532			Base
P28	J47	2	0.100	0.042	0.7979	0.053			Base
P28	J47	1	0.360	–	–	–	-0.039	0.219	Base

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P29	J59	1	-0.110	–	–	–			Surface
P29	J59	3	0.147	0.084	0.8862	0.095			Surface
P29	J59	3	-0.027	0.199	0.8862	0.224			Surface
P29	J59	3	-0.050	0.098	0.8862	0.111			Surface
P29	J59	3	-0.077	0.188	0.8862	0.212			Surface
P29	J59	3	0.000	0.062	0.8862	0.070			Surface
P29	J59	4	-0.078	0.209	0.9213	0.227			Surface
P29	J59	3	-0.113	0.064	0.8862	0.072			Surface
P29	J59	3	-0.137	0.023	0.8862	0.026	-0.049	0.130	Surface
P30	J65	3	-0.060	0.095	0.8862	0.108			Surface
P30	J65	3	0.020	0.082	0.8862	0.092			Surface
P30	J65	1	0.090	–	–	–			Surface
P30	J65	1	-0.050	–	–	–	0.000	0.100	Surface
P32	J46	1	0.220	–	–	–			Surface
P32	J46	1	0.060	–	–	–			Surface
P32	J46	1	-0.250	–	–	–			Surface
P32	J46	1	-0.120	–	–	–			Surface
P32	J46	1	-0.360	–	–	–			Surface
P32	J46	2	-0.115	0.247	0.7979	0.310			Surface
P32	J46	2	0.020	0.141	0.7979	0.177			Surface
P32	J46	2	0.020	0.141	0.7979	0.177			Surface
P32	J46	3	0.000	0.315	0.8862	0.356			Surface
P32	J46	1	-0.080	–	–	–			Surface
P32	J46	1	0.310	–	–	–			Surface
P32	J46	1	0.150	–	–	–			Surface
P32	J46	1	-0.030	–	–	–			Surface
P32	J46	1	0.120	–	–	–			Surface
P32	J46	1	0.080	–	–	–			Surface
P32	J46	1	-0.040	–	–	–			Surface
P32	J46	1	0.180	–	–	–			Surface
P32	J46	1	0.040	–	–	–			Surface
P32	J46	1	-0.060	–	–	–			Surface
P32	J46	1	0.110	–	–	–			Surface
P32	J46	1	-0.070	–	–	–			Surface
P32	J46	2	-0.010	0.042	0.7979	0.053			Surface
P32	J46	2	0.070	0.170	0.7979	0.213			Surface
P32	J46	2	-0.165	0.007	0.7979	0.009			Surface
P32	J46	1	-0.410	–	–	–			Surface
P32	J46	1	-0.070	–	–	–			Surface
P32	J46	1	-0.240	–	–	–			Surface
P32	J46	1	0.340	–	–	–			Surface
P32	J46	3	-0.117	0.083	0.8862	0.094			Surface
P32	J46	1	-0.020	–	–	–			Surface
P32	J46	1	-0.050	–	–	–	-0.016	0.174	Surface
P32	J72	5	0.026	0.146	0.9400	0.155			Surface
P32	J72	6	0.007	0.148	0.9515	0.156			Surface
P32	J72	3	-0.033	0.227	0.8862	0.257			Surface

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P32	J72	3	0.213	0.080	0.8862	0.091			Surface
P32	J72	5	0.078	0.182	0.9400	0.194			Surface
P32	J72	5	0.136	0.099	0.9400	0.105			Surface
P32	J72	3	0.147	0.142	0.8862	0.160			Surface
P32	J72	4	0.045	0.312	0.9213	0.338	0.077	0.182	Surface
P32	J76	4	0.100	0.191	0.9213	0.208			Interm
P32	J76	3	-0.150	0.010	0.8862	0.011			Interm
P32	J76	5	0.130	0.341	0.9400	0.362			Interm
P32	J76	4	0.078	0.080	0.9213	0.087			Interm
P32	J76	3	0.190	0.035	0.8862	0.039			Interm
P32	J76	3	-0.107	0.301	0.8862	0.340			Interm
P32	J76	3	0.027	0.031	0.8862	0.034			Interm
P32	J76	4	0.148	0.206	0.9213	0.223			Interm
P32	J76	4	-0.018	0.091	0.9213	0.098			Interm
P32	J76	4	0.190	0.183	0.9213	0.198			Interm
P32	J76	3	0.217	0.276	0.8862	0.312			Interm
P32	J76	3	0.300	0.233	0.8862	0.263	0.092	0.181	Interm
P32	J79	6	0.225	0.072	0.9515	0.076			Surface
P32	J79	5	0.264	0.066	0.9400	0.070			Surface
P32	J79	4	0.193	0.128	0.9213	0.139			Surface
P32	J79	3	0.220	0.128	0.8862	0.144			Surface
P32	J79	4	-0.020	0.172	0.9213	0.186			Surface
P32	J79	3	0.137	0.074	0.8862	0.083			Surface
P32	J79	3	0.110	0.062	0.8862	0.070			Surface
P32	J79	3	0.217	0.057	0.8862	0.064			Surface
P32	J79	4	0.213	0.104	0.9213	0.113			Surface
P32	J79	5	0.138	0.192	0.9400	0.204			Surface
P32	J79	4	0.085	0.153	0.9213	0.166			Surface
P32	J79	5	-0.164	0.163	0.9400	0.174			Surface
P32	J79	3	-0.150	0.106	0.8862	0.119			Surface
P32	J79	5	0.176	0.093	0.9400	0.099			Surface
P32	J79	5	0.128	0.121	0.9400	0.129			Surface
P32	J79	5	-0.024	0.210	0.9400	0.223			Surface
P32	J79	5	0.148	0.097	0.9400	0.104			Surface
P32	J79	3	0.237	0.076	0.8862	0.086			Surface
P32	J79	5	0.196	0.209	0.9400	0.223			Surface
P32	J79	3	-0.020	0.078	0.8862	0.088			Surface
P32	J79	3	0.110	0.123	0.8862	0.139			Surface
P32	J79	4	0.098	0.095	0.9213	0.103			Surface
P32	J79	3	0.097	0.038	0.8862	0.043			Surface
P32	J79	3	0.043	0.142	0.8862	0.160	0.111	0.125	Surface
P33	J73	1	0.320	–	–	–			Interm
P33	J73	3	0.050	0.233	0.8862	0.262			Interm
P33	J73	3	0.023	0.501	0.8862	0.566			Interm
P33	J73	5	0.052	0.211	0.9400	0.224			Interm
P33	J73	4	-0.043	0.195	0.9213	0.211			Interm
P33	J73	3	0.057	0.096	0.8862	0.108			Interm

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P33	J73	3	0.153	0.241	0.8862	0.272			Interm
P33	J73	3	0.013	0.146	0.8862	0.165	0.078	0.258	Interm
P33	J75	1	-0.100	–	–	–			Surface
P33	J75	1	-0.150	–	–	–			Surface
P33	J75	1	0.050	–	–	–			Surface
P33	J75	1	-0.160	–	–	–			Surface
P33	J75	1	-0.030	–	–	–			Surface
P33	J75	1	0.370	–	–	–			Surface
P33	J75	1	-0.170	–	–	–			Surface
P33	J75	1	-0.100	–	–	–			Surface
P33	J75	1	-0.100	–	–	–			Surface
P33	J75	1	0.240	–	–	–	-0.015	–	Surface
P33	J77	4	-0.120	0.228	0.9213	0.248			Surface
P33	J77	4	0.130	0.182	0.9213	0.197			Surface
P33	J77	4	0.325	0.090	0.9213	0.097			Surface
P33	J77	4	0.028	0.200	0.9213	0.217			Surface
P33	J77	3	-0.027	0.220	0.8862	0.248			Surface
P33	J77	3	0.257	0.327	0.8862	0.369	0.099	0.229	Surface
P33	J78	4	0.138	0.488	0.9213	0.530			Surface
P33	J78	3	0.213	0.261	0.8862	0.294			Surface
P33	J78	3	-0.203	0.300	0.8862	0.339			Surface
P33	J78	3	0.020	0.230	0.8862	0.260	0.042	0.356	Surface
P34	J62	4	-0.005	0.227	0.9213	0.247			Surface
P34	J62	4	0.205	0.067	0.9213	0.072			Surface
P34	J62	6	-0.100	0.121	0.9515	0.127			Surface
P34	J62	4	-0.123	0.087	0.9213	0.094			Surface
P34	J62	4	-0.148	0.366	0.9213	0.397			Surface
P34	J62	4	0.103	0.085	0.9213	0.092			Surface
P34	J62	2	-0.090	0.014	0.7979	0.018	-0.023	0.150	Surface
P34	J80	2	-0.045	0.064	0.7979	0.080			Surface
P34	J80	2	0.080	0.071	0.7979	0.089			Surface
P34	J80	3	0.060	0.087	0.8862	0.098			Surface
P34	J80	1	-0.010	–	–	–			Surface
P34	J80	3	-0.027	0.049	0.8862	0.056			Surface
P34	J80	1	-0.230	–	–	–	-0.029	0.081	Surface
P34	J81	2	-0.085	0.035	0.7979	0.044			Surface
P34	J81	2	0.000	0.184	0.7979	0.230			Surface
P34	J81	1	0.160	–	–	–			Surface
P34	J81	2	0.160	0.339	0.7979	0.425			Surface
P34	J81	2	0.195	0.318	0.7979	0.399			Surface
P34	J81	2	0.015	0.064	0.7979	0.080			Surface
P34	J81	2	0.235	0.304	0.7979	0.381	0.097	0.260	Surface
P35	J32	3	-0.053	0.219	0.8862	0.248			Surface
P35	J32	1	-0.180	–	–	–			Surface
P35	J32	3	-0.017	0.081	0.8862	0.092			Surface
P35	J32	3	-0.137	0.090	0.8862	0.101			Surface
P35	J32	3	-0.060	0.087	0.8862	0.098			Surface

Table B.4. Summary of Unbiased Lot Std Dev for AC for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P35	J32	1	0.270	–	–	–	-0.029	0.135	Surface
P35	J38	2	-0.130	0.099	0.7979	0.124			Surface
P35	J38	2	0.060	0.057	0.7979	0.071			Surface
P35	J38	1	0.260	–	–	–			Surface
P35	J38	2	0.075	0.078	0.7979	0.097			Surface
P35	J38	2	0.070	0.042	0.7979	0.053			Surface
P35	J38	1	0.160	–	–	–			Surface
P35	J38	2	-0.010	0.212	0.7979	0.266			Surface
P35	J38	3	0.250	0.070	0.8862	0.079			Surface
P35	J38	5	0.096	0.067	0.9400	0.072			Surface
P35	J38	2	0.085	0.092	0.7979	0.115			Surface
P35	J38	4	0.060	0.060	0.9213	0.065			Surface
P35	J38	3	0.007	0.119	0.8862	0.135			Surface
P35	J38	3	0.010	0.118	0.8862	0.133			Surface
P35	J38	2	-0.110	0.156	0.7979	0.195			Surface
P35	J38	1	-0.020	–	–	–			Surface
P35	J38	1	-0.070	–	–	–	0.050	0.117	Surface

Table B.5. Summary of Unbiased Lot Std Dev for AV for Each Project

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P01	J02	2	-0.205	0.148	0.7979	0.186			Interm
P01	J02	3	-0.300	0.999	0.8862	1.128			Interm
P01	J02	2	-0.505	0.092	0.7979	0.115			Interm
P01	J02	1	-0.090	–	–	–	-0.275	0.476	Interm
P01	J07	3	0.337	0.546	0.8862	0.617			Surface
P01	J07	3	0.290	0.620	0.8862	0.700			Surface
P01	J07	5	0.538	0.307	0.94	0.327			Surface
P01	J07	3	0.577	0.067	0.8862	0.075			Surface
P01	J07	3	-0.180	0.265	0.8862	0.299			Surface
P01	J07	1	0.890	–	–	–			Surface
P01	J07	3	-0.470	0.214	0.8862	0.241			Surface
P01	J07	5	0.632	0.188	0.94	0.200			Surface
P01	J07	4	0.378	0.678	0.9213	0.736	0.332	0.399	Surface
P01	J10	3	-0.950	0.130	0.8862	0.147			Interm
P01	J10	1	-1.110	–	–	–			Interm
P01	J10	1	-1.120	–	–	–			Interm
P01	J10	4	-0.288	0.698	0.9213	0.758			Interm
P01	J10	3	-0.530	0.303	0.8862	0.342			Interm
P01	J10	1	-0.440	–	–	–			Interm
P01	J10	3	-0.153	0.392	0.8862	0.442			Interm
P01	J10	1	-0.630	–	–	–			Interm
P01	J10	1	-0.130	–	–	–			Interm
P01	J10	1	-0.200	–	–	–			Interm
P01	J10	2	-0.400	0.368	0.7979	0.461			Interm
P01	J10	2	-0.345	0.021	0.7979	0.027			Interm
P01	J10	4	-0.408	0.443	0.9213	0.481			Interm
P01	J10	2	-0.890	0.141	0.7979	0.177			Interm
P01	J10	2	-0.280	0.212	0.7979	0.266			Interm
P01	J10	3	0.233	0.162	0.8862	0.182			Interm
P01	J10	2	0.405	0.035	0.7979	0.044			Interm
P01	J10	3	-0.083	0.480	0.8862	0.542	-0.407	0.322	Interm
P01	J19	1	-0.670	–	–	–			Surface
P01	J19	1	0.250	–	–	–			Surface
P01	J19	2	-0.590	0.467	0.7979	0.585			Surface
P01	J19	2	-0.420	0.495	0.7979	0.620			Surface
P01	J19	1	-1.030	–	–	–			Surface
P01	J19	1	-0.290	–	–	–			Surface
P01	J19	1	0.760	–	–	–			Surface
P01	J19	1	0.590	–	–	–			Surface
P01	J19	2	-0.145	0.474	0.7979	0.594			Surface
P01	J19	1	-0.950	–	–	–			Surface
P01	J19	1	-0.050	–	–	–			Surface
P01	J19	2	-0.880	0.240	0.7979	0.301			Surface
P01	J19	1	-1.070	–	–	–			Surface
P01	J19	1	-1.000	–	–	–	-0.393	0.525	Surface
P01	J23	4	-0.530	0.283	0.9213	0.307			Interm
P01	J23	3	-0.050	0.358	0.8862	0.404			Interm

Table B.5. Summary of Unbiased Lot Std Dev for AV for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P01	J23	1	0.190	–	–	–			Interm
P01	J23	2	-0.405	0.276	0.7979	0.346			Interm
P01	J23	1	-0.550	–	–	–			Interm
P01	J23	1	-0.500	–	–	–	-0.308	0.352	Interm
P02	J04	4	-0.035	0.215	0.9213	0.233			Interm
P02	J04	1	0.200	–	–	–			Interm
P02	J04	2	-0.460	0.028	0.7979	0.035			Interm
P02	J04	2	-0.420	0.141	0.7979	0.177			Interm
P02	J04	4	-0.688	0.103	0.9213	0.112			Interm
P02	J04	1	-1.020	–	–	–			Interm
P02	J04	4	-0.703	0.239	0.9213	0.260			Interm
P02	J04	1	0.050	–	–	–			Interm
P02	J04	1	0.060	–	–	–			Interm
P02	J04	2	0.055	0.290	0.7979	0.363			Interm
P02	J04	3	-0.213	0.568	0.8862	0.640			Interm
P02	J04	1	0.260	–	–	–			Interm
P02	J04	1	0.830	–	–	–			Interm
P02	J04	3	0.910	0.297	0.8862	0.335	-0.084	0.270	Interm
P02	J05	2	0.495	0.247	0.7979	0.310			Surface
P02	J05	1	0.630	–	–	–			Surface
P02	J05	2	-0.210	0.382	0.7979	0.479			Surface
P02	J05	1	0.450	–	–	–			Surface
P02	J05	1	0.870	–	–	–			Surface
P02	J05	1	0.130	–	–	–	0.394	0.394	Surface
P02	J09	1	-0.200	–	–	–			Interm
P02	J09	2	0.425	0.417	0.7979	0.523			Interm
P02	J09	1	-0.840	–	–	–			Interm
P02	J09	3	-0.473	0.580	0.8862	0.654			Interm
P02	J09	2	-0.115	0.332	0.7979	0.417			Interm
P02	J09	2	0.185	0.502	0.7979	0.629			Interm
P02	J09	1	-0.390	–	–	–			Interm
P02	J09	1	0.140	–	–	–			Interm
P02	J09	2	-0.810	0.000	0.7979	0.000			Interm
P02	J09	3	-0.333	0.491	0.8862	0.554			Interm
P02	J09	2	-0.015	0.417	0.7979	0.523			Interm
P02	J09	2	-0.010	0.467	0.7979	0.585			Interm
P02	J09	1	0.400	–	–	–			Interm
P02	J09	4	-0.093	0.462	0.9213	0.501			Interm
P02	J09	2	-0.295	0.431	0.7979	0.541			Interm
P02	J09	1	0.030	–	–	–			Interm
P02	J09	2	-0.010	0.099	0.7979	0.124			Interm
P02	J09	2	0.920	0.198	0.7979	0.248	-0.082	0.441	Interm
P02	J13	1	0.330	–	–	–			Surface
P02	J13	1	-0.080	–	–	–			Surface
P02	J13	2	0.695	0.163	0.7979	0.204			Surface
P02	J13	1	0.880	–	–	–			Surface
P02	J13	1	0.900	–	–	–			Surface

Table B.5. Summary of Unbiased Lot Std Dev for AV for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P02	J13	1	-0.430	–	–	–			Surface
P02	J13	2	0.755	0.318	0.7979	0.399			Surface
P02	J13	1	0.350	–	–	–			Surface
P02	J13	1	-0.110	–	–	–			Surface
P02	J13	1	0.670	–	–	–			Surface
P02	J13	1	0.550	–	–	–			Surface
P02	J13	2	0.700	0.057	0.7979	0.071			Surface
P02	J13	2	0.870	0.382	0.7979	0.479			Surface
P02	J13	1	-0.870	–	–	–	0.372	0.288	Surface
P02	J15	1	0.420	–	–	–			Surface
P02	J15	4	0.688	0.266	0.9213	0.288			Surface
P02	J15	4	0.783	0.359	0.9213	0.390			Surface
P02	J15	5	0.772	0.142	0.94	0.151			Surface
P02	J15	3	0.163	0.663	0.8862	0.748			Surface
P02	J15	1	-1.070	–	–	–	0.293	0.394	Surface
P04	J08	2	-0.020	0.255	0.7979	0.319			Interm
P04	J08	2	-0.110	0.764	0.7979	0.957			Interm
P04	J08	2	0.210	0.141	0.7979	0.177			Interm
P04	J08	2	0.105	0.346	0.7979	0.434			Interm
P04	J08	2	0.480	0.735	0.7979	0.922	0.133	0.562	Interm
P04	J14	3	0.620	0.036	0.8862	0.041			Surface
P04	J14	4	-0.138	0.551	0.9213	0.598			Surface
P04	J14	4	0.638	0.121	0.9213	0.131			Surface
P04	J14	3	0.333	0.561	0.8862	0.633			Surface
P04	J14	3	-0.237	0.393	0.8862	0.443	0.243	0.369	Surface
P05	J25	1	-0.680	–	–	–			Surface
P05	J25	1	0.050	–	–	–			Surface
P05	J25	1	-0.070	–	–	–			Surface
P05	J25	1	-0.850	–	–	–			Surface
P05	J25	1	0.100	–	–	–			Surface
P05	J25	1	0.580	–	–	–			Surface
P05	J25	1	0.460	–	–	–			Surface
P05	J25	1	0.500	–	–	–	0.011	#DIV/0!	Surface
P05	J27	2	0.190	0.184	0.7979	0.230			Interm
P05	J27	2	0.310	0.396	0.7979	0.496			Interm
P05	J27	2	0.380	0.141	0.7979	0.177			Interm
P05	J27	2	0.490	0.042	0.7979	0.053			Interm
P05	J27	2	-0.485	0.375	0.7979	0.470			Interm
P05	J27	2	0.140	0.113	0.7979	0.142			Interm
P05	J27	1	0.120	–	–	–			Interm
P05	J27	2	0.660	0.325	0.7979	0.408	0.226	0.282	Interm
P06	J24	3	-0.257	0.302	0.8862	0.340			Surface
P06	J24	3	-0.493	0.378	0.8862	0.427			Surface
P06	J24	3	-0.493	0.297	0.8862	0.335			Surface
P06	J24	3	-0.123	0.785	0.8862	0.886			Surface
P06	J24	3	-0.587	0.282	0.8862	0.318	-0.391	0.461	Surface
P07	J30	3	0.473	0.167	0.8862	0.189			Surface

Table B.5. Summary of Unbiased Lot Std Dev for AV for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P07	J30	1	0.280	–	–	–			Surface
P07	J30	1	0.240	–	–	–			Surface
P07	J30	1	0.760	–	–	–			Surface
P07	J30	4	-0.120	0.441	0.9213	0.479			Surface
P07	J30	2	0.230	0.226	0.7979	0.284			Surface
P07	J30	2	-0.650	0.580	0.7979	0.727			Surface
P07	J30	1	0.230	–	–	–			Surface
P07	J30	3	0.030	0.435	0.8862	0.491			Surface
P07	J30	3	-0.433	0.414	0.8862	0.467			Surface
P07	J30	3	0.310	0.276	0.8862	0.312			Surface
P07	J30	3	0.180	0.733	0.8862	0.827			Surface
P07	J30	2	-0.595	0.361	0.7979	0.452			Surface
P07	J30	3	-0.097	0.661	0.8862	0.745			Surface
P07	J30	3	-0.153	0.081	0.8862	0.092			Surface
P07	J30	1	0.360	–	–	–			Surface
P07	J30	2	-0.155	0.884	0.7979	1.108			Surface
P07	J30	1	0.790	–	–	–			Surface
P07	J30	1	0.000	–	–	–	0.088	0.514	Surface
P09	J35	3	0.727	0.272	0.8862	0.307			Surface
P09	J35	3	-0.193	0.193	0.8862	0.218			Surface
P09	J35	3	0.347	0.459	0.8862	0.518	0.293	0.348	Surface
P09	J83	3	0.207	0.326	0.8862	0.368			Surface
P09	J83	3	-0.507	0.586	0.8862	0.661			Surface
P09	J83	2	-0.790	0.354	0.7979	0.443	-0.363	0.491	Surface
P10	J12	1	-0.370	–	–	–			Surface
P10	J12	1	0.550	–	–	–			Surface
P10	J12	1	0.290	–	–	–			Surface
P10	J12	2	0.705	0.247	0.7979	0.310			Surface
P10	J12	1	0.960	–	–	–			Surface
P10	J12	1	1.040	–	–	–			Surface
P10	J12	1	0.010	–	–	–			Surface
P10	J12	1	-0.140	–	–	–			Surface
P10	J12	2	1.310	1.556	0.7979	1.950			Surface
P10	J12	2	0.115	0.148	0.7979	0.186			Surface
P10	J12	2	0.435	0.035	0.7979	0.044			Surface
P10	J12	2	0.235	0.247	0.7979	0.310			Surface
P10	J12	2	-0.025	0.460	0.7979	0.576	0.393	0.563	Surface
P10	J31	2	-0.740	0.085	0.7979	0.106			Interm
P10	J31	2	0.145	0.502	0.7979	0.629			Interm
P10	J31	2	0.415	0.106	0.7979	0.133			Interm
P10	J31	2	0.600	0.212	0.7979	0.266			Interm
P10	J31	1	1.020	–	–	–			Interm
P10	J31	2	0.690	0.071	0.7979	0.089			Interm
P10	J31	2	0.025	0.361	0.7979	0.452			Interm
P10	J31	1	-0.070	–	–	–			Interm
P10	J31	2	0.120	0.933	0.7979	1.170			Interm
P10	J31	2	0.960	0.028	0.7979	0.035			Interm

Table B.5. Summary of Unbiased Lot Std Dev for AV for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P10	J31	2	0.825	0.177	0.7979	0.222			Interm
P10	J31	2	0.735	0.460	0.7979	0.576			Interm
P10	J31	2	0.395	0.021	0.7979	0.027			Interm
P10	J31	2	0.360	0.156	0.7979	0.195			Interm
P10	J31	2	0.795	0.460	0.7979	0.576			Interm
P10	J31	2	0.890	0.042	0.7979	0.053			Interm
P10	J31	2	-0.020	0.071	0.7979	0.089			Interm
P10	J31	2	0.220	0.071	0.7979	0.089			Interm
P10	J31	2	0.285	0.502	0.7979	0.629			Interm
P10	J31	2	0.715	0.262	0.7979	0.328			Interm
P10	J31	2	-0.110	0.127	0.7979	0.160			Interm
P10	J31	1	-0.140	–	–	–			Interm
P10	J31	2	0.075	0.445	0.7979	0.558			Interm
P10	J31	2	-0.715	0.502	0.7979	0.629			Interm
P10	J31	2	-0.385	0.332	0.7979	0.417			Interm
P10	J31	2	0.035	0.587	0.7979	0.736			Interm
P10	J31	1	-0.640	–	–	–			Interm
P10	J31	2	-0.445	0.841	0.7979	1.055			Interm
P10	J31	2	-0.640	0.014	0.7979	0.018			Interm
P10	J31	2	0.215	0.389	0.7979	0.487			Interm
P10	J31	2	0.570	0.735	0.7979	0.922			Interm
P10	J31	2	0.490	0.764	0.7979	0.957			Interm
P10	J31	2	0.160	0.721	0.7979	0.904			Interm
P10	J31	2	0.080	0.424	0.7979	0.532			Interm
P10	J31	2	0.410	0.127	0.7979	0.160			Interm
P10	J31	2	-0.515	0.219	0.7979	0.275			Interm
P10	J31	2	0.010	0.382	0.7979	0.479			Interm
P10	J31	2	-0.455	0.502	0.7979	0.629			Interm
P10	J31	2	-0.255	0.955	0.7979	1.196			Interm
P10	J31	2	-0.180	0.085	0.7979	0.106			Interm
P10	J31	1	0.320	–	–	–	0.152	0.441	Interm
P10	J37	1	0.850	–	–	–			Interm
P10	J37	2	0.015	0.177	0.7979	0.222			Interm
P10	J37	2	-0.270	0.382	0.7979	0.479			Interm
P10	J37	2	0.620	0.000	0.7979	0.000			Interm
P10	J37	2	0.605	0.276	0.7979	0.346			Interm
P10	J37	1	0.320	–	–	–			Interm
P10	J37	2	0.625	0.290	0.7979	0.363			Interm
P10	J37	2	0.365	0.262	0.7979	0.328			Interm
P10	J37	2	0.790	0.085	0.7979	0.106			Interm
P10	J37	2	0.855	0.092	0.7979	0.115			Interm
P10	J37	2	0.775	0.134	0.7979	0.168			Interm
P10	J37	2	0.895	0.064	0.7979	0.080	0.537	0.221	Interm
P10	J82	2	0.260	0.170	0.7979	0.213			Interm
P10	J82	2	0.745	0.431	0.7979	0.541			Interm
P10	J82	2	0.870	0.113	0.7979	0.142			Interm
P10	J82	2	1.110	0.085	0.7979	0.106			Interm

Table B.5. Summary of Unbiased Lot Std Dev for AV for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P10	J82	2	0.755	0.233	0.7979	0.292			Interm
P10	J82	1	0.820	–	–	–			Interm
P10	J82	2	0.775	0.064	0.7979	0.080			Interm
P10	J82	2	0.960	0.141	0.7979	0.177	0.787	0.222	Interm
P11	J41	3	0.573	0.385	0.8862	0.435			Surface
P11	J41	1	0.190	–	–	–			Surface
P11	J41	2	-0.320	0.325	0.7979	0.408			Surface
P11	J41	4	-0.053	0.062	0.9213	0.068	0.098	0.303	Surface
P12	J38	4	-0.603	0.324	0.9213	0.351			Surface
P12	J38	2	-1.860	0.594	0.7979	0.744			Surface
P12	J38	1	-1.420	–	–	–			Surface
P12	J38	1	-0.560	–	–	–			Surface
P12	J38	3	-0.217	0.232	0.8862	0.262			Surface
P12	J38	3	-0.080	0.843	0.8862	0.952	-0.790	0.577	Surface
P13	J03	3	-0.880	0.297	0.8862	0.335			Surface
P13	J03	3	0.107	0.899	0.8862	1.015			Surface
P13	J03	1	0.720	–	–	–			Surface
P13	J03	3	-0.593	0.431	0.8862	0.486			Surface
P13	J03	1	-0.180	–	–	–			Surface
P13	J03	1	-0.560	–	–	–			Surface
P13	J03	3	-0.133	0.422	0.8862	0.476			Surface
P13	J03	1	1.130	–	–	–	-0.049	0.578	Surface
P13	J43	2	-0.585	0.318	0.7979	0.399			Surface
P13	J43	2	-0.370	1.061	0.7979	1.329			Surface
P13	J43	2	-0.645	0.021	0.7979	0.027			Surface
P13	J43	2	0.615	0.643	0.7979	0.806			Surface
P13	J43	3	-0.190	0.963	0.8862	1.087			Surface
P13	J43	4	0.080	0.799	0.9213	0.867			Surface
P13	J43	3	0.597	0.615	0.8862	0.693			Surface
P13	J43	1	1.710	–	–	–	0.151	0.744	Surface
P14	J16	1	0.500	–	–	–			Surface
P14	J16	2	-0.135	0.148	0.7979	0.186			Surface
P14	J16	3	-0.823	0.112	0.8862	0.126			Surface
P14	J16	2	0.220	0.099	0.7979	0.124			Surface
P14	J16	1	-0.300	–	–	–			Surface
P14	J16	4	-0.515	0.812	0.9213	0.881			Surface
P14	J16	3	-0.813	0.172	0.8862	0.194			Surface
P14	J16	4	-0.430	1.246	0.9213	1.353			Surface
P14	J16	4	-0.470	1.431	0.9213	1.554			Surface
P14	J16	2	-0.155	0.431	0.7979	0.541			Surface
P14	J16	1	-0.800	–	–	–			Surface
P14	J16	2	-0.875	0.050	0.7979	0.062			Surface
P14	J16	3	-0.410	0.131	0.8862	0.148	-0.385	0.517	Surface
P16	J20	3	0.380	0.613	0.8862	0.692			Surface
P16	J20	3	0.460	1.070	0.8862	1.208			Surface
P16	J20	3	-0.347	0.441	0.8862	0.498	0.164	0.799	Surface
P17	J22	2	-0.870	0.014	0.7979	0.018			Interm

Table B.5. Summary of Unbiased Lot Std Dev for AV for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P17	J22	2	-0.765	0.304	0.7979	0.381			Interm
P17	J22	2	-0.380	0.735	0.7979	0.922			Interm
P17	J22	1	0.010	–	–	–			Interm
P17	J22	2	-0.340	0.707	0.7979	0.886			Interm
P17	J22	2	0.020	0.919	0.7979	1.152	-0.388	0.672	Interm
P18	J48	1	-1.500	–	–	–			Surface
P18	J48	3	-0.913	0.376	0.8862	0.424			Surface
P18	J48	1	-1.070	–	–	–			Surface
P18	J48	2	-0.425	0.247	0.7979	0.310			Surface
P18	J48	3	-0.123	0.090	0.8862	0.102			Surface
P18	J48	1	-0.450	–	–	–			Surface
P18	J48	1	1.680	–	–	–	-0.400	0.279	Surface
P19	J49	2	0.170	0.283	0.7979	0.354			Surface
P19	J49	1	0.040	–	–	–			Surface
P19	J49	3	-0.850	0.282	0.8862	0.318			Surface
P19	J49	4	-0.708	0.314	0.9213	0.341			Surface
P19	J49	4	-0.495	0.651	0.9213	0.707			Surface
P19	J49	3	-0.740	0.959	0.8862	1.082			Surface
P19	J49	3	-0.360	0.579	0.8862	0.653	-0.420	0.576	Surface
P20	J50	1	-1.540	–	–	–			Surface
P20	J50	5	-0.588	0.307	0.94	0.327			Surface
P20	J50	2	-0.345	0.629	0.7979	0.789			Surface
P20	J50	4	0.313	0.192	0.9213	0.208			Surface
P20	J50	1	0.210	–	–	–			Surface
P20	J50	2	0.200	0.057	0.7979	0.071			Surface
P20	J50	5	-0.204	0.272	0.94	0.289			Surface
P20	J50	3	-0.367	0.281	0.8862	0.317			Surface
P20	J50	1	-0.770	–	–	–			Surface
P20	J50	1	-0.100	–	–	–			Surface
P20	J50	5	-0.356	0.578	0.94	0.615			Surface
P20	J50	1	-0.750	–	–	–			Surface
P20	J50	2	-0.335	0.969	0.7979	1.214			Surface
P20	J50	4	-0.430	0.468	0.9213	0.508			Surface
P20	J50	5	0.210	0.732	0.94	0.778			Surface
P20	J50	2	-0.885	0.177	0.7979	0.222			Surface
P20	J50	2	0.065	0.064	0.7979	0.080	-0.334	0.452	Surface
P21	J34	4	-0.210	0.421	0.9213	0.456			Interm
P21	J34	3	0.150	0.212	0.8862	0.239			Interm
P21	J34	1	0.310	–	–	–	0.083	0.348	Interm
P21	J39	1	-0.840	–	–	–			Surface
P21	J39	4	-0.853	0.092	0.9213	0.100			Surface
P21	J39	2	-0.905	0.120	0.7979	0.151			Surface
P21	J39	4	-0.878	0.103	0.9213	0.112			Surface
P21	J39	3	-0.827	0.193	0.8862	0.218			Surface
P21	J39	1	-0.460	–	–	–	-0.794	0.145	Surface
P22	J54	6	-0.148	1.176	0.9515	1.236			Surface
P22	J54	5	0.338	0.384	0.94	0.409			Surface

Table B.5. Summary of Unbiased Lot Std Dev for AV for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P22	J54	1	0.540	–	–	–	0.243	0.822	Surface
P24	J56	1	1.100	–	–	–			Surface
P24	J56	5	-0.234	0.794	0.94	0.845			Surface
P24	J56	1	-0.250	–	–	–			Surface
P24	J56	3	-0.660	0.302	0.8862	0.341			Surface
P24	J56	1	1.430	–	–	–			Surface
P24	J56	3	-0.123	0.229	0.8862	0.258			Surface
P24	J56	1	-0.830	–	–	–			Surface
P24	J56	1	-1.040	–	–	–			Surface
P24	J56	3	-0.520	0.790	0.8862	0.892			Surface
P24	J56	1	-0.980	–	–	–			Surface
P24	J56	4	-0.628	1.296	0.9213	1.406			Surface
P24	J56	2	0.390	0.099	0.7979	0.124			Surface
P24	J56	1	1.300	–	–	–			Surface
P24	J56	3	-0.067	0.980	0.8862	1.106			Surface
P24	J56	1	-0.480	–	–	–			Surface
P24	J56	2	-0.540	0.651	0.7979	0.815			Surface
P24	J56	4	-0.980	0.169	0.9213	0.184			Surface
P24	J56	3	0.413	0.352	0.8862	0.398	-0.150	0.637	Surface
P24	J64	1	0.000	–	–	–			Surface
P24	J64	2	-0.630	0.212	0.7979	0.266			Surface
P24	J64	2	-0.935	0.163	0.7979	0.204			Surface
P24	J64	2	-0.415	0.247	0.7979	0.310			Surface
P24	J64	2	-0.775	0.064	0.7979	0.080			Surface
P24	J64	2	-0.570	0.071	0.7979	0.089			Surface
P24	J64	2	-0.850	0.170	0.7979	0.213	-0.596	0.193	Surface
P24	J67	1	0.030	–	–	–			Surface
P24	J67	1	1.170	–	–	–			Surface
P24	J67	1	-1.130	–	–	–			Surface
P24	J67	2	-0.660	0.000	0.7979	0.000			Surface
P24	J67	3	0.033	0.454	0.8862	0.512			Surface
P24	J67	2	-0.385	0.799	0.7979	1.001	-0.157	0.505	Surface
P25	J29	2	0.295	0.205	0.7979	0.257			Interm
P25	J29	2	1.310	0.523	0.7979	0.656			Interm
P25	J29	2	0.625	0.064	0.7979	0.080			Interm
P25	J29	2	0.690	0.156	0.7979	0.195			Interm
P25	J29	1	-0.380	–	–	–			Interm
P25	J29	2	0.560	0.000	0.7979	0.000			Interm
P25	J29	1	1.050	–	–	–	0.593	0.238	Interm
P25	J36	1	0.480	–	–	–			Surface
P25	J36	2	-0.490	0.905	0.7979	1.134			Surface
P25	J36	3	0.440	0.236	0.8862	0.266			Surface
P25	J36	2	0.885	0.346	0.7979	0.434			Surface
P25	J36	1	0.310	–	–	–			Surface
P25	J36	1	0.850	–	–	–	0.413	0.612	Surface
P26	J58	1	-0.050	–	–	–			Surface
P26	J58	1	-0.630	–	–	–			Surface

Table B.5. Summary of Unbiased Lot Std Dev for AV for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P26	J58	1	0.370	–	–	–			Surface
P26	J58	1	0.940	–	–	–			Surface
P26	J58	1	-0.300	–	–	–			Surface
P26	J58	1	-0.300	–	–	–			Surface
P26	J58	1	0.270	–	–	–			Surface
P26	J58	1	0.120	–	–	–			Surface
P26	J58	1	-0.350	–	–	–			Surface
P26	J58	1	0.210	–	–	–			Surface
P26	J58	2	1.465	0.163	0.7979	0.204			Surface
P26	J58	1	0.440	–	–	–	0.182	0.204	Surface
P26	J62	4	-0.485	0.507	0.9213	0.550			Surface
P26	J62	4	0.668	0.332	0.9213	0.360			Surface
P26	J62	3	0.553	0.097	0.8862	0.110			Surface
P26	J62	3	0.903	0.731	0.8862	0.824			Surface
P26	J62	3	0.750	0.326	0.8862	0.368			Surface
P26	J62	3	0.480	0.249	0.8862	0.281			Surface
P26	J62	4	-0.043	0.435	0.9213	0.472			Surface
P26	J62	3	0.223	0.853	0.8862	0.963			Surface
P26	J62	4	0.270	0.452	0.9213	0.491	0.369	0.491	Surface
P26	J69	4	-0.168	0.388	0.9213	0.422			Surface
P26	J69	3	-0.120	0.528	0.8862	0.596			Surface
P26	J69	3	-0.067	0.353	0.8862	0.398			Surface
P26	J69	3	-0.110	0.380	0.8862	0.429			Surface
P26	J69	3	-0.170	0.229	0.8862	0.258			Surface
P26	J69	3	-0.330	0.545	0.8862	0.615			Surface
P26	J69	3	-0.477	0.608	0.8862	0.686			Surface
P26	J69	3	0.380	0.272	0.8862	0.307			Surface
P26	J69	3	0.047	0.499	0.8862	0.563			Surface
P26	J69	4	0.205	0.416	0.9213	0.452			Surface
P26	J69	3	1.083	0.442	0.8862	0.499			Surface
P26	J69	4	0.778	0.237	0.9213	0.257			Surface
P26	J69	3	0.353	0.461	0.8862	0.520			Surface
P26	J69	3	0.483	0.225	0.8862	0.254			Surface
P26	J69	3	-0.433	0.117	0.8862	0.132			Surface
P26	J69	3	0.213	0.663	0.8862	0.748			Surface
P26	J69	1	1.910	–	–	–			Surface
P26	J69	1	1.010	–	–	–	0.255	0.446	Surface
P27	J53	1	-0.840	–	–	–			Interm
P27	J53	1	0.300	–	–	–			Interm
P27	J53	1	-0.240	–	–	–			Interm
P27	J53	1	0.220	–	–	–			Interm
P27	J53	1	-0.750	–	–	–			Interm
P27	J53	2	-0.175	0.035	0.7979	0.044			Interm
P27	J53	1	-0.270	–	–	–			Interm
P27	J53	1	-0.020	–	–	–			Interm
P27	J53	1	-0.280	–	–	–			Interm
P27	J53	1	0.090	–	–	–			Interm

Table B.5. Summary of Unbiased Lot Std Dev for AV for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P27	J53	1	-0.220	–	–	–			Interm
P27	J53	1	-1.050	–	–	–			Interm
P27	J53	1	0.070	–	–	–			Interm
P27	J55	3	-0.263	0.306	0.8862	0.345			Surface
P27	J55	3	0.060	0.220	0.8862	0.248			Surface
P27	J55	3	0.300	0.528	0.8862	0.596			Surface
P27	J55	3	0.107	0.670	0.8862	0.756			Surface
P27	J55	3	0.463	0.163	0.8862	0.183	0.133	0.426	Surface
P27	J60	1	0.860	–	–	–			Interm
P27	J60	1	0.110	–	–	–			Interm
P27	J60	1	0.060	–	–	–			Interm
P27	J60	1	1.090	–	–	–			Interm
P27	J60	1	-0.390	–	–	–			Interm
P27	J60	1	-0.210	–	–	–			Interm
P27	J60	1	-0.450	–	–	–			Interm
P27	J60	1	0.500	–	–	–			Interm
P27	J60	1	-0.860	–	–	–			Interm
P27	J60	1	0.110	–	–	–			Interm
P27	J60	1	0.450	–	–	–			Interm
P27	J60	1	0.220	–	–	–			Interm
P27	J60	1	0.470	–	–	–			Interm
P27	J60	1	-1.080	–	–	–			Interm
P27	J60	1	-0.760	–	–	–			Interm
P27	J60	1	0.630	–	–	–	0.047	–	Interm
P27	J61	1	0.310	–	–	–			Surface
P27	J61	1	-0.060	–	–	–			Surface
P27	J61	1	-0.930	–	–	–			Surface
P27	J61	1	-0.310	–	–	–			Surface
P27	J61	1	-0.800	–	–	–			Surface
P27	J61	1	0.400	–	–	–			Surface
P27	J61	1	-0.900	–	–	–			Surface
P27	J61	1	-0.810	–	–	–			Surface
P27	J61	1	-0.180	–	–	–	-0.364	#DIV/0!	Surface
P27	J71	3	0.410	0.531	0.8862	0.599			Surface
P27	J71	4	0.200	0.391	0.9213	0.425			Surface
P27	J71	3	0.147	0.263	0.8862	0.296			Surface
P27	J71	2	0.500	0.566	0.7979	0.709			Surface
P27	J71	1	-0.060	–	–	–			Surface
P27	J71	3	0.533	0.547	0.8862	0.617			Surface
P27	J71	3	-0.357	0.643	0.8862	0.725			Surface
P27	J71	5	0.118	0.574	0.94	0.610			Surface
P27	J71	3	0.343	0.531	0.8862	0.599	0.204	0.573	Surface
P28	J39	3	-0.860	0.270	0.8862	0.305			Surface
P28	J39	1	-0.900	–	–	–			Surface
P28	J39	4	-0.700	0.324	0.9213	0.351			Surface
P28	J39	5	-0.674	0.106	0.94	0.112			Surface
P28	J39	5	-0.472	0.243	0.94	0.259			Surface

Table B.5. Summary of Unbiased Lot Std Dev for AV for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P28	J39	1	-0.400	–	–	–			Surface
P28	J39	3	-0.507	0.105	0.8862	0.119			Surface
P28	J39	1	-0.530	–	–	–			Surface
P28	J39	1	0.150	–	–	–	-0.544	0.229	Surface
P28	J42	2	-0.180	0.750	0.7979	0.939			Interm
P28	J42	1	0.830	–	–	–			Interm
P28	J42	1	0.010	–	–	–			Interm
P28	J42	1	0.820	–	–	–			Interm
P28	J42	1	-0.040	–	–	–			Interm
P28	J42	1	-0.360	–	–	–			Interm
P28	J42	1	0.010	–	–	–			Interm
P28	J42	1	0.010	–	–	–			Interm
P28	J42	2	-0.140	0.198	0.7979	0.248			Interm
P28	J42	1	0.030	–	–	–			Interm
P28	J42	1	-0.010	–	–	–			Interm
P28	J42	1	-0.550	–	–	–			Interm
P28	J42	1	-0.550	–	–	–	-0.009	0.594	Interm
P29	J59	1	-0.030	–	–	–			Surface
P29	J59	3	-0.180	0.270	0.8862	0.304			Surface
P29	J59	3	0.283	0.220	0.8862	0.249			Surface
P29	J59	3	-0.180	0.170	0.8862	0.192			Surface
P29	J59	3	0.417	0.396	0.8862	0.446			Surface
P29	J59	3	-0.107	0.214	0.8862	0.241			Surface
P29	J59	4	-0.045	0.160	0.9213	0.173			Surface
P29	J59	3	-0.090	0.135	0.8862	0.153			Surface
P29	J59	3	-0.133	0.205	0.8862	0.232	-0.007	0.249	Surface
P30	J65	3	0.640	0.390	0.8862	0.440			Surface
P30	J65	3	0.427	0.021	0.8862	0.023			Surface
P30	J65	1	0.450	–	–	–			Surface
P30	J65	1	0.430	–	–	–	0.487	0.232	Surface
P32	J72	5	0.312	0.165	0.94	0.175			Surface
P32	J72	6	0.588	0.387	0.9515	0.407			Surface
P32	J72	3	0.447	0.076	0.8862	0.085			Surface
P32	J72	3	-0.300	0.070	0.8862	0.079			Surface
P32	J72	5	-0.334	0.155	0.94	0.165			Surface
P32	J72	5	-0.500	0.221	0.94	0.235			Surface
P32	J72	3	-0.523	0.261	0.8862	0.294			Surface
P32	J72	4	-0.265	0.430	0.9213	0.467	-0.072	0.238	Surface
P32	J76	4	-0.660	0.281	0.9213	0.305			Interm
P32	J76	3	-0.537	0.309	0.8862	0.349			Interm
P32	J76	5	-0.524	0.400	0.94	0.425			Interm
P32	J76	4	-0.430	0.576	0.9213	0.625			Interm
P32	J76	3	-0.513	0.196	0.8862	0.221			Interm
P32	J76	3	-0.477	0.150	0.8862	0.170			Interm
P32	J76	3	-0.563	0.121	0.8862	0.137			Interm
P32	J76	4	-0.550	0.507	0.9213	0.551			Interm
P32	J76	4	-0.840	0.203	0.9213	0.220			Interm

Table B.5. Summary of Unbiased Lot Std Dev for AV for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P32	J76	4	-0.795	0.216	0.9213	0.234			Interm
P32	J76	3	-0.880	0.159	0.8862	0.179			Interm
P32	J76	3	-0.400	0.278	0.8862	0.314	-0.597	0.311	Interm
P32	J79	6	-0.413	0.534	0.9515	0.562			Surface
P32	J79	5	-0.222	0.311	0.94	0.330			Surface
P32	J79	4	-0.125	0.424	0.9213	0.460			Surface
P32	J79	3	-0.673	0.523	0.8862	0.590			Surface
P32	J79	4	-0.123	0.180	0.9213	0.195			Surface
P32	J79	3	-0.333	0.102	0.8862	0.115			Surface
P32	J79	3	0.017	0.701	0.8862	0.791			Surface
P32	J79	3	0.220	0.246	0.8862	0.277			Surface
P32	J79	4	-0.008	0.280	0.9213	0.304			Surface
P32	J79	5	-0.074	0.690	0.94	0.734			Surface
P32	J79	4	-0.175	0.308	0.9213	0.334			Surface
P32	J79	5	0.062	0.337	0.94	0.358			Surface
P32	J79	3	0.317	0.266	0.8862	0.300			Surface
P32	J79	5	-0.514	0.412	0.94	0.439			Surface
P32	J79	5	-0.472	0.604	0.94	0.643			Surface
P32	J79	5	-0.744	0.297	0.94	0.316			Surface
P32	J79	5	-0.224	0.196	0.94	0.208			Surface
P32	J79	3	-0.303	0.622	0.8862	0.702			Surface
P32	J79	5	-0.110	0.296	0.94	0.314			Surface
P32	J79	3	0.313	0.535	0.8862	0.604			Surface
P32	J79	3	-0.023	0.356	0.8862	0.402			Surface
P32	J79	4	-0.545	0.580	0.9213	0.630			Surface
P32	J79	3	-0.767	0.296	0.8862	0.334			Surface
P32	J79	3	-0.927	0.455	0.8862	0.513	-0.244	0.436	Surface
P33	J73	1	-0.230	–	–	–			Interm
P33	J73	3	0.267	0.326	0.8862	0.368			Interm
P33	J73	3	-0.613	0.755	0.8862	0.852			Interm
P33	J73	5	0.068	0.588	0.94	0.626			Interm
P33	J73	4	0.490	0.140	0.9213	0.152			Interm
P33	J73	3	0.033	0.281	0.8862	0.317			Interm
P33	J73	3	0.410	0.593	0.8862	0.669			Interm
P33	J73	3	0.263	0.338	0.8862	0.382	0.086	0.481	Interm
P33	J77	4	1.135	0.413	0.9213	0.448			Surface
P33	J77	4	0.360	0.329	0.9213	0.357			Surface
P33	J77	4	-0.308	0.189	0.9213	0.205			Surface
P33	J77	4	0.645	0.429	0.9213	0.466			Surface
P33	J77	3	0.903	0.098	0.8862	0.111			Surface
P33	J77	3	0.040	0.819	0.8862	0.924	0.463	0.419	Surface
P34	J62	4	0.173	0.593	0.9213	0.643			Surface
P34	J62	4	-0.595	0.112	0.9213	0.121			Surface
P34	J62	6	0.362	0.285	0.9515	0.300			Surface
P34	J62	4	0.745	0.827	0.9213	0.898			Surface
P34	J62	4	0.303	1.080	0.9213	1.172			Surface
P34	J62	4	-0.040	0.598	0.9213	0.649			Surface

Table B.5. Summary of Unbiased Lot Std Dev for AV for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P34	J62	2	-0.125	0.120	0.7979	0.151	0.117	0.562	Surface
P34	J81	2	1.090	0.042	0.7979	0.053			Surface
P34	J81	2	0.370	0.127	0.7979	0.160			Surface
P34	J81	1	0.290	–	–	–			Surface
P34	J81	2	-0.335	0.587	0.7979	0.736			Surface
P34	J81	2	-0.400	0.311	0.7979	0.390			Surface
P34	J81	2	-0.165	0.050	0.7979	0.062			Surface
P34	J81	2	-0.215	0.346	0.7979	0.434	0.091	0.306	Surface
P35	J32	3	0.023	1.028	0.8862	1.160			Surface
P35	J32	1	0.170	–	–	–			Surface
P35	J32	3	0.373	0.295	0.8862	0.333			Surface
P35	J32	3	0.350	0.223	0.8862	0.252			Surface
P35	J32	3	0.890	0.036	0.8862	0.041			Surface
P35	J32	1	0.510	–	–	–	0.386	0.446	Surface
P35	J38	2	-0.205	0.219	0.7979	0.275			Surface
P35	J38	2	-0.305	0.318	0.7979	0.399			Surface
P35	J38	1	-0.300	–	–	–			Surface
P35	J38	2	0.180	0.764	0.7979	0.957			Surface
P35	J38	2	0.210	0.014	0.7979	0.018			Surface
P35	J38	1	0.040	–	–	–			Surface
P35	J38	2	0.100	0.000	0.7979	0.000			Surface
P35	J38	3	-0.600	0.239	0.8862	0.270			Surface
P35	J38	5	-0.150	0.453	0.94	0.482			Surface
P35	J38	2	0.175	0.050	0.7979	0.062			Surface
P35	J38	4	0.048	0.098	0.9213	0.106			Surface
P35	J38	3	0.263	0.006	0.8862	0.007			Surface
P35	J38	3	0.183	0.133	0.8862	0.150			Surface
P35	J38	2	0.595	0.106	0.7979	0.133			Surface
P35	J38	1	0.620	–	–	–			Surface
P35	J38	1	0.450	–	–	–	0.082	0.238	Surface

Table B.6. Summary of Unbiased Lot Std Dev for VMA for Each Project

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P01	J02	2	0.020	0.679	0.7979	0.851			Interm
P01	J02	3	0.227	0.779	0.8862	0.879			Interm
P01	J02	2	-0.165	0.318	0.7979	0.399			Interm
P01	J02	1	-0.220	–	–	–	-0.035	0.70948	Interm
P01	J07	3	0.590	0.053	0.8862	0.060			Surface
P01	J07	3	0.300	0.892	0.8862	1.006			Surface
P01	J07	5	0.368	0.512	0.9400	0.545			Surface
P01	J07	3	0.607	0.265	0.8862	0.299			Surface
P01	J07	3	-0.010	0.245	0.8862	0.277			Surface
P01	J07	1	0.400	–	–	–			Surface
P01	J07	3	-0.387	0.471	0.8862	0.531			Surface
P01	J07	5	0.094	0.357	0.9400	0.380			Surface
P01	J07	4	0.320	0.336	0.9213	0.364	0.254	0.43264	Surface
P01	J10	3	-0.577	0.354	0.8862	0.400			Interm
P01	J10	1	-0.320	–	–	–			Interm
P01	J10	1	-2.000	–	–	–			Interm
P01	J10	4	-0.243	0.255	0.9213	0.277			Interm
P01	J10	3	-0.473	0.376	0.8862	0.424			Interm
P01	J10	1	-0.020	–	–	–			Interm
P01	J10	3	-0.567	0.210	0.8862	0.237			Interm
P01	J10	1	-0.130	–	–	–			Interm
P01	J10	1	0.200	–	–	–			Interm
P01	J10	1	-0.350	–	–	–			Interm
P01	J10	2	0.215	0.912	0.7979	1.143			Interm
P01	J10	2	-0.120	0.085	0.7979	0.106			Interm
P01	J10	4	-0.253	0.200	0.9213	0.217			Interm
P01	J10	2	-0.310	0.297	0.7979	0.372			Interm
P01	J10	2	-0.145	0.120	0.7979	0.151			Interm
P01	J10	3	0.330	0.471	0.8862	0.532			Interm
P01	J10	2	-0.190	0.099	0.7979	0.124			Interm
P01	J10	3	-0.507	0.359	0.8862	0.405	-0.303	0.36569	Interm
P01	J19	1	-0.420	–	–	–			Surface
P01	J19	1	0.860	–	–	–			Surface
P01	J19	2	-0.460	0.481	0.7979	0.603			Surface
P01	J19	2	-0.465	0.276	0.7979	0.346			Surface
P01	J19	1	-0.700	–	–	–			Surface
P01	J19	1	0.280	–	–	–			Surface
P01	J19	1	1.130	–	–	–			Surface
P01	J19	1	1.130	–	–	–			Surface
P01	J19	2	0.200	0.057	0.7979	0.071			Surface
P01	J19	1	-0.600	–	–	–			Surface
P01	J19	1	0.200	–	–	–			Surface
P01	J19	2	-0.355	0.643	0.7979	0.806			Surface
P01	J19	1	0.170	–	–	–			Surface
P01	J19	1	-0.540	–	–	–	0.031	0.45640	Surface
P01	J23	4	0.188	0.296	0.9213	0.321			Interm
P01	J23	3	-0.217	0.751	0.8862	0.847			Interm

Table B.6. Summary of Unbiased Lot Std Dev for VMA for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P01	J23	1	0.080	–	–	–			Interm
P01	J23	2	-0.290	0.721	0.7979	0.904			Interm
P01	J23	1	0.340	–	–	–			Interm
P01	J23	1	-0.240	–	–	–	-0.023	0.69080	Interm
P02	J04	4	0.485	0.253	0.9213	0.274			Interm
P02	J04	1	0.840	–	–	–			Interm
P02	J04	2	-0.265	0.078	0.7979	0.097			Interm
P02	J04	2	0.285	0.559	0.7979	0.700			Interm
P02	J04	4	-0.350	0.384	0.9213	0.417			Interm
P02	J04	1	0.990	–	–	–			Interm
P02	J04	4	-0.528	0.333	0.9213	0.361			Interm
P02	J04	1	0.950	–	–	–			Interm
P02	J04	1	1.100	–	–	–			Interm
P02	J04	2	0.225	0.375	0.7979	0.470			Interm
P02	J04	3	0.030	0.193	0.8862	0.218			Interm
P02	J04	1	0.820	–	–	–			Interm
P02	J04	1	0.620	–	–	–			Interm
P02	J04	3	0.737	0.421	0.8862	0.475	0.424	0.37651	Interm
P02	J05	2	0.475	0.262	0.7979	0.328			Surface
P02	J05	1	0.450	–	–	–			Surface
P02	J05	2	-0.040	0.071	0.7979	0.089			Surface
P02	J05	1	0.220	–	–	–			Surface
P02	J05	1	0.450	–	–	–			Surface
P02	J05	1	0.830	–	–	–	0.398	0.20826	Surface
P02	J09	1	0.400	–	–	–			Interm
P02	J09	2	0.595	0.276	0.7979	0.346			Interm
P02	J09	1	0.150	–	–	–			Interm
P02	J09	3	0.307	0.549	0.8862	0.620			Interm
P02	J09	2	-0.275	0.346	0.7979	0.434			Interm
P02	J09	2	0.550	0.156	0.7979	0.195			Interm
P02	J09	1	-1.350	–	–	–			Interm
P02	J09	1	0.440	–	–	–			Interm
P02	J09	2	-0.900	0.141	0.7979	0.177			Interm
P02	J09	3	0.350	0.531	0.8862	0.599			Interm
P02	J09	2	-0.220	0.424	0.7979	0.532			Interm
P02	J09	2	-0.250	1.018	0.7979	1.276			Interm
P02	J09	1	0.960	–	–	–			Interm
P02	J09	4	0.108	0.557	0.9213	0.604			Interm
P02	J09	2	-0.745	0.247	0.7979	0.310			Interm
P02	J09	1	-0.340	–	–	–			Interm
P02	J09	2	-0.070	0.354	0.7979	0.443			Interm
P02	J09	2	0.670	0.608	0.7979	0.762	0.021	0.52488	Interm
P02	J13	1	0.660	–	–	–			Surface
P02	J13	1	-0.230	–	–	–			Surface
P02	J13	2	1.060	0.127	0.7979	0.160			Surface
P02	J13	1	1.060	–	–	–			Surface
P02	J13	1	0.280	–	–	–			Surface

Table B.6. Summary of Unbiased Lot Std Dev for VMA for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P02	J13	1	0.390	–	–	–			Surface
P02	J13	2	-0.105	0.417	0.7979	0.523			Surface
P02	J13	1	-0.600	–	–	–			Surface
P02	J13	1	-0.760	–	–	–			Surface
P02	J13	1	0.180	–	–	–			Surface
P02	J13	1	0.380	–	–	–			Surface
P02	J13	2	-0.435	0.361	0.7979	0.452			Surface
P02	J13	2	0.805	0.233	0.7979	0.292			Surface
P02	J13	1	0.180	–	–	–	0.205	0.35670	Surface
P02	J15	1	1.120	–	–	–			Surface
P02	J15	4	0.578	0.113	0.9213	0.123			Surface
P02	J15	4	0.255	0.218	0.9213	0.237			Surface
P02	J15	5	0.730	0.619	0.9400	0.659			Surface
P02	J15	3	-0.100	0.820	0.8862	0.926			Surface
P02	J15	1	-0.520	–	–	–	0.344	0.48596	Surface
P04	J08	2	-0.230	1.245	0.7979	1.560			Interm
P04	J08	2	0.705	0.601	0.7979	0.753			Interm
P04	J08	2	0.860	0.481	0.7979	0.603			Interm
P04	J08	2	1.085	0.615	0.7979	0.771			Interm
P04	J08	2	0.615	0.658	0.7979	0.824	0.607	0.90216	Interm
P04	J14	3	0.377	0.391	0.8862	0.441			Surface
P04	J14	4	0.070	0.595	0.9213	0.646			Surface
P04	J14	4	0.793	0.490	0.9213	0.532			Surface
P04	J14	3	0.410	0.308	0.8862	0.348			Surface
P04	J14	3	0.083	0.528	0.8862	0.596	0.347	0.51253	Surface
P05	J25	1	-1.400	–	–	–			Surface
P05	J25	1	0.030	–	–	–			Surface
P05	J25	1	-0.270	–	–	–			Surface
P05	J25	1	-0.990	–	–	–			Surface
P05	J25	1	-0.370	–	–	–			Surface
P05	J25	1	1.000	–	–	–			Surface
P05	J25	1	0.140	–	–	–			Surface
P05	J25	1	0.090	–	–	–	-0.221	#DIV/0!	Surface
P05	J27	2	0.015	0.417	0.7979	0.523			Interm
P05	J27	2	0.345	0.403	0.7979	0.505			Interm
P05	J27	2	0.370	0.495	0.7979	0.620			Interm
P05	J27	2	0.150	0.028	0.7979	0.035			Interm
P05	J27	2	-0.590	0.170	0.7979	0.213			Interm
P05	J27	2	0.020	0.000	0.7979	0.000			Interm
P05	J27	1	-0.110	–	–	–			Interm
P05	J27	2	0.130	0.764	0.7979	0.957	0.041	0.40766	Interm
P06	J24	3	-0.493	0.416	0.8862	0.469			Surface
P06	J24	3	-0.187	0.577	0.8862	0.651			Surface
P06	J24	3	-0.140	0.060	0.8862	0.068			Surface
P06	J24	3	0.053	0.858	0.8862	0.968			Surface
P06	J24	3	-0.283	0.522	0.8862	0.589	-0.210	0.54906	Surface
P07	J30	3	0.363	0.119	0.8862	0.135			Surface

Table B.6. Summary of Unbiased Lot Std Dev for VMA for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P07	J30	1	0.230	–	–	–			Surface
P07	J30	1	0.020	–	–	–			Surface
P07	J30	1	0.590	–	–	–			Surface
P07	J30	4	0.213	0.518	0.9213	0.562			Surface
P07	J30	2	0.225	0.120	0.7979	0.151			Surface
P07	J30	2	-0.420	0.467	0.7979	0.585			Surface
P07	J30	1	0.070	–	–	–			Surface
P07	J30	3	-0.080	0.229	0.8862	0.258			Surface
P07	J30	3	-0.357	0.611	0.8862	0.689			Surface
P07	J30	3	0.327	0.511	0.8862	0.576			Surface
P07	J30	3	-0.093	0.638	0.8862	0.720			Surface
P07	J30	2	-0.515	0.120	0.7979	0.151			Surface
P07	J30	3	-0.360	0.416	0.8862	0.469			Surface
P07	J30	3	-0.420	0.076	0.8862	0.085			Surface
P07	J30	1	0.320	–	–	–			Surface
P07	J30	2	-0.335	0.559	0.7979	0.700			Surface
P07	J30	1	0.300	–	–	–			Surface
P07	J30	1	0.420	–	–	–	0.026	0.42341	Surface
P09	J35	3	0.413	0.690	0.8862	0.778			Surface
P09	J35	3	-0.057	0.115	0.8862	0.130			Surface
P09	J35	3	0.333	0.257	0.8862	0.290	0.230	0.39950	Surface
P09	J83	3	-0.013	0.631	0.8862	0.712			Surface
P09	J83	3	-0.463	0.598	0.8862	0.674			Surface
P09	J83	2	-0.610	0.410	0.7979	0.514	-0.362	0.63339	Surface
P10	J12	1	0.710	–	–	–			Surface
P10	J12	1	0.690	–	–	–			Surface
P10	J12	1	0.940	–	–	–			Surface
P10	J12	2	1.070	0.028	0.7979	0.035			Surface
P10	J12	1	0.160	–	–	–			Surface
P10	J12	1	0.320	–	–	–			Surface
P10	J12	1	-0.470	–	–	–			Surface
P10	J12	1	-0.750	–	–	–			Surface
P10	J12	2	1.330	0.424	0.7979	0.532			Surface
P10	J12	2	0.065	0.219	0.7979	0.275			Surface
P10	J12	2	-0.170	0.141	0.7979	0.177			Surface
P10	J12	2	-0.420	0.311	0.7979	0.390			Surface
P10	J12	2	-0.310	0.339	0.7979	0.425	0.243	0.30574	Surface
P10	J31	2	-0.730	0.509	0.7979	0.638			Interm
P10	J31	2	0.890	0.170	0.7979	0.213			Interm
P10	J31	2	0.305	0.658	0.7979	0.824			Interm
P10	J31	2	-0.030	0.495	0.7979	0.620			Interm
P10	J31	1	1.000	–	–	–			Interm
P10	J31	2	0.425	0.672	0.7979	0.842			Interm
P10	J31	2	0.275	0.092	0.7979	0.115			Interm
P10	J31	1	0.900	–	–	–			Interm
P10	J31	2	0.410	0.325	0.7979	0.408			Interm
P10	J31	2	0.125	0.021	0.7979	0.027			Interm

Table B.6. Summary of Unbiased Lot Std Dev for VMA for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P10	J31	2	0.790	0.156	0.7979	0.195			Interm
P10	J31	2	0.915	0.502	0.7979	0.629			Interm
P10	J31	2	0.815	0.148	0.7979	0.186			Interm
P10	J31	2	0.465	0.757	0.7979	0.948			Interm
P10	J31	2	0.645	0.643	0.7979	0.806			Interm
P10	J31	2	0.540	0.014	0.7979	0.018			Interm
P10	J31	2	0.590	0.665	0.7979	0.833			Interm
P10	J31	2	0.175	1.209	0.7979	1.515			Interm
P10	J31	2	0.015	0.544	0.7979	0.682			Interm
P10	J31	2	0.630	0.085	0.7979	0.106			Interm
P10	J31	2	0.070	1.259	0.7979	1.577			Interm
P10	J31	1	0.650	–	–	–			Interm
P10	J31	2	0.160	0.764	0.7979	0.957			Interm
P10	J31	2	-0.720	0.028	0.7979	0.035			Interm
P10	J31	2	-0.730	0.509	0.7979	0.638			Interm
P10	J31	2	0.180	0.226	0.7979	0.284			Interm
P10	J31	1	-0.420	–	–	–			Interm
P10	J31	2	-0.910	0.156	0.7979	0.195			Interm
P10	J31	2	-0.610	0.622	0.7979	0.780			Interm
P10	J31	2	0.395	0.148	0.7979	0.186			Interm
P10	J31	2	0.100	0.184	0.7979	0.230			Interm
P10	J31	2	0.655	0.672	0.7979	0.842			Interm
P10	J31	2	0.200	1.089	0.7979	1.365			Interm
P10	J31	2	0.405	0.813	0.7979	1.019			Interm
P10	J31	2	0.775	0.276	0.7979	0.346			Interm
P10	J31	2	0.030	0.184	0.7979	0.230			Interm
P10	J31	2	-0.530	0.495	0.7979	0.620			Interm
P10	J31	2	0.270	0.948	0.7979	1.188			Interm
P10	J31	2	-0.220	0.354	0.7979	0.443			Interm
P10	J31	2	0.075	0.757	0.7979	0.948			Interm
P10	J31	1	0.370	–	–	–	0.228	0.59696	Interm
P10	J37	1	0.870	–	–	–			Interm
P10	J37	2	-0.255	0.191	0.7979	0.239			Interm
P10	J37	2	-0.175	0.092	0.7979	0.115			Interm
P10	J37	2	0.020	0.467	0.7979	0.585			Interm
P10	J37	2	0.190	0.962	0.7979	1.205			Interm
P10	J37	1	0.650	–	–	–			Interm
P10	J37	2	0.755	0.163	0.7979	0.204			Interm
P10	J37	2	1.530	1.796	0.7979	2.251			Interm
P10	J37	2	0.655	0.346	0.7979	0.434			Interm
P10	J37	2	0.000	0.156	0.7979	0.195			Interm
P10	J37	2	0.875	0.007	0.7979	0.009			Interm
P10	J37	2	0.065	0.092	0.7979	0.115	0.432	0.53527	Interm
P10	J82	2	-0.350	0.014	0.7979	0.018			Interm
P10	J82	2	0.375	0.643	0.7979	0.806			Interm
P10	J82	2	1.080	0.311	0.7979	0.390			Interm
P10	J82	2	1.125	0.163	0.7979	0.204			Interm

Table B.6. Summary of Unbiased Lot Std Dev for VMA for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P10	J82	2	0.380	0.170	0.7979	0.213			Interm
P10	J82	1	1.010	–	–	–			Interm
P10	J82	2	1.265	0.177	0.7979	0.222			Interm
P10	J82	2	0.500	0.354	0.7979	0.443	0.673	0.32790	Interm
P11	J41	3	0.290	0.330	0.8862	0.372			Surface
P11	J41	1	0.290	–	–	–			Surface
P11	J41	2	0.250	0.410	0.7979	0.514			Surface
P11	J41	4	0.343	0.200	0.9213	0.218	0.293	0.36796	Surface
P12	J38	4	-0.695	0.285	0.9213	0.309			Surface
P12	J38	2	-1.085	0.417	0.7979	0.523			Surface
P12	J38	1	-0.810	–	–	–			Surface
P12	J38	1	-0.770	–	–	–			Surface
P12	J38	3	-0.060	0.426	0.8862	0.480			Surface
P12	J38	3	0.120	0.977	0.8862	1.102	-0.550	0.60363	Surface
P13	J03	3	-0.553	0.190	0.8862	0.215			Surface
P13	J03	3	-0.050	0.344	0.8862	0.388			Surface
P13	J03	1	-0.160	–	–	–			Surface
P13	J03	3	-0.013	0.380	0.8862	0.429			Surface
P13	J03	1	-0.170	–	–	–			Surface
P13	J03	1	-0.290	–	–	–			Surface
P13	J03	3	0.013	0.202	0.8862	0.228			Surface
P13	J03	1	1.010	–	–	–	-0.027	0.31494	Surface
P13	J43	2	0.110	0.523	0.7979	0.656			Surface
P13	J43	2	-0.220	0.806	0.7979	1.010			Surface
P13	J43	2	-0.455	0.191	0.7979	0.239			Surface
P13	J43	2	0.375	0.191	0.7979	0.239			Surface
P13	J43	3	0.203	0.681	0.8862	0.768			Surface
P13	J43	4	0.083	0.440	0.9213	0.477			Surface
P13	J43	3	0.350	0.644	0.8862	0.727			Surface
P13	J43	1	1.330	–	–	–	0.222	0.58815	Surface
P14	J16	1	-0.420	–	–	–			Surface
P14	J16	2	-0.475	0.290	0.7979	0.363			Surface
P14	J16	3	-1.227	0.550	0.8862	0.621			Surface
P14	J16	2	0.275	0.460	0.7979	0.576			Surface
P14	J16	1	-0.320	–	–	–			Surface
P14	J16	4	-0.458	0.567	0.9213	0.616			Surface
P14	J16	3	-0.700	0.087	0.8862	0.098			Surface
P14	J16	4	-1.030	0.825	0.9213	0.896			Surface
P14	J16	4	-0.845	0.527	0.9213	0.572			Surface
P14	J16	2	-0.670	0.113	0.7979	0.142			Surface
P14	J16	1	-1.250	–	–	–			Surface
P14	J16	2	-0.675	0.163	0.7979	0.204			Surface
P14	J16	3	-0.807	0.140	0.8862	0.158	-0.662	0.42451	Surface
P16	J20	3	-0.283	0.770	0.8862	0.869			Surface
P16	J20	3	-0.120	0.355	0.8862	0.401			Surface
P16	J20	3	-0.300	0.149	0.8862	0.169	-0.234	0.47925	Surface
P17	J22	2	-0.430	0.057	0.7979	0.071			Interm

Table B.6. Summary of Unbiased Lot Std Dev for VMA for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P17	J22	2	-0.930	0.198	0.7979	0.248			Interm
P17	J22	2	-0.215	0.615	0.7979	0.771			Interm
P17	J22	1	-0.700	–	–	–			Interm
P17	J22	2	-0.495	0.926	0.7979	1.161			Interm
P17	J22	2	-0.155	0.686	0.7979	0.860	-0.488	0.62212	Interm
P18	J48	1	-0.110	–	–	–			Surface
P18	J48	3	-0.447	0.212	0.8862	0.239			Surface
P18	J48	1	-0.930	–	–	–			Surface
P18	J48	2	0.145	0.064	0.7979	0.080			Surface
P18	J48	3	0.067	0.767	0.8862	0.866			Surface
P18	J48	1	-0.130	–	–	–			Surface
P18	J48	1	1.330	–	–	–	-0.011	0.39494	Surface
P19	J49	2	-0.015	0.078	0.7979	0.097			Surface
P19	J49	1	-0.210	–	–	–			Surface
P19	J49	3	-0.683	0.300	0.8862	0.338			Surface
P19	J49	4	-0.415	0.251	0.9213	0.273			Surface
P19	J49	4	-1.055	0.840	0.9213	0.912			Surface
P19	J49	3	-0.497	1.028	0.8862	1.160			Surface
P19	J49	3	-0.713	0.155	0.8862	0.175	-0.513	0.49258	Surface
P20	J50	1	-0.510	–	–	–			Surface
P20	J50	5	-0.724	0.151	0.9400	0.160			Surface
P20	J50	2	-0.735	0.247	0.7979	0.310			Surface
P20	J50	4	0.025	0.139	0.9213	0.151			Surface
P20	J50	1	0.190	–	–	–			Surface
P20	J50	2	0.410	0.141	0.7979	0.177			Surface
P20	J50	5	0.072	0.326	0.9400	0.347			Surface
P20	J50	3	-0.197	0.292	0.8862	0.329			Surface
P20	J50	1	0.020	–	–	–			Surface
P20	J50	1	-0.360	–	–	–			Surface
P20	J50	5	-0.188	0.488	0.9400	0.520			Surface
P20	J50	1	-0.890	–	–	–			Surface
P20	J50	2	0.080	0.552	0.7979	0.691			Surface
P20	J50	4	-0.328	0.347	0.9213	0.377			Surface
P20	J50	5	-0.166	0.490	0.9400	0.521			Surface
P20	J50	2	-0.280	0.127	0.7979	0.160			Surface
P20	J50	2	-0.030	0.057	0.7979	0.071	-0.212	0.31784	Surface
P21	J34	4	0.333	0.190	0.9213	0.206			Interm
P21	J34	3	0.130	0.046	0.8862	0.052			Interm
P21	J34	1	0.120	–	–	–	0.194	0.12896	Interm
P21	J39	1	-0.510	–	–	–			Surface
P21	J39	4	-0.568	0.029	0.9213	0.031			Surface
P21	J39	2	-0.585	0.035	0.7979	0.044			Surface
P21	J39	4	-0.800	0.272	0.9213	0.296			Surface
P21	J39	3	-0.900	0.289	0.8862	0.326			Surface
P21	J39	1	-0.680	–	–	–	-0.674	0.17437	Surface
P22	J54	6	0.078	1.029	0.9515	1.082			Surface
P22	J54	5	0.280	0.338	0.9400	0.360			Surface

Table B.6. Summary of Unbiased Lot Std Dev for VMA for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P22	J54	1	0.730	–	–	–	0.363	0.72070	Surface
P24	J56	1	0.240	–	–	–			Surface
P24	J56	5	-0.232	0.623	0.9400	0.662			Surface
P24	J56	1	-0.130	–	–	–			Surface
P24	J56	3	-0.373	0.042	0.8862	0.047			Surface
P24	J56	1	-0.800	–	–	–			Surface
P24	J56	3	-0.220	0.053	0.8862	0.060			Surface
P24	J56	1	-0.180	–	–	–			Surface
P24	J56	1	-0.370	–	–	–			Surface
P24	J56	3	-0.307	0.358	0.8862	0.404			Surface
P24	J56	1	-0.460	–	–	–			Surface
P24	J56	4	-0.140	0.349	0.9213	0.379			Surface
P24	J56	2	0.520	0.141	0.7979	0.177			Surface
P24	J56	1	1.420	–	–	–			Surface
P24	J56	3	-0.333	0.555	0.8862	0.626			Surface
P24	J56	1	-0.330	–	–	–			Surface
P24	J56	2	-0.305	0.035	0.7979	0.044			Surface
P24	J56	4	-0.663	0.268	0.9213	0.290			Surface
P24	J56	3	-0.113	1.003	0.8862	1.131	-0.154	0.38212	Surface
P24	J64	1	0.000	–	–	–			Surface
P24	J64	2	0.010	0.382	0.7979	0.479			Surface
P24	J64	2	-0.375	0.021	0.7979	0.027			Surface
P24	J64	2	0.055	0.247	0.7979	0.310			Surface
P24	J64	2	-0.525	0.007	0.7979	0.009			Surface
P24	J64	2	-0.185	0.134	0.7979	0.168			Surface
P24	J64	2	-0.360	0.127	0.7979	0.160	-0.197	0.19201	Surface
P24	J67	1	-0.040	–	–	–			Surface
P24	J67	1	0.030	–	–	–			Surface
P24	J67	1	-0.810	–	–	–			Surface
P24	J67	2	-0.660	0.269	0.7979	0.337			Surface
P24	J67	3	-0.340	0.510	0.8862	0.576			Surface
P24	J67	2	-0.190	0.679	0.7979	0.851	-0.335	0.58778	Surface
P25	J29	2	0.445	0.771	0.7979	0.966			Interm
P25	J29	2	0.645	0.120	0.7979	0.151			Interm
P25	J29	2	0.740	0.481	0.7979	0.603			Interm
P25	J29	2	0.010	0.071	0.7979	0.089			Interm
P25	J29	1	-0.440	–	–	–			Interm
P25	J29	2	0.695	0.163	0.7979	0.204			Interm
P25	J29	1	0.620	–	–	–	0.388	0.40234	Interm
P25	J36	1	0.870	–	–	–			Surface
P25	J36	2	-0.320	0.919	0.7979	1.152			Surface
P25	J36	3	0.857	0.690	0.8862	0.778			Surface
P25	J36	2	1.365	0.403	0.7979	0.505			Surface
P25	J36	1	0.510	–	–	–			Surface
P25	J36	1	0.960	–	–	–	0.707	0.81181	Surface
P26	J58	1	-0.420	–	–	–			Surface
P26	J58	1	-0.240	–	–	–			Surface

Table B.6. Summary of Unbiased Lot Std Dev for VMA for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P26	J58	1	0.370	–	–	–			Surface
P26	J58	1	0.380	–	–	–			Surface
P26	J58	1	-0.470	–	–	–			Surface
P26	J58	1	0.320	–	–	–			Surface
P26	J58	1	0.400	–	–	–			Surface
P26	J58	1	0.050	–	–	–			Surface
P26	J58	1	0.120	–	–	–			Surface
P26	J58	1	0.080	–	–	–			Surface
P26	J58	2	1.105	0.544	0.7979	0.682			Surface
P26	J58	1	0.950	–	–	–	0.220	0.68238	Surface
P26	J62	4	-0.095	0.440	0.9213	0.477			Surface
P26	J62	4	0.610	0.421	0.9213	0.457			Surface
P26	J62	3	0.237	0.242	0.8862	0.273			Surface
P26	J62	3	0.423	0.626	0.8862	0.707			Surface
P26	J62	3	0.607	0.179	0.8862	0.202			Surface
P26	J62	3	0.693	0.410	0.8862	0.463			Surface
P26	J62	4	0.068	0.526	0.9213	0.571			Surface
P26	J62	3	0.513	0.129	0.8862	0.146			Surface
P26	J62	4	0.243	0.238	0.9213	0.258	0.366	0.39487	Surface
P26	J69	4	0.438	0.439	0.9213	0.476			Surface
P26	J69	3	-0.137	0.068	0.8862	0.077			Surface
P26	J69	3	-0.360	0.381	0.8862	0.430			Surface
P26	J69	3	0.017	0.421	0.8862	0.476			Surface
P26	J69	3	0.107	0.096	0.8862	0.108			Surface
P26	J69	3	-0.100	0.456	0.8862	0.515			Surface
P26	J69	3	-0.197	0.153	0.8862	0.173			Surface
P26	J69	3	0.163	0.068	0.8862	0.077			Surface
P26	J69	3	-0.163	0.448	0.8862	0.505			Surface
P26	J69	4	0.423	0.171	0.9213	0.186			Surface
P26	J69	3	1.123	0.350	0.8862	0.395			Surface
P26	J69	4	0.600	0.362	0.9213	0.393			Surface
P26	J69	3	-0.103	0.045	0.8862	0.051			Surface
P26	J69	3	-0.093	0.257	0.8862	0.290			Surface
P26	J69	3	0.020	0.161	0.8862	0.182			Surface
P26	J69	3	0.320	0.312	0.8862	0.352			Surface
P26	J69	1	0.600	–	–	–			Surface
P26	J69	1	1.080	–	–	–	0.208	0.29281	Surface
P27	J53	1	-0.710	–	–	–			Interm
P27	J53	1	-0.100	–	–	–			Interm
P27	J53	1	-0.730	–	–	–			Interm
P27	J53	1	-0.350	–	–	–			Interm
P27	J53	1	0.120	–	–	–			Interm
P27	J53	2	0.100	0.382	0.7979	0.479			Interm
P27	J53	1	0.020	–	–	–			Interm
P27	J53	1	0.120	–	–	–			Interm
P27	J53	1	0.130	–	–	–			Interm
P27	J53	1	0.010	–	–	–			Interm

Table B.6. Summary of Unbiased Lot Std Dev for VMA for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P27	J53	1	0.110	–	–	–			Interm
P27	J53	1	0.020	–	–	–			Interm
P27	J53	1	0.610	–	–	–			Interm
P27	J53	1	1.070	–	–	–	0.030	0.47856	Interm
P27	J55	3	0.290	0.598	0.8862	0.675			Surface
P27	J55	3	0.370	0.425	0.8862	0.480			Surface
P27	J55	3	0.590	0.130	0.8862	0.147			Surface
P27	J55	3	0.400	0.278	0.8862	0.314			Surface
P27	J55	3	0.663	0.232	0.8862	0.262	0.463	0.37539	Surface
P27	J60	1	1.050	–	–	–			Interm
P27	J60	1	1.110	–	–	–			Interm
P27	J60	1	0.850	–	–	–			Interm
P27	J60	1	0.740	–	–	–			Interm
P27	J60	1	0.270	–	–	–			Interm
P27	J60	1	0.760	–	–	–			Interm
P27	J60	1	-0.010	–	–	–			Interm
P27	J60	1	1.750	–	–	–			Interm
P27	J60	1	0.200	–	–	–			Interm
P27	J60	1	0.980	–	–	–			Interm
P27	J60	1	-0.010	–	–	–			Interm
P27	J60	1	0.790	–	–	–			Interm
P27	J60	1	0.180	–	–	–			Interm
P27	J60	1	-0.020	–	–	–			Interm
P27	J60	1	0.520	–	–	–	0.611	#DIV/0!	Interm
P27	J61	1	0.410	–	–	–			Surface
P27	J61	1	-0.070	–	–	–			Surface
P27	J61	1	-1.260	–	–	–			Surface
P27	J61	1	0.080	–	–	–			Surface
P27	J61	1	-0.380	–	–	–			Surface
P27	J61	1	0.370	–	–	–			Surface
P27	J61	1	-0.550	–	–	–			Surface
P27	J61	1	-0.660	–	–	–			Surface
P27	J61	1	-0.510	–	–	–	-0.286	#DIV/0!	Surface
P27	J71	3	0.453	0.284	0.8862	0.321			Surface
P27	J71	4	0.350	0.295	0.9213	0.320			Surface
P27	J71	3	-0.082	0.642	0.8862	0.725			Surface
P27	J71	2	0.550	0.820	0.7979	1.028			Surface
P27	J71	1	0.280	–	–	–			Surface
P27	J71	3	0.457	0.458	0.8862	0.516			Surface
P27	J71	3	0.080	0.332	0.8862	0.374			Surface
P27	J71	5	0.262	0.414	0.9400	0.440			Surface
P27	J71	3	0.480	0.330	0.8862	0.372	0.314	0.51209	Surface
P28	J39	3	-0.420	0.306	0.8862	0.346			Surface
P28	J39	1	-0.840	–	–	–			Surface
P28	J39	4	-0.325	0.078	0.9213	0.084			Surface
P28	J39	5	-0.518	0.290	0.9400	0.308			Surface
P28	J39	5	-0.356	0.112	0.9400	0.120			Surface

Table B.6. Summary of Unbiased Lot Std Dev for VMA for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P28	J39	1	-0.170	–	–	–			Surface
P28	J39	3	-0.277	0.049	0.8862	0.056			Surface
P28	J39	1	-0.450	–	–	–			Surface
P28	J39	1	-0.450	–	–	–	-0.423	0.18268	Surface
P28	J42	2	-0.225	0.841	0.7979	1.055			Interm
P28	J42	1	0.680	–	–	–			Interm
P28	J42	1	-0.620	–	–	–			Interm
P28	J42	1	0.390	–	–	–			Interm
P28	J42	1	-0.170	–	–	–			Interm
P28	J42	1	-0.140	–	–	–			Interm
P28	J42	1	0.940	–	–	–			Interm
P28	J42	1	0.940	–	–	–			Interm
P28	J42	2	0.210	0.071	0.7979	0.089			Interm
P28	J42	1	0.270	–	–	–			Interm
P28	J42	1	0.370	–	–	–			Interm
P28	J42	1	-0.260	–	–	–			Interm
P28	J42	1	0.160	–	–	–	0.196	0.57161	Interm
P29	J59	1	-0.210	–	–	–			Surface
P29	J59	3	0.223	0.055	0.8862	0.062			Surface
P29	J59	3	0.273	0.360	0.8862	0.406			Surface
P29	J59	3	-0.177	0.171	0.8862	0.193			Surface
P29	J59	3	0.280	0.469	0.8862	0.529			Surface
P29	J59	3	-0.020	0.148	0.8862	0.167			Surface
P29	J59	4	-0.113	0.427	0.9213	0.463			Surface
P29	J59	3	-0.200	0.061	0.8862	0.069			Surface
P29	J59	3	-0.303	0.153	0.8862	0.172	-0.027	0.25769	Surface
P30	J65	3	0.493	0.220	0.8862	0.248			Surface
P30	J65	3	0.467	0.182	0.8862	0.206			Surface
P30	J65	1	0.630	–	–	–			Surface
P30	J65	1	0.330	–	–	–	0.480	0.22703	Surface
P32	J72	5	0.344	0.415	0.9400	0.442			Surface
P32	J72	6	0.525	0.416	0.9515	0.437			Surface
P32	J72	3	0.317	0.536	0.8862	0.605			Surface
P32	J72	3	0.250	0.148	0.8862	0.167			Surface
P32	J72	5	-0.102	0.521	0.9400	0.554			Surface
P32	J72	5	-0.108	0.411	0.9400	0.437			Surface
P32	J72	3	-0.117	0.107	0.8862	0.121			Surface
P32	J72	4	-0.095	0.353	0.9213	0.384	0.127	0.39329	Surface
P32	J76	4	-0.095	0.560	0.9213	0.608			Interm
P32	J76	3	-0.513	0.302	0.8862	0.341			Interm
P32	J76	5	0.098	0.658	0.9400	0.700			Interm
P32	J76	4	-0.060	0.354	0.9213	0.384			Interm
P32	J76	3	0.260	0.269	0.8862	0.303			Interm
P32	J76	3	-0.420	0.566	0.8862	0.639			Interm
P32	J76	3	-0.173	0.169	0.8862	0.191			Interm
P32	J76	4	0.155	0.153	0.9213	0.166			Interm
P32	J76	4	-0.510	0.188	0.9213	0.204			Interm

Table B.6. Summary of Unbiased Lot Std Dev for VMA for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P32	J76	4	0.015	0.365	0.9213	0.397			Interm
P32	J76	3	-0.003	0.537	0.8862	0.606			Interm
P32	J76	3	0.187	0.376	0.8862	0.424	-0.088	0.41358	Interm
P32	J79	6	0.162	0.417	0.9515	0.438			Surface
P32	J79	5	0.456	0.215	0.9400	0.229			Surface
P32	J79	4	0.373	0.387	0.9213	0.420			Surface
P32	J79	3	-0.060	0.410	0.8862	0.462			Surface
P32	J79	4	-0.115	0.411	0.9213	0.446			Surface
P32	J79	3	0.077	0.230	0.8862	0.260			Surface
P32	J79	3	0.307	0.497	0.8862	0.561			Surface
P32	J79	3	0.713	0.344	0.8862	0.388			Surface
P32	J79	4	0.523	0.464	0.9213	0.503			Surface
P32	J79	5	0.276	0.632	0.9400	0.673			Surface
P32	J79	4	-0.678	1.187	0.9213	1.288			Surface
P32	J79	5	-0.270	0.290	0.9400	0.308			Surface
P32	J79	3	0.017	0.032	0.8862	0.036			Surface
P32	J79	5	0.010	0.452	0.9400	0.481			Surface
P32	J79	5	-0.060	0.439	0.9400	0.467			Surface
P32	J79	5	-0.680	0.322	0.9400	0.343			Surface
P32	J79	5	0.218	0.280	0.9400	0.298			Surface
P32	J79	3	0.333	0.548	0.8862	0.619			Surface
P32	J79	5	0.388	0.459	0.9400	0.488			Surface
P32	J79	3	0.280	0.632	0.8862	0.713			Surface
P32	J79	3	0.307	0.448	0.8862	0.506			Surface
P32	J79	4	-0.233	0.351	0.9213	0.381			Surface
P32	J79	3	-0.413	0.178	0.8862	0.201			Surface
P32	J79	3	-0.697	0.217	0.8862	0.245	0.051	0.44816	Surface
P33	J73	1	0.420	–	–	–			Interm
P33	J73	3	0.277	0.220	0.8862	0.248			Interm
P33	J73	3	-0.590	0.488	0.8862	0.550			Interm
P33	J73	5	0.070	0.143	0.9400	0.153			Interm
P33	J73	4	0.258	0.506	0.9213	0.550			Interm
P33	J73	3	0.093	0.045	0.8862	0.051			Interm
P33	J73	3	0.647	0.212	0.8862	0.239			Interm
P33	J73	3	0.197	0.236	0.8862	0.266	0.171	0.29383	Interm
P33	J77	4	-0.210	0.492	0.9213	0.534			Surface
P33	J77	4	-0.323	0.434	0.9213	0.471			Surface
P33	J77	4	-0.518	0.159	0.9213	0.172			Surface
P33	J77	4	0.660	0.518	0.9213	0.562			Surface
P33	J77	3	0.783	0.466	0.8862	0.526			Surface
P33	J77	3	0.663	0.171	0.8862	0.193	0.176	0.40976	Surface
P34	J62	4	0.170	0.284	0.9213	0.309			Surface
P34	J62	4	-0.053	0.162	0.9213	0.176			Surface
P34	J62	6	0.117	0.401	0.9515	0.421			Surface
P34	J62	4	0.450	0.615	0.9213	0.668			Surface
P34	J62	4	-0.023	0.442	0.9213	0.480			Surface
P34	J62	4	0.125	0.408	0.9213	0.443			Surface

Table B.6. Summary of Unbiased Lot Std Dev for VMA for Each Project (*continued*)

Project Number	JMF Number	Lot Size	Lot Mean	Lot St Dev (biased)	c_4	Lot St Dev (unbiased)	Average Lot Mean	Avg Lot SD Unbiased	Course
P34	J62	2	-0.365	0.092	0.7979	0.115	0.060	0.37308	Surface
P34	J81	2	0.800	0.028	0.7979	0.035			Surface
P34	J81	2	0.395	0.516	0.7979	0.647			Surface
P34	J81	1	0.650	–	–	–			Surface
P34	J81	2	0.115	0.262	0.7979	0.328			Surface
P34	J81	2	0.100	0.481	0.7979	0.603			Surface
P34	J81	2	-0.110	0.212	0.7979	0.266			Surface
P34	J81	2	0.280	0.948	0.7979	1.188	0.319	0.51105	Surface
P35	J32	3	-0.103	0.530	0.8862	0.598			Surface
P35	J32	1	-0.270	–	–	–			Surface
P35	J32	3	0.280	0.243	0.8862	0.275			Surface
P35	J32	3	0.013	0.216	0.8862	0.243			Surface
P35	J32	3	0.650	0.139	0.8862	0.157			Surface
P35	J32	1	1.010	–	–	–	0.263	0.31821	Surface
P35	J38	2	-0.445	0.021	0.7979	0.027			Surface
P35	J38	2	-0.135	0.389	0.7979	0.487			Surface
P35	J38	1	0.350	–	–	–			Surface
P35	J38	2	0.335	0.841	0.7979	1.055			Surface
P35	J38	2	0.350	0.071	0.7979	0.089			Surface
P35	J38	1	0.190	–	–	–			Surface
P35	J38	2	0.075	0.460	0.7979	0.576			Surface
P35	J38	3	0.033	0.306	0.8862	0.345			Surface
P35	J38	5	0.090	0.326	0.9400	0.346			Surface
P35	J38	2	0.350	0.226	0.7979	0.284			Surface
P35	J38	4	0.180	0.146	0.9213	0.158			Surface
P35	J38	3	0.280	0.265	0.8862	0.299			Surface
P35	J38	3	0.210	0.312	0.8862	0.353			Surface
P35	J38	2	0.325	0.247	0.7979	0.310			Surface
P35	J38	1	0.550	–	–	–			Surface
P35	J38	1	0.300	–	–	–	0.190	0.36074	Surface

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APPENDIX C — PWL VALUES FOR EACH DENSITY LOT FOR EACH PROJECT

One potential point of concern with the Density data is the relatively low value for the average densities on the various projects. These individual project average values ranged from a low of 88.65 to a high of 94.12, and the average for all projects was around 92.4. The specification "target" values for density were 94.0 for Interstate paving and 93.0 for Other paving. To further investigate how well the projects for which data were obtained met the specification requirements, lot PWL values were calculated. For each project, the PWL value for each lot was calculated and the average PWL for all lots on the project was also calculated. These results are shown in the following tables.

Table C.1. Summary of Density Lot PWL Values for Each Interstate Paving Project

Project Number	JMF Number	Lot Sample Size	Lot Mean	Lot Standard Deviation	Lot PWL	Average Lot PWL	Mix Type
P01	J02	10	94.37	0.821	98.75		Binder 1
P01	J02	1	92.47	—	—		Binder 1
P01	J02	5	93.81	0.746	100.00		Binder 1
P01	J02	6	93.58	0.862	96.76	98.50	Binder 1
P01	J10	3	92.32	0.101	100.00		Interm B
P01	J10	4	93.07	0.546	100.00		Interm B
P01	J10	4	92.54	0.167	100.00		Interm B
P01	J10	5	93.10	0.977	81.27		Interm B
P01	J10	3	92.76	0.487	97.10		Interm B
P01	J10	5	92.95	0.557	92.90		Interm B
P01	J10	6	93.18	0.508	99.78	96.42	Interm B
P23	J33	3	91.96	1.587	45.82		Interm B
P23	J33	3	91.23	1.572	32.05		Interm B
P23	J33	5	91.84	1.426	41.05		Interm B
P23	J33	5	91.48	1.422	32.22	37.76	Interm B
P32	J76	9	93.84	0.817	99.04		Interm B
P32	J76	6	94.23	1.12	95.56		Interm B
P32	J76	10	92.79	0.548	85.95		Interm B
P32	J76	10	93.09	0.856	85.04		Interm B
P32	J76	10	93.02	0.75	86.35		Interm B
P32	J76	6	92.09	1.437	47.19		Interm B
P32	J76	7	92.49	0.988	60.89		Interm B
P32	J76	6	93.33	1.738	68.87		Interm B
P32	J76	9	93.34	0.964	88.41		Interm B
P32	J76	9	93.60	0.77	97.85		Interm B
P32	J76	10	93.69	0.972	94.46		Interm B
P32	J76	7	93.38	0.781	94.89		Interm B
P32	J76	6	93.56	1.381	82.08	83.58	Interm B
P33	J73	5	93.59	2.214	58.07		Interm B
P33	J73	7	93.19	2.129	58.52		
P33	J73	5	92.78	0.918	72.01		Interm B
P33	J73	10	93.49	0.96	91.58		Interm B
P33	J73	7	93.24	1.004	84.86		Interm B
P33	J73	9	92.81	1.335	66.98		Interm B
P33	J73	7	93.53	1.371	81.44		Interm B
P33	J73	6	92.75	1.219	66.31	72.47	Interm B
Total / Average		**229**	**93.01**	**1.030**	**79.54**	**77.75**	**Interm**

Continued

Table C.1. Summary of Density Lot PWL Values for Each Interstate Paving Project (*cont*)

Project Number	JMF Number	Lot Sample Size	Lot Mean	Lot Standard Deviation	Lot PWL	Average Lot PWL	Mix Type
P01	J07	5	92.50	0.217	93.73		Surf 1C
P01	J07	4	93.55	0.396	100.00		Surf 1C
P01	J07	6	93.19	0.346	100.00		Surf 1C
P01	J07	7	93.70	1.101	92.15	96.47	Surf 1C
P26	J62	8	93.39	2.154	59.34		Surf A
P26	J62	4	93.86	0.823	100.00		Surf A
P26	J62	3	92.48	0.295	80.71		Surf A
P26	J62	5	91.70	1.538	38.49		Surf A
P26	J62	5	92.81	1.195	67.92		Surf A
P26	J62	4	92.99	0.705	87.35		Surf A
P26	J62	5	93.07	0.878	83.37		Surf A
P26	J62	3	93.23	0.363	100.00		Surf A
P26	J62	5	92.05	0.931	44.27	73.49	Surf A
P26	J69	5	93.27	1.226	79.78		Surf A
P26	J69	6	93.00	2.265	54.68		Surf A
P26	J69	4	92.82	2.080	59.94		Surf A
P26	J69	5	94.13	0.564	100.00		Surf A
P26	J69	4	93.83	0.651	100.00		Surf A
P26	J69	5	94.29	0.664	100.00		Surf A
P26	J69	6	93.37	0.994	88.45		Surf A
P26	J69	5	93.10	0.721	90.49		Surf A
P26	J69	5	93.33	0.967	88.40		Surf A
P26	J69	5	93.26	1.282	78.34		Surf A
P26	J69	5	92.78	0.737	77.08		Surf A
P26	J69	6	92.38	1.020	56.47		Surf A
P26	J69	6	93.79	0.782	100.00		Surf A
P26	J69	6	94.38	0.674	100.00		Surf A
P26	J69	5	93.05	1.633	68.26		Surf A
P26	J69	3	93.54	0.650	100.00	83.86	Surf A
P32	J74	6	93.20	1.348	76.06	76.06	Surf A

Continued

Table C.1. Summary of Density Lot PWL Values for Each Interstate Paving Project (*cont*)

Project Number	JMF Number	Lot Sample Size	Lot Mean	Lot Standard Deviation	Lot PWL	Average Lot PWL	Mix Type
P32	J79	10	93.03	0.817	84.44		Surf A
P32	J79	8	92.99	0.655	88.97		Surf A
P32	J79	10	92.98	1.174	74.17		Surf A
P32	J79	4	92.80	0.896	72.32		Surf A
P32	J79	10	92.78	0.706	79.07		Surf A
P32	J79	4	93.15	0.334	100.00		Surf A
P32	J79	8	93.03	0.520	95.79		Surf A
P32	J79	4	93.01	0.311	100.00		Surf A
P32	J79	9	92.53	1.713	56.45		Surf A
P32	J79	9	92.93	0.609	88.76		Surf A
P32	J79	11	92.77	0.489	87.99		Surf A
P32	J79	5	93.07	0.870	83.64		Surf A
P32	J79	5	91.26	0.663	5.49		Surf A
P32	J79	10	92.45	0.985	59.68		Surf A
P32	J79	6	92.21	1.104	50.33		Surf A
P32	J79	8	92.61	1.033	64.78		Surf A
P32	J79	5	92.5	0.479	71.82		Surf A
P32	J79	4	93.49	0.645	100.00		Surf A
P32	J79	7	93.26	1.135	82.07		Surf A
P32	J79	5	92.47	0.408	73.00		Surf A
P32	J79	7	92.97	0.617	89.97		Surf A
P32	J79	8	92.95	1.120	74.16		Surf A
P32	J79	6	92.05	1.201	45.42		Surf A
P32	J79	3	93.19	1.344	72.02	75.01	Surf A
P33	J77	8	91.71	0.736	25.97		Surf A
P33	J77	8	93.54	1.144	87.94		Surf A
P33	J77	7	93.78	0.594	100.00		Surf A
P33	J77	7	91.68	1.967	40.16		Surf A
P33	J77	6	92.03	1.454	45.71		Surf A
P33	J77	4	93.55	0.756	100.00	66.63	Surf A
P34	J62	5	94.03	1.002	100.00		Surf A
P34	J62	5	92.58	1.314	60.25		Surf A
P34	J62	10	91.67	1.927	39.20		Surf A
P34	J62	5	93.74	1.461	82.29	70.43	Surf A
P01	J07	5	92.7	0.369	93.10		Surf B
P01	J07	4	92.99	0.648	90.64		Surf B
P01	J07	3	92.53	0.217	100.00		Surf B
P01	J07	5	92.35	0.128	88.49		Surf B
P01	J07	3	93.28	1.109	81.94	90.83	Surf B
P03	J15	4	93.56	0.606	100.00		Surf B
P03	J15	4	92.49	0.801	62.07		Surf B
P03	J15	10	92.8	1.583	63.24		Surf B
P03	J15	4	93.97	0.692	100.00		Surf B
P03	J15	3	94.25	0.778	100.00	85.06	Surf B

Continued

Table C.1. Summary of Density Lot PWL Values for Each Interstate Paving Project (*cont*)

Project Number	JMF Number	Lot Sample Size	Lot Mean	Lot Standard Deviation	Lot PWL	Average Lot PWL	Mix Type
P23	J63	3	92.76	0.487	97.10		Surf B
P23	J63	3	93.10	0.487	100.00		Surf B
P23	J63	3	92.83	0.487	100.00		Surf B
P23	J63	3	92.87	0.487	100.00		Surf B
P23	J63	3	93.40	0.637	100.00		Surf B
P23	J63	3	93.71	0.643	100.00	99.52	Surf B
P32	J72	12	93.05	0.726	88.09		Surf B
P32	J72	14	92.89	0.641	85.95		Surf B
P32	J72	5	92.30	0.783	54.54		Surf B
P32	J72	5	93.40	1.298	81.37		Surf B
P32	J72	10	93.33	1.303	79.46		Surf B
P32	J72	9	93.61	0.525	100.00		Surf B
P32	J72	6	93.01	0.647	90.23		Surf B
P32	J72	9	92.86	0.642	84.72	83.05	Surf B
Total / Average		**515**	**93.01**	**0.888**	**80.55**	**81.06**	**Surface**
Total / Average		**229**	**93.01**	**1.030**	**79.54**	**77.75**	**Interm**
Total / Average		**744**	**93.01**	**0.928**	**80.26**	**80.57**	**All**

Table C.2. Summary of Density Lot PWL Values for Each Other Paving Project

Project Number	JMF Number	Lot Sample Size	Lot Mean	Lot Standard Deviation	Lot PWL	Average Lot PWL	Mix Type
P01	J23	5	93.68	0.970	100.00		Interm B
P01	J23	3	93.86	1.572	100.00	100.00	Interm B
P03	J04	5	93.11	1.170	98.47		Interm B
P03	J04	4	94.31	1.150	98.99		Interm B
P03	J04	12	94.61	0.729	98.05		Interm B
P03	J04	3	93.93	0.615	100.00		Interm B
P03	J04	6	91.99	1.267	72.20	93.54	Interm B
P36	J09	3	93.06	0.318	100.00		Interm B
P36	J09	3	93.17	1.364	100.00		Interm B
P36	J09	7	92.51	1.445	81.29		Interm B
P36	J09	4	92.71	1.943	75.90		Interm B
P36	J09	4	92.71	1.943	75.90	86.62	Interm B
Total / Average		**59**	**93.36**	**1.207**	**91.73**	**93.39**	**Interm**
P06	J26	14	90.05	1.159	16.11	16.11	Surf 1
P06	J24	6	90.44	1.455	31.23		Surf 1D
P06	J24	6	89.83	1.669	21.47		Surf 1D
P06	J24	5	92.36	0.481	100.00		Surf 1D
P06	J24	4	93.37	0.565	100.00		Surf 1D
P06	J24	4	92.45	0.522	100.00	70.54	Surf 1D
P04	J14	8	88.73	1.624	5.25		Surf 1R
P04	J14	8	90.28	0.605	5.25		Surf 1R
P04	J14	6	90.08	1.271	19.63		Surf 1R
P04	J14	9	89.95	1.186	14.62		Surf 1R
P04	J14	5	89.94	1.356	18.49	12.65	Surf 1R
P08	J11	8	88.65	1.161	0.16	0.16	Surf 1R
P27	J55	5	92.71	0.546	100.00		Surf B
P27	J55	6	91.83	0.863	75.68		Surf B
P27	J55	7	92.50	0.504	100.00		Surf B
P27	J55	6	92.15	0.489	99.83	93.88	Surf B
P27	J70	5	93.22	1.498	92.95		Surf B
P27	J70	7	93.36	0.949	100.00		Surf B
P27	J70	4	92.32	0.559	100.00		Surf B
P27	J70	5	92.75	1.001	97.10		Surf B
P27	J70	3	93.38	0.757	100.00		Surf B
P27	J70	6	92.70	1.092	92.85		Surf B
P27	J70	3	92.72	1.222	100.00	97.56	Surf B
P30	J65	5	93.57	3.130	52.85		Surf B
P30	J65	3	94.02	0.575	100.00	76.43	Surf B
P31	J71	5	94.06	0.286	100.00		Surf B
P31	J71	3	94.24	0.822	100.00	100.00	Surf B
P13	J03	9	92.01	1.519	69.70	69.70	Surf C

Continued

Table C.2. Summary of Density Lot PWL Values for Each Other Paving Project (*continued*)

Project Number	JMF Number	Lot Sample Size	Lot Mean	Lot Standard Deviation	Lot PWL	Average Lot PWL	Mix Type
P14	J16	6	92.68	1.456	84.26		Surf C
P14	J16	7	92.92	1.035	96.95		Surf C
P14	J16	6	92.73	0.722	100.00		Surf C
P14	J16	10	91.75	1.788	61.55		Surf C
P14	J16	5	92.12	0.600	96.83		Surf C
P14	J16	4	93.07	1.135	100.00	89.93	Surf C
P15	J44	3	92.75	0.751	100.00		Surf C
P15	J44	3	92.56	0.751	100.00		Surf C
P15	J44	4	92.60	1.908	74.46		Surf C
P15	J44	4	92.90	1.919	79.53		Surf C
P15	J44	4	92.60	1.908	74.46	85.69	Surf C
P16	J20	4	91.38	1.445	54.15		Surf C
P16	J20	4	91.15	0.527	46.84		Surf C
P16	J20	4	92.22	0.967	85.16	62.05	Surf C
P18	J48	7	91.62	1.883	58.31		Surf C
P18	J48	3	92.01	1.960	61.65		Surf C
P18	J48	8	91.31	1.884	52.21	57.39	Surf C
P20	J50	11	92.63	0.936	94.42		Surf C
P20	J50	12	91.85	0.850	77.46		Surf C
P20	J50	11	92.17	0.916	85.52		Surf C
P20	J50	7	92.43	0.866	93.38		Surf C
P20	J50	8	92.72	1.239	89.42		Surf C
P20	J50	8	92.80	1.000	95.84		Surf C
P20	J50	10	92.36	0.610	98.26	90.61	Surf C
P24	J56	11	92.90	1.636	83.12		Surf C
P24	J56	4	93.80	0.637	100.00		Surf C
P24	J56	6	93.54	1.088	100.00		Surf C
P24	J56	8	92.57	0.825	96.57		Surf C
P24	J56	9	93.37	0.894	99.97		Surf C
P24	J56	9	93.15	0.629	100.00		Surf C
P24	J56	9	93.05	1.037	97.56	96.75	Surf C
P26	J59	6	91.69	0.945	68.64		Surf C
P26	J59	8	92.09	0.961	81.94		Surf C
P26	J59	7	90.40	1.338	28.39		Surf C
P26	J59	11	90.59	1.235	31.52		Surf C
P26	J59	6	91.16	0.706	47.92		Surf C
P26	J59	7	91.09	0.841	45.11		Surf C
P26	J59	8	90.06	1.795	26.98		Surf C
P26	J59	2	92.64	0.983	100.00	53.81	Surf C

Continued

Table C.2. Summary of Density Lot PWL Values for Each Other Paving Project (*continued*)

Project Number	JMF Number	Lot Sample Size	Lot Mean	Lot Standard Deviation	Lot PWL	Average Lot PWL	Mix Type
P28	J39	7	92.98	0.999	98.19		Surf C
P28	J39	11	93.37	1.278	95.40		Surf C
P28	J39	7	93.27	1.861	80.99		Surf C
P28	J39	3	93.49	0.600	100.00	93.65	Surf C
Total / Average		**457**	**92.17**	**1.102**	**75.44**	**68.64**	**Surface**
Total / Average		**59**	**93.36**	**1.207**	**91.73**	**93.39**	**Interm**
Total / Average		**516**	**92.34**	**1.117**	**77.96**	**73.36**	**All**

APPENDIX D — VERIFICATION TEST DATA

The acceptance test results and their corresponding verification test results were provided by SCDOT for 10 projects. Most of these projects were different than those that were analyzed for determining typical process variability values. As such, the verification projects are referred to as V01 to V10. All of the test results along with the *F*-test and *t*-test results are presented in the following tables.

Table D.1. Asphalt Content Verification Test Results Data

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V01	Interm B	1	4.74	4.79
V01	Interm B	1	4.97	
V01	Interm B	1	4.63	
V01	Interm B	1	4.76	4.88
V01	Interm B	1	5.00	4.68
V01	Interm B	1	4.66	
V01	Interm B	1	4.36	
V01	Interm B	1	4.60	
V01	Interm B	2	4.70	
V01	Interm B	2	4.23	4.76
V01	Interm B	2	4.97	4.78
V01	Interm B	2	4.38	4.54
V01	Interm B	2	4.62	
V01	Interm B	3	4.50	
V01	Interm B	3	4.59	
V01	Interm B	3	4.31	
V01	Interm B	3	4.93	
V01	Interm B	4	4.63	4.52
V01	Interm B	4	4.69	
V01	Surf A	1	4.90	4.69
V01	Surf A	1	4.83	4.84
V01	Surf A	1	4.87	5.03
V01	Surf A	2	4.92	4.72
V01	Surf A	3	5.08	5.22
V01	Surf A	4	4.95	
V01	Surf A	5	4.89	4.91
V02	Interm B	1	4.93	
V02	Interm B	2	4.45	4.03
V02	Interm B	2		4.52
V02	Interm B	3	4.36	4.14
V02	Interm B	3	4.59	
V02	Interm B	4	4.65	
V02	Interm B	5	4.14	4.40
V02	Interm B	5	4.56	3.94
V02	Surf A	1	4.83	4.88
V02	Surf A	1	5.08	4.77
V02	Surf A	1	4.76	4.78
V02	Surf A	1		4.98
V02	Surf A	2	5.10	4.66
V02	Surf A	2	5.23	5.14
V02	Surf A	2	4.91	
V02	Surf A	2	5.08	
V02	Surf A	3	4.89	4.77
V02	Surf A	3	4.98	
V02	Surf A	3	4.81	
V02	Surf A	4	5.35	5.13
V02	Surf A	4	5.06	

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V02	Surf A	4	5.32	
V02	Surf A	5	4.88	
V02	Surf A	5	5.03	
V02	Surf A	5	4.74	
V02	Surf A	5	5.01	
V02	Surf A	5	4.54	4.80
V02	Surf A	5	5.14	
V02	Surf A	6	4.98	5.05
V02	Surf A	6	4.93	
V02	Surf A	6	4.96	
V02	Surf A	6	4.77	
V02	Surf A	7	5.06	4.86
V02	Surf A	7	4.99	
V02	Surf A	7	5.12	
V02	Surf A	8	4.87	4.35
V02	Surf A	8	4.71	
V02	Surf A	8	5.01	
V02	Surf A	9	5.07	4.83
V02	Surf A	9	5.08	
V02	Surf A	9	5.01	4.79
V02	Surf A	9	4.96	
V02	Surf A	9	5.20	
V02	Surf A	10	4.93	4.92
V02	Surf A	10	5.05	
V02	Surf A	10	5.08	5.11
V02	Surf A	11	5.01	4.86
V02	Surf A	11	4.89	
V02	Surf A	11	5.13	5.20
V02	Surf A	11	5.25	
V02	Surf A	11	4.90	
V02	Surf A	12	4.80	
V02	Surf A	12	4.95	
V02	Surf A	12	5.07	
V02	Surf A	12	4.89	
V02	Surf A	13	5.21	5.13
V02	Surf A	13	4.88	
V02	Surf A	13	4.93	
V02	Surf A	13	5.02	
V02	Surf A	14	5.23	5.08
V02	Surf A	14	4.87	
V02	Surf A	14	4.89	
V02	Surf A	14	5.02	5.03
V02	Surf A	14	5.04	
V02	Surf A	14	4.74	
V02	Surf A	15	5.18	5.04
V02	Surf A	15	4.73	5.25
V02	Surf A	15	5.11	
V02	Surf A	15	4.91	

Table D.1. Asphalt Content Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V02	Surf A	16	5.12	4.97
V02	Surf A	16	4.58	4.91
V02	Surf A	16	5.00	
V02	Surf A	16	5.08	
V02	Surf A	17	4.81	5.16
V02	Surf A	17	4.81	5.10
V02	Surf A	17	4.73	
V02	Surf A	17	4.78	
V02	Surf A	*18*	*5.17*	*4.84*
V02	Surf A	*18*	*4.66*	
V02	Surf A	*18*	*5.00*	*4.79*
V02	Surf A	*18*	*5.17*	
V02	Surf A	*19*	*4.86*	*4.94*
V02	Surf A	*19*	*4.97*	
V02	Surf A	*19*	*5.35*	*5.00*
V02	Surf A	*19*	*4.83*	
V02	Surf A	*20*	*5.03*	*5.19*
V02	Surf A	*20*	*4.90*	
V02	Surf A	*20*	*4.67*	
V02	Surf A	*20*	*4.97*	
V02	Surf A	21	5.11	5.22
V02	Surf A	21	5.14	
V02	Surf A	21	4.89	
V02	Surf A	21	4.91	
V02	Surf A	22	5.16	
V02	Surf A	22	4.79	
V02	Surf A	*18*	*5.17*	*4.84*
V02	Surf A	*18*	*4.66*	
V02	Surf A	*18*	*5.00*	*4.79*
V02	Surf A	*18*	*5.17*	
V02	Surf A	*19*	*4.86*	*4.94*
V02	Surf A	*19*	*4.97*	
V02	Surf A	*19*	*5.35*	*5.00*
V02	Surf A	*19*	*4.83*	
V02	Surf A	*20*	*5.03*	*5.19*
V02	Surf A	*20*	*4.90*	
V02	Surf A	*20*	*4.67*	
V02	Surf A	*20*	*4.97*	
V02	Surf B	1	5.27	5.18
V02	Surf B	1	5.19	
V02	Surf B	1	5.30	4.79
V02	Surf B	1	4.87	
V02	Surf B	2	5.27	4.82
V02	Surf B	2	5.12	
V02	Surf B	2	5.14	4.96
V02	Surf B	2	5.04	4.56
V02	Surf B	2	4.83	

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V02	Surf B	3	5.09	V02
V02	Surf B	3	4.75	V02
V02	Surf B	3	5.09	V02
V02	Surf B	4	5.26	V02
V02	Surf B	4	4.98	V02
V02	Surf B	4	5.18	V02
V02	Surf B	6	4.96	V02
V02	Surf B	6	4.98	V02
V02	Surf B	6	5.04	V02
V02	Surf B	2	5.10	V02
V02	Surf B	2	5.07	V02
V02	Surf B	2	5.07	V02
V02	Surf B	3	4.76	V02
V02	Surf B	3	5.16	V02
V02	Surf B	3	5.05	V02
V02	Surf B	4	5.20	V02
V02	Surf B	4	4.74	V02
V02	Surf B	4	5.01	V02
V02	Surf B	4	5.34	V02
V02	Surf B	5	5.23	V02
V02	Surf B	5	5.15	V02
V02	Surf B	5	5.03	V02
V02	Surf B	6	5.21	V02
V02	Surf B	6	5.09	V02
V02	Surf B	6	4.95	V02
V02	Surf B	6	5.12	V02
V02	Surf B	6	4.80	V02
V02	Surf B	5	4.93	V02
V02	Surf B	5	5.03	V02
V02	Surf B	5	4.93	V02
V02	Surf B	6	5.11	V02
V02	Surf B	6	4.76	V02
V02	Surf B	6	4.92	V02
V02	Surf B	6	5.05	V02
V02	Surf B	6	4.83	V02
V02	Surf B	6	4.95	V02
V02	Surf B	7	4.77	V02
V02	Surf B	7	5.20	V02
V02	Surf B	7	4.88	V02
V02	Surf B	7	4.88	V02
V02	Surf B	8	4.96	V02
V02	Surf B	8	5.10	V02
V02	Surf B	8	5.08	V02
V02	Surf B	9	5.07	V02
V02	Surf B	9	4.78	V02
V02	Surf B	9	4.70	V02
V02	Surf B	10	4.98	V02

Table D.1. Asphalt Content Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V02	Surf B	10	4.83	4.89
V02	Surf B	10	5.04	
V02	Surf B	11	5.30	
V02	Surf B	11	5.21	
V02	Surf B	11	4.87	
V02	Surf B	12	4.78	4.88
V02	Surf B	12	4.57	
V02	Surf B	12	5.11	
V02	Surf B	12	5.23	
V02	Surf B	13	4.93	
V02	Surf B	7	5.23	5.01
V02	Surf B	7	5.06	5.18
V02	Surf B			4.93
V03	Surf E	1	6.32	6.54
V03	Surf E	2	5.99	6.08
V03	Surf E	2	5.96	
V03	Surf E	3	6.15	5.76
V03	Surf E	3	6.09	5.81
V03	Surf E	3	6.21	
V03	Surf E	4	6.13	
V03	Surf E	4	5.65	
V03	Surf E	4	6.10	
V03	Surf E	5	5.87	5.68
V03	Surf E	6	5.98	5.97
V03	Surf E	6	6.06	
V03	Surf E	7	6.20	6.11
V03	Surf E	7	6.18	5.37
V03	Surf E	8	5.35	
V03	Surf E	9	6.05	
V03	Surf E	10	6.07	5.76
V03	Surf E			6.45
V03	Surf E	11	5.99	
V03	Surf E	12	6.11	5.27
V03	Surf E	13	6.09	5.95
V03	Surf E	1	5.92	5.94
V03	Surf E	2	5.98	
V03	Surf E	2	6.14	
V03	Surf E	14	6.09	5.77
V03	Surf E	14	6.08	
V03	Surf E	15	6.17	5.78
V03	Surf E	15	6.06	
V03	Surf E	15	6.10	
V03	Surf E	16	5.89	5.99
V03	Surf E	16	5.84	
V03	Surf E	16	5.93	
V03	Surf E	17	6.00	5.83

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V03	Surf E	17/Sumter	6.12	6.04
V03	Surf E	17/Sumter	6.18	
V03	Surf E	18/Sumter	6.02	6.02
V03	Surf E	18/Sumter	6.06	6.01
V03	Surf E	18/Sumter	6.14	6.15
V03	Surf E	19	6.12	6.18
V03	Surf E	19	6.03	6.02
V03	Surf E	19	6.17	
V03	Surf E	19	6.17	
V03	Surf E	20	5.91	6.05
V03	Surf E	20	5.88	
V03	Surf E	20	5.93	
V03	Surf E	21	6.29	6.06
V03	Surf E	21	6.02	
V03	Surf E	21	6.16	
V03	Surf E	21	6.11	
V03	Surf E	22	5.69	5.95
V03	Surf E	22	6.54	6.10
V03	Surf E	22	6.29	
V03	Surf E	22	6.04	
V03	Surf E	23	5.91	5.91
V03	Surf E	23	6.21	6.12
V03	Surf E	23	6.26	
V03	Surf E	24	6.22	6.35
V03	Surf E	24	6.04	
V03	Surf E	24	5.85	
V03	Surf E	24	6.33	
V03	Surf E	25	6.07	
V03	Surf E	25	6.06	
V03	Surf E	25	6.18	
V03	Surf E	26	6.31	6.32
V03	Surf E	26	6.32	6.65
V03	Surf E	26	6.27	
V03	Surf E	26	6.01	
V03	Surf E	27	5.89	5.74
V03	Surf E	27	5.86	5.78
V03	Surf E	28	5.93	
V04	Surf B	1	5.25	5.48
V04	Surf B	1	5.08	5.34
V04	Surf B	1	4.86	
V04	Surf B	1	5.01	5.16
V04	Surf B	1	5.00	
V04	Surf B	2	4.96	5.42
V04	Surf B	2	4.85	
V04	Surf B	2	5.03	
V04	Surf B	2	5.13	
V04	Surf B	3	4.89	4.94

Table D.1. Asphalt Content Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V04	Surf B	3	4.96	4.99
V04	Surf B	3	4.70	4.91
V04	Surf B	3	4.82	
V04	Surf B	4	4.55	4.43
V04	Surf B	4	4.59	
V04	Surf B	4	4.71	
V04	Surf B	5	4.84	4.93
V04	Surf B	5	4.84	4.74
V04	Surf B	5	4.79	
V04	Surf B	5	4.79	
V04	Surf B	6	4.80	4.62
V04	Surf B	6	4.68	
V04	Surf B	6	4.43	
V04	Surf B	6	4.82	
V04	Surf B	6	4.99	
V05	Interm B	2	4.82	5.27
V05	Interm B	2	4.85	
V05	Interm B	2	5.18	5.38
V05	Interm B	2	5.15	
V05	Interm B	3	4.74	5.28
V05	Interm B	3	4.76	
V05	Interm B	3	4.75	
V05	Interm B	4	5.21	
V05	Interm B	4	5.37	5.55
V05	Interm B	4	4.95	
V05	Interm B	4	4.98	
V05	Interm B	4	4.59	
V05	Interm B	5	5.05	5.22
V05	Interm B	5	4.93	5.25
V05	Interm B	5	4.89	
V05	Interm B	5	5.04	
V05	Interm B	6	4.80	
V05	Interm B	6	4.86	
V05	Interm B	6	5.07	
V05	Interm B	6	4.73	
V05	Interm B	7	5.07	
V05	Interm B	7	5.13	
V05	Interm B	7	5.07	
V05	Interm B	8	4.70	5.06
V05	Interm B	8	4.55	
V05	Interm B	8	5.13	
V05	Interm B	9	4.96	
V05	Interm B	9	4.92	5.16
V05	Interm B	9	4.90	5.49
V05	Interm B	10	4.75	5.34
V05	Interm B	10		5.15
V05	Interm B	*11*	*4.79*	*5.11*
V05	Interm B	*11*	*4.82*	

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V05	Interm B	*11*	*4.95*	
V05	Interm B	*11*	*4.97*	
V05	Interm B	12	4.92	5.37
V05	Interm B	12	5.13	
V05	Interm B	12	5.33	5.44
V05	Interm B	12	4.98	
V05	Interm B	13	5.42	5.20
V05	Interm B	13	4.88	
V05	Interm B	13	5.05	
V05	Interm B	14	5.01	5.42
V05	Interm B	14	4.90	5.27
V05	Interm B	14	5.13	
V05	Interm B	15	4.48	
V05	Interm B	*11*	*4.79*	*5.11*
V05	Interm B	*11*	*4.82*	
V05	Interm B	*11*	*4.95*	
V05	Interm B	*11*	*4.97*	
V05	Surf A	1	5.41	
V05	Surf A	1	5.17	
V05	Surf A	2	5.16	5.34
V05	Surf A	2	5.25	
V05	Surf A	2	5.17	5.28
V05	Surf A	2	5.28	
V05	Surf A	2	5.33	
V05	Surf A	2	5.16	
V05	Surf A	3	5.29	5.34
V05	Surf A	3	5.19	
V05	Surf A	3	5.20	
V05	Surf A	3	5.30	
V05	Surf A	3	5.34	
V05	Surf A	4	5.22	5.29
V05	Surf A	4	5.23	
V05	Surf A	4	5.01	
V05	Surf A	4	5.31	
V05	Surf A	5	5.11	5.50
V05	Surf A	5	5.36	
V05	Surf A	5	5.19	
V05	Surf A	6	4.77	4.72
V05	Surf A	6	4.91	
V05	Surf A	6	5.11	5.15
V05	Surf A	6	5.13	
V05	Surf A	7	5.11	5.09
V05	Surf A	7	5.08	
V05	Surf A	7	5.22	
V05	Surf A	8	5.06	5.13
V05	Surf A	8	5.09	
V05	Surf A	8	5.18	

Table D.1. Asphalt Content Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V05	Surf A	9	5.28	5.11
V05	Surf A	9	5.20	5.20
V05	Surf A	9	5.17	
V05	Surf A	10	5.22	5.18
V05	Surf A	10	5.18	5.27
V05	Surf A	10	5.35	
V05	Surf A	10	5.10	
V05	Surf A	11	5.01	
V05	Surf A	11	5.07	4.94
V05	Surf A	11	5.31	4.92
V05	Surf A	11	4.93	
V05	Surf A	11	5.37	
V05	Surf A	12	5.13	5.01
V05	Surf A	12	4.86	5.03
V05	Surf A	12	5.20	
V05	Surf A	12	5.15	
V05	Surf A	13	5.02	5.14
V05	Surf A	13	4.64	4.96
V05	Surf A	13	4.69	
V05	Surf A	13	4.93	
V05	Surf A	13	4.90	5.27
V05	Surf A	14	4.81	
V05	Surf A	14	4.97	
V05	Surf A	14	4.77	5.14
V05	Surf A	15	5.08	
V05	Surf A	15	5.08	5.25
V05	Surf A	15	5.28	
V05	Surf A	15	5.19	
V05	Surf A	15	5.25	5.32
V05	Surf A	16	5.34	
V05	Surf A	16	5.10	5.26
V05	Surf A	16	5.04	
V05	Surf A	16	5.06	
V05	Surf A	16	5.10	5.52
V05	Surf A	17	5.20	
V05	Surf A	17	5.03	
V05	Surf A	17	5.10	5.42
V05	Surf A	17	4.89	
V05	Surf A	17	4.66	
V05	Surf A	18	5.11	
V05	Surf A	18	5.32	
V05	Surf A	18	5.08	5.33
V05	Surf A	18	5.11	
V05	Surf A	18	5.12	5.49
V05	Surf A	19	5.17	
V05	Surf A	19	5.32	5.58
V05	Surf A	19	5.22	5.65
V05	Surf A	20	5.16	5.45

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V05	Surf A	20	5.38	
V05	Surf A	20	5.36	5.65
V05	Surf A	20	5.22	
V05	Surf A	20	4.86	
V05	Surf A	21	5.07	5.18
V05	Surf A	21	4.94	
V05	Surf A	21	4.93	
V05	Surf A	22	5.25	
V05	Surf A	22	5.02	5.17
V05	Surf A	22	5.06	5.13
V05	Surf A	23	5.18	5.28
V05	Surf A	23	4.98	
V05	Surf A	23	5.06	
V05	Surf A	23	5.17	
V05	Surf A	24	5.14	5.15
V05	Surf A	24	5.08	
V05	Surf A	24	5.07	
V05	Surf A	25	5.17	
V05	Surf A	25	4.89	
V05	Surf B	1	4.96	
V05	Surf B	1	4.81	
V05	Surf B	1	5.14	5.18
V05	Surf B	1	5.05	
V05	Surf B	1	5.17	
V05	Surf B	2	5.06	
V05	Surf B	2	5.22	5.08
V05	Surf B	2	4.85	
V05	Surf B	2	5.11	5.10
V05	Surf B	2	4.94	
V05	Surf B	2	4.86	5.13
V05	Surf B	3	4.90	
V05	Surf B	3	5.22	
V05	Surf B	3	4.78	5.09
V05	Surf B	*4*	*5.13*	
V05	Surf B	*4*	*5.29*	
V05	Surf B	*4*	*5.22*	
V05	Surf B	*5*	*5.08*	*5.23*
V05	Surf B	*5*	*4.95*	*5.34*
V05	Surf B	*5*	*5.18*	
V05	Surf B	*5*	*4.86*	
V05	Surf B	*5*	*5.32*	
V05	Surf B	6	5.17	5.40
V05	Surf B	6	5.19	5.36
V05	Surf B	6	4.96	5.37
V05	Surf B	6	5.17	
V05	Surf B	6	5.19	
V05	Surf B	7	5.31	

Table D.1. Asphalt Content Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V05	Surf B	7	5.06	
V05	Surf B	7	5.07	
V05	Surf B	8	5.38	5.32
V05	Surf B	8	4.64	
V05	Surf B	8	5.16	5.39
V05	Surf B	8	5.00	
V05	Surf B	*4*	*5.13*	
V05	Surf B	*4*	*5.29*	
V05	Surf B	*4*	*5.22*	
V05	Surf B	*5*	*5.08*	*5.23*
V05	Surf B	*5*	*4.95*	*5.34*
V05	Surf B	*5*	*5.18*	
V05	Surf B	*5*	*4.86*	
V05	Surf B	*5*	*5.32*	
V05	Surf E	1	6.22	6.72
V05	Surf E	2	6.06	6.09
V05	Surf E	3	5.75	
V05	Surf E	5	5.88	6.36
V05	Surf E			5.91
V05	Surf E			6.03
V05	Surf E	6	5.64	5.93
V05	Surf E	6		5.88
V05	Surf E	7	5.71	5.91
V05	Surf E	7	6.06	6.10
V05	Surf E	8	5.92	6.22
V05	Surf E	8	6.12	
V05	Surf E	9	6.12	6.18
V05	Surf E	9	5.92	6.21
V05	Surf E	10	5.68	6.05
V05	Surf E	10	6.01	
V05	Surf E	10	6.31	
V05	Surf E	11	5.92	6.17
V05	Surf E	11		5.99
V05	Surf E	12	6.31	6.47
V05	Surf E	14	6.15	6.32
V05	Surf E	21	6.08	6.40
V05	Surf E	21		6.38
V05	Surf E	22	5.96	6.24
V05	Surf E	23		6.33
V05	Surf E	24	6.18	6.36
V05	Surf E	25	6.04	6.39
V05	Surf E	26	5.94	5.84
V05	Surf E	27	6.11	6.05
V05	Surf E	28	5.93	5.96
V05	Surf E	29		6.11
V05	Surf E	30	5.96	5.94
V05	Surf E	30	6.02	6.18
V05	Surf E	31	6.19	5.93
V05	Surf E	31	5.95	6.03
V05	Surf E	31		6.06
V05	Surf E	32	5.84	6.14
V05	Surf E	32	5.83	6.11
V05	Surf E	33	5.59	6.20
V05	Surf E	35	5.93	
V05	Surf E	36	5.76	6.04
V05	Surf E	36		6.12
V05	Surf E	36		5.85
V05	Surf E	37	6.34	5.79
V05	Surf E	38	5.95	6.02
V05	Surf E	38	5.79	6.00
V05	Surf E	38	5.91	
V06	Interm C	1	5.27	
V06	Interm C	2	5.22	4.94
V06	Interm C	3	5.16	5.17
V06	Interm C	3		5.41
V06	Interm C	4	5.22	5.44
V06	Interm C	5	5.62	
V06	Interm C	5	5.16	
V07	Base A	1	5.09	5.40
V07	Base A	1	5.55	
V07	Base A	2	5.13	5.13
V07	Base A	2	5.29	
V07	Base A	2	5.09	
V07	Base A	3	5.87	5.54
V07	Base A	3	4.77	
V07	Base A	3	4.52	
V07	Base A	4	4.83	5.45
V07	Base A	4	5.14	
V07	Base A	4	4.97	
V07	Base A	4	5.15	
V07	Base A	5	5.32	5.56
V07	Base A	5	4.81	
V07	Base A	5	4.15	
V07	Base A	6	4.65	
V07	Base A	6	5.02	
V07	Base A	6	4.96	
V07	Base A	7	4.94	5.04
V07	Base A	7	5.06	5.20
V07	Base A	8	5.29	5.18
V07	Base A	8	4.91	5.13

Table D.1. Asphalt Content Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V07	Base A	8	4.97	4.97
V07	Base A	8	5.20	
V07	Base A	8	5.08	
V07	Base A	9	4.93	5.32
V07	Base A	9	5.09	
V07	Base A	9	5.56	
V07	Base A	10	4.80	4.92
V07	Base A			5.28
V07	Base A	11	5.56	4.85
V07	Base A	12	4.75	5.09
V07	Base A	13	4.75	5.39
V07	Base A	13	4.20	
V07	Base A	14	4.59	4.29
V07	Base A	14	5.02	
V07	Base A	15	5.13	
V07	Base A	16	5.32	4.54
V07	Base A	17	4.80	5.30
V07	Base A	17		5.40
V07	Base A	18	4.88	5.14
V07	Base A	18		5.41
V07	Base A	19	5.42	5.49
V07	Base A	19		5.74
V07	Base A	20	4.80	
V07	Base A	20	4.95	
V07	Base A	21	4.66	4.54
V07	Base A	1	4.57	4.98
V07	Base A	2	4.36	4.82
V07	Base A	2		4.64
V07	Base A	3	5.17	5.02
V07	Base A	3		4.79
V07	Base A	4	4.88	
V07	Base A	5	5.40	
V07	Base A	6	4.84	4.40
V07	Base A	6		4.66
V07	Base A	7	5.02	5.18
V07	Base A	8	5.07	4.72
V07	Base A	8		4.59
V07	Base A	9	5.06	
V07	Base A	10	4.92	
V07	Base A	11	5.31	4.64
V07	Base A	12	4.83	5.18
V07	Base A	13	5.13	5.41
V07	Base A	14	4.68	4.83
V07	Base A	15	5.33	4.92

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V07	Base A	16	4.59	5.13
V07	Base A	17	4.74	
V07	Base A	18	4.81	
V07	Base A	19	4.97	4.99
V07	Base A	19		4.95
V07	Base A	19		5.35
V08	Surf E	1	6.49	6.74
V08	Surf E	2	6.12	6.23
V08	Surf E	2		6.15
V08	Surf E	3	6.26	6.01
V08	Surf E	4	6.41	6.39
V08	Surf E	4		6.18
V08	Surf E	5	6.41	6.39
V08	Surf E	5		6.33
V09	Surf A	1	5.06	4.76
V09	Surf A	1	4.88	
V09	Surf A	1	4.53	
V09	Surf A	1	4.71	
V09	Surf A	2	5.01	4.98
V09	Surf A	2	5.04	4.86
V09	Surf A	2	4.91	
V09	Surf A	2	5.06	
V09	Surf A	3	4.82	4.69
V09	Surf A	3	4.80	4.47
V09	Surf A	3	4.71	4.77
V09	Surf A	3	4.71	
V09	Surf A	3	4.48	
V09	Surf A	3	4.68	
V09	Surf A	4	4.79	4.79
V09	Surf A	4	4.60	
V09	Surf A	4	4.62	4.42
V09	Surf A	4	4.70	
V09	Surf A	5	4.44	4.61
V09	Surf A	5	4.91	
V09	Surf A	5	5.01	4.04
V09	Surf A	5	4.25	
V09	Surf A	6	5.03	4.86
V09	Surf A	6	4.86	4.70
V09	Surf A	6	4.86	
V09	Surf A	6	4.86	4.80
V09	Surf A	7	4.72	
V09	Surf A	7	4.70	
V09	Surf E	1	5.91	5.98
V09	Surf E	1	6.00	5.86
V09	Surf E	2		6.08
V09	Surf E	2	6.13	
V09	Surf E	3	5.96	5.97

Table D.1. Asphalt Content Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V09	Surf E	3	6.10	5.94
V09	Surf E	4	5.99	5.79
V09	Surf E	5	6.03	5.95
V09	Surf E	5	5.94	
V09	Surf E	5	5.95	
V10	Interm B	1	4.82	4.41
V10	Interm B	1		4.86
V10	Interm B	2	4.51	4.32
V10	Interm B	2	4.34	
V10	Interm B	2	4.80	
V10	Interm B	3	4.28	4.73
V10	Interm B	3	4.19	
V10	Interm B	3	5.10	4.95
V10	Interm B	*4*	*4.45*	*5.11*
V10	Interm B	*4*	*4.38*	
V10	Interm B	*4*	*4.84*	*4.79*
V10	Interm B	*4*	*4.38*	
V10	Interm B	*4*	*4.71*	
V10	Interm B	*5*	*4.65*	
V10	Interm B	*5*	*4.19*	
V10	Interm B	*5*	*4.46*	
V10	Interm B	*5*	*4.53*	
V10	Interm B	6	4.54	
V10	Interm B	6	4.66	
V10	Interm B	6	4.47	
V10	Interm B	7	4.93	4.80
V10	Interm B	7	4.54	
V10	Interm B	7	4.49	4.63
V10	Interm B	7		5.16
V10	Interm B	8	4.38	4.63
V10	Interm B	8		4.56
V10	Interm B	8	4.67	
V10	Interm B	*4*	*4.45*	*5.11*
V10	Interm B	*4*	*4.38*	
V10	Interm B	*4*	*4.84*	*4.79*
V10	Interm B	*4*	*4.38*	
V10	Interm B	*4*	*4.71*	
V10	Interm B	*5*	*4.65*	
V10	Interm B	*5*	*4.19*	
V10	Interm B	*5*	*4.46*	
V10	Interm B	*5*	*4.53*	
V10	Surf A	1	4.60	4.72
V10	Surf A	1	4.22	4.90
V10	Surf A	1	4.73	4.70
V10	Surf A	1	4.37	
V10	Surf A	2	4.60	
V10	Surf A	2	4.99	4.56

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V10	Surf A	2	4.72	4.77
V10	Surf A	2	4.61	
V10	Surf A	*3*	*4.84*	
V10	Surf A	*3*	*5.05*	
V10	Surf A	*3*	*4.89*	*5.12*
V10	Surf A	*3*	*4.92*	*5.11*
V10	Surf A	*4*	*4.59*	
V10	Surf A	*4*	*4.80*	
V10	Surf A	*4*	*4.36*	*5.09*
V10	Surf A	*4*	*4.76*	
V10	Surf A	*5*	*4.32*	*4.80*
V10	Surf A	*5*	*4.71*	
V10	Surf A	*5*	*4.69*	
V10	Surf A	6	4.51	4.92
V10	Surf A	6	4.90	5.41
V10	Surf A	6	5.16	5.55
V10	Surf A	7	4.96	4.95
V10	Surf A	7		4.85
V10	Surf A	*3*	*4.84*	
V10	Surf A	*3*	*5.05*	
V10	Surf A	*3*	*4.89*	*5.12*
V10	Surf A	*3*	*4.92*	*5.11*
V10	Surf A	*4*	*4.59*	
V10	Surf A	*4*	*4.80*	
V10	Surf A	*4*	*4.36*	*5.09*
V10	Surf A	*4*	*4.76*	
V10	Surf A	*5*	*4.32*	*4.80*
V10	Surf A	*5*	*4.71*	
V10	Surf A	*5*	*4.69*	
V10	Surf E	1	6.40	6.58
V10	Surf E	2	6.35	6.52
V10	Surf E	2		6.25
V10	Surf E	3	6.55	6.60
V10	Surf E	4	6.34	6.68
V10	Surf E	4		6.44
V10	Surf E	5	6.47	
V10	Surf E	6	6.87	6.50
V10	Surf E	7	6.33	6.44
V10	Surf E	8	6.40	6.51
V10	Surf E	9	6.40	6.54
V10	Surf E	10	6.74	6.71

Table D.2. Air Voids Verification Test Results Data

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V01	Interm B	1	3.07	2.56
V01	Interm B	1	2.96	
V01	Interm B	1	4.47	
V01	Interm B	1	3.16	2.79
V01	Interm B	1	3.51	4.06
V01	Interm B	1	4.27	
V01	Interm B	1	4.15	
V01	Interm B	1	4.38	
V01	Interm B	2	3.14	
V01	Interm B	2	4.56	4.04
V01	Interm B	2	2.95	3.52
V01	Interm B	2	4.02	4.67
V01	Interm B	2	4.34	
V01	Interm B	3	3.98	
V01	Interm B	3	3.02	
V01	Interm B	3	4.79	
V01	Interm B	3	2.72	
V01	Interm B	4	3.23	4.24
V01	Interm B	4	3.80	
V01	Surf A	1	3.60	3.22
V01	Surf A	1	3.74	3.02
V01	Surf A	1	2.92	2.50
V01	Surf A	2	2.74	2.77
V01	Surf A	3	3.10	3.20
V01	Surf A	4	2.66	
V01	Surf A	5	4.62	3.18
V02	Interm B	1	3.31	
V02	Interm B	2	3.52	4.73
V02	Interm B	2		2.78
V02	Interm B	3	3.35	4.64
V02	Interm B	3	4.02	
V02	Interm B	4	2.87	
V02	Interm B	5	4.33	3.44
V02	Interm B	5	3.05	3.47
V02	Surf A	1	4.06	6.72
V02	Surf A	1	2.46	3.93
V02	Surf A	1	2.60	2.14
V02	Surf A	1		2.57
V02	Surf A	2	3.07	3.03
V02	Surf A	2	2.35	2.32
V02	Surf A	2	2.37	
V02	Surf A	2	2.21	
V02	Surf A	3	2.52	2.41
V02	Surf A	3	2.28	
V02	Surf A	3	2.60	
V02	Surf A	4	2.10	3.07
V02	Surf A	4	2.12	
V02	Surf A	4	2.54	
V02	Surf A	5	3.12	
V02	Surf A	5	3.34	
V02	Surf A	5	3.37	
V02	Surf A	5	2.77	
V02	Surf A	5	2.29	3.73
V02	Surf A	5	2.94	
V02	Surf A	6	3.09	3.17
V02	Surf A	6	2.95	
V02	Surf A	6	2.78	
V02	Surf A	6	2.80	
V02	Surf A	7	2.90	3.55
V02	Surf A	7	3.12	
V02	Surf A	7	3.01	
V02	Surf A	8	3.59	5.90
V02	Surf A	8	3.38	
V02	Surf A	8	2.80	
V02	Surf A	9	3.54	3.60
V02	Surf A	9	3.73	
V02	Surf A	9	3.23	3.95
V02	Surf A	9	3.19	
V02	Surf A	9	2.50	
V02	Surf A	10	3.29	3.62
V02	Surf A	10	2.59	
V02	Surf A	10	2.35	2.50
V02	Surf A	11	2.69	4.16
V02	Surf A	11	3.60	
V02	Surf A	11	3.11	4.59
V02	Surf A	11	2.10	
V02	Surf A	11	2.65	
V02	Surf A	12	2.68	
V02	Surf A	12	2.25	
V02	Surf A	12	2.32	
V02	Surf A	12	2.73	
V02	Surf A	13	2.66	2.54
V02	Surf A	13	2.63	
V02	Surf A	13	2.71	
V02	Surf A	13	2.26	
V02	Surf A	14	2.15	2.92
V02	Surf A	14	2.19	
V02	Surf A	14	3.00	
V02	Surf A	14	2.52	2.67
V02	Surf A	14	2.86	
V02	Surf A	14	3.28	
V02	Surf A	15	2.14	2.34
V02	Surf A	15	2.79	3.19
V02	Surf A	15	2.97	
V02	Surf A	15	2.61	

Table D.2. Air Voids Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V02	Surf A	16	2.79	2.04
V02	Surf A	16	2.69	2.39
V02	Surf A	16	2.68	
V02	Surf A	16	2.12	
V02	Surf A	17	3.55	3.30
V02	Surf A	17	3.09	3.66
V02	Surf A	17	4.02	
V02	Surf A	17	2.98	
V02	Surf A	*18*	*1.34*	*4.21*
V02	Surf A	*18*	*4.25*	
V02	Surf A	*18*	*3.17*	*5.32*
V02	Surf A	*18*	*2.88*	
V02	Surf A	*19*	*3.16*	*3.64*
V02	Surf A	*19*	*3.39*	
V02	Surf A	*19*	*2.95*	*4.10*
V02	Surf A	*19*	*3.14*	
V02	Surf A	*20*	*2.76*	*2.59*
V02	Surf A	*20*	*2.30*	
V02	Surf A	*20*	*2.80*	
V02	Surf A	*20*	*3.16*	
V02	Surf A	21	2.15	2.25
V02	Surf A	21	2.77	
V02	Surf A	21	3.38	
V02	Surf A	21	3.31	
V02	Surf A	22	3.40	
V02	Surf A	22	2.45	
V02	Surf A	*18*	*1.34*	*4.21*
V02	Surf A	*18*	*4.25*	
V02	Surf A	*18*	*3.17*	*5.32*
V02	Surf A	*18*	*2.88*	
V02	Surf A	*19*	*3.16*	*3.64*
V02	Surf A	*19*	*3.39*	
V02	Surf A	*19*	*2.95*	*4.10*
V02	Surf A	*19*	*3.14*	
V02	Surf A	*20*	*2.76*	*2.59*
V02	Surf A	*20*	*2.30*	
V02	Surf A	*20*	*2.80*	
V02	Surf A	*20*	*3.16*	
V02	Surf B	1	3.05	3.14
V02	Surf B	1	3.33	
V02	Surf B	1	2.14	3.75
V02	Surf B	1	2.29	
V02	Surf B	2	3.09	4.35
V02	Surf B	2	3.11	
V02	Surf B	2	2.92	4.83
V02	Surf B	2	3.45	4.44
V02	Surf B	2	3.70	

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V02	Surf B	3	2.93	3.04
V02	Surf B	3	3.79	4.68
V02	Surf B	3	3.69	3.60
V02	Surf B	4	2.62	2.80
V02	Surf B	4	3.28	
V02	Surf B	4	2.58	
V02	Surf B	6	2.21	2.27
V02	Surf B	6	3.41	2.92
V02	Surf B	6	2.05	
V02	Surf B	2	2.43	
V02	Surf B	2	3.51	
V02	Surf B	2	3.18	
V02	Surf B	3	3.44	4.60
V02	Surf B	3	2.88	4.37
V02	Surf B	3	3.23	3.63
V02	Surf B	4	2.58	2.79
V02	Surf B	4	3.29	
V02	Surf B	4	3.03	
V02	Surf B	4	2.27	
V02	Surf B	5	3.06	2.70
V02	Surf B	5	3.21	
V02	Surf B	5	3.04	
V02	Surf B	6	2.37	2.85
V02	Surf B	6	2.84	2.54
V02	Surf B	6	2.94	
V02	Surf B	6	3.01	
V02	Surf B	6	3.15	
V02	Surf B	5	3.74	3.57
V02	Surf B	5	3.15	
V02	Surf B	5	2.96	
V02	Surf B	6	2.63	
V02	Surf B	6	2.84	4.01
V02	Surf B	6	3.25	4.10
V02	Surf B	6	3.09	
V02	Surf B	6	2.94	
V02	Surf B	6	2.53	
V02	Surf B	7	3.82	
V02	Surf B	7	2.42	
V02	Surf B	7	2.33	
V02	Surf B	7	2.92	
V02	Surf B	8	3.46	3.31
V02	Surf B	8	2.99	3.48
V02	Surf B	8	2.39	
V02	Surf B	9	3.50	3.58
V02	Surf B	9	3.44	3.34
V02	Surf B	9	2.95	
V02	Surf B	10	3.66	4.70

Table D.2. Air Voids Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V02	Surf B	10	3.11	5.09
V02	Surf B	10	3.12	
V02	Surf B	11	2.65	
V02	Surf B	11	3.54	
V02	Surf B	11	3.74	
V02	Surf B	12	3.78	5.44
V02	Surf B	12	5.03	
V02	Surf B	12	3.86	
V02	Surf B	12	3.49	
V02	Surf B	13	3.85	
V02	Surf B	7	3.32	3.80
V02	Surf B	7	2.54	3.81
V02	Surf B			3.96
V04	Surf B	1	2.79	2.62
V04	Surf B	1	2.80	3.55
V04	Surf B	1	3.31	
V04	Surf B	1	3.15	2.05
V04	Surf B	1	3.01	
V04	Surf B	2	3.05	3.39
V04	Surf B	2	2.84	
V04	Surf B	2	3.44	
V04	Surf B	2	3.09	
V04	Surf B	3	2.78	3.41
V04	Surf B	3	3.07	3.18
V04	Surf B	3	3.09	3.30
V04	Surf B	3	3.45	
V04	Surf B	4	3.94	4.18
V04	Surf B	4	3.74	
V04	Surf B	4	3.17	
V04	Surf B	5	3.07	3.52
V04	Surf B	5	2.83	2.49
V04	Surf B	5	3.30	
V04	Surf B	5	3.52	
V04	Surf B	6	4.32	5.59
V04	Surf B	6	3.85	
V04	Surf B	6	4.19	
V04	Surf B	6	3.35	
V04	Surf B	6	3.92	
V05	Interm B	2	2.68	3.87
V05	Interm B	2	2.98	
V05	Interm B	2	3.16	3.59
V05	Interm B	2	2.54	
V05	Interm B	3	2.78	3.55
V05	Interm B	3	2.79	
V05	Interm B	3	3.32	
V05	Interm B	4	3.02	
V05	Interm B	4	2.48	4.15
V05	Interm B	4	3.59	

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V05	Interm B	4	2.92	
V05	Interm B	4	2.87	
V05	Interm B	5	3.29	2.57
V05	Interm B	5	2.84	3.01
V05	Interm B	5	2.96	
V05	Interm B	5	2.58	
V05	Interm B	6	3.08	
V05	Interm B	6	3.12	
V05	Interm B	6	2.82	
V05	Interm B	6	2.72	
V05	Interm B	7	2.78	
V05	Interm B	7	3.17	
V05	Interm B	7	3.01	
V05	Interm B	8	3.12	4.65
V05	Interm B	8	3.10	
V05	Interm B	8	2.85	
V05	Interm B	9	3.03	
V05	Interm B	9	2.98	4.10
V05	Interm B	9	2.80	4.13
V05	Interm B	10	3.71	4.73
V05	Interm B	10		3.40
V05	Interm B	*11*	*2.96*	*3.73*
V05	Interm B	*11*	*2.52*	
V05	Interm B	*11*	*2.60*	
V05	Interm B	*11*	*2.56*	
V05	Interm B	12	3.02	3.41
V05	Interm B	12	2.54	
V05	Interm B	12	2.66	2.60
V05	Interm B	12	2.60	
V05	Interm B	13	2.44	3.56
V05	Interm B	13	2.68	
V05	Interm B	13	2.74	
V05	Interm B	14	3.42	3.28
V05	Interm B	14	2.92	4.20
V05	Interm B	14	2.96	
V05	Interm B	15	4.07	
V05	Interm B	*11*	*2.96*	*3.73*
V05	Interm B	*11*	*2.52*	
V05	Interm B	*11*	*2.60*	
V05	Interm B	*11*	*2.56*	
V05	Surf A	1	2.53	
V05	Surf A	1	2.76	
V05	Surf A	2	4.01	5.03
V05	Surf A	2	3.70	
V05	Surf A	2	2.89	3.64
V05	Surf A	2	2.55	
V05	Surf A	2	3.09	

Table D.2. Air Voids Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V05	Surf A	2	3.30	
V05	Surf A	3	3.71	4.21
V05	Surf A	3	3.58	
V05	Surf A	3	3.72	
V05	Surf A	3	3.07	
V05	Surf A	3	3.16	
V05	Surf A	4	3.80	4.39
V05	Surf A	4	3.85	
V05	Surf A	4	3.60	
V05	Surf A	4	2.93	
V05	Surf A	5	2.84	3.54
V05	Surf A	5	2.57	
V05	Surf A	5	3.58	
V05	Surf A	6	3.44	4.34
V05	Surf A	6	3.80	
V05	Surf A	6	3.55	4.37
V05	Surf A	6	3.40	
V05	Surf A	7	3.41	4.21
V05	Surf A	7	3.22	
V05	Surf A	7	3.38	
V05	Surf A	8	4.21	4.80
V05	Surf A	8	3.96	
V05	Surf A	8	2.89	
V05	Surf A	9	4.16	5.23
V05	Surf A	9	3.68	5.09
V05	Surf A	9	3.83	
V05	Surf A	10	3.48	4.61
V05	Surf A	10	3.86	4.65
V05	Surf A	10	3.94	
V05	Surf A	10	3.37	
V05	Surf A	11	4.01	
V05	Surf A	11	4.61	4.04
V05	Surf A	11	3.24	4.77
V05	Surf A	11	3.09	
V05	Surf A	11	3.03	
V05	Surf A	12	3.68	5.21
V05	Surf A	12	3.20	5.06
V05	Surf A	12	3.83	
V05	Surf A	12	3.27	
V05	Surf A	13	3.69	4.88
V05	Surf A	13	3.95	6.03
V05	Surf A	13	4.04	
V05	Surf A	13	3.18	
V05	Surf A	13	3.80	4.33
V05	Surf A	14	4.15	
V05	Surf A	14	3.68	
V05	Surf A	14	4.13	4.37
V05	Surf A	15	3.24	

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V05	Surf A	15	3.35	4.00
V05	Surf A	15	3.70	
V05	Surf A	15	2.77	
V05	Surf A	15	2.72	3.41
V05	Surf A	16	2.47	
V05	Surf A	16	2.72	3.06
V05	Surf A	16	3.43	
V05	Surf A	16	3.39	
V05	Surf A	16	3.98	3.65
V05	Surf A	17	2.81	
V05	Surf A	17	2.62	
V05	Surf A	17	3.00	3.51
V05	Surf A	17	2.80	
V05	Surf A	17	3.40	
V05	Surf A	18	3.13	
V05	Surf A	18	3.43	
V05	Surf A	18	3.47	3.38
V05	Surf A	18	3.55	
V05	Surf A	18	3.65	2.98
V05	Surf A	19	3.96	
V05	Surf A	19	3.42	3.09
V05	Surf A	19	2.72	1.97
V05	Surf A	20	3.43	3.79
V05	Surf A	20	3.83	
V05	Surf A	20	3.44	2.51
V05	Surf A	20	3.20	
V05	Surf A	20	3.90	
V05	Surf A	21	4.51	4.35
V05	Surf A	21	3.44	
V05	Surf A	21	4.00	
V05	Surf A	22	3.75	
V05	Surf A	22	3.94	4.15
V05	Surf A	22	3.25	3.49
V05	Surf A	23	2.57	3.72
V05	Surf A	23	3.67	
V05	Surf A	23	3.58	
V05	Surf A	23	2.68	
V05	Surf A	24	2.58	3.61
V05	Surf A	24	3.16	
V05	Surf A	24	2.97	
V05	Surf A	25	2.22	
V05	Surf A	25	3.04	
V05	Surf B	1	4.02	
V05	Surf B	1	3.59	
V05	Surf B	1	3.76	5.30
V05	Surf B	1	3.92	
V05	Surf B	1	3.87	

Table D.2. Air Voids Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V05	Surf B	2	4.53	
V05	Surf B	2	3.70	5.77
V05	Surf B	2	4.55	
V05	Surf B	2	4.26	4.79
V05	Surf B	2	3.84	
V05	Surf B	2	3.77	5.06
V05	Surf B	3	3.88	
V05	Surf B	3	4.00	
V05	Surf B	3	4.02	5.25
V05	Surf B	*4*	*3.25*	
V05	Surf B	*4*	*3.14*	
V05	Surf B	*4*	*3.27*	
V05	Surf B	*5*	*3.13*	*4.72*
V05	Surf B	*5*	*3.15*	*3.95*
V05	Surf B	*5*	*3.08*	
V05	Surf B	*5*	*3.11*	
V05	Surf B	*5*	*3.46*	
V05	Surf B	6	3.03	3.60
V05	Surf B	6	3.33	3.05
V05	Surf B	6	2.71	3.54
V05	Surf B	6	2.98	
V05	Surf B	6	3.05	
V05	Surf B	7	2.70	
V05	Surf B	7	3.19	
V05	Surf B	7	3.10	
V05	Surf B	8	2.73	3.71
V05	Surf B	8	3.78	
V05	Surf B	8	3.21	3.49
V05	Surf B	8	3.30	
V05	Surf B	*4*	*3.25*	
V05	Surf B	*4*	*3.14*	
V05	Surf B	*4*	*3.27*	
V05	Surf B	*5*	*3.13*	*4.72*
V05	Surf B	*5*	*3.15*	*3.95*
V05	Surf B	*5*	*3.08*	
V05	Surf B	*5*	*3.11*	
V05	Surf B	*5*	*3.46*	
V06	Interm C	1	5.04	
V06	Interm C	2	5.01	5.21
V06	Interm C	3	4.41	5.54
V06	Interm C	3		4.13
V06	Interm C	4	4.83	4.29
V06	Interm C	5	4.26	
V06	Interm C	5	5.25	
V09	Surf A	1	2.85	4.46
V09	Surf A	1	3.45	
V09	Surf A	1	3.89	

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V09	Surf A	1	4.22	
V09	Surf A	2	2.98	3.67
V09	Surf A	2	2.71	3.19
V09	Surf A	2	2.84	
V09	Surf A	2	2.81	
V09	Surf A	3	3.52	2.81
V09	Surf A	3	3.66	4.93
V09	Surf A	3	3.78	3.93
V09	Surf A	3	4.08	
V09	Surf A	3	3.52	
V09	Surf A	3	4.19	
V09	Surf A	4	3.04	3.84
V09	Surf A	4	4.25	
V09	Surf A	4	5.02	4.57
V09	Surf A	4	4.39	
V09	Surf A	5	4.37	4.25
V09	Surf A	5	3.66	
V09	Surf A	5	2.24	4.62
V09	Surf A	5	4.66	
V09	Surf A	6	2.69	2.56
V09	Surf A	6	4.11	4.02
V09	Surf A	6	3.56	
V09	Surf A	6	3.20	3.42
V09	Surf A	7	3.22	
V09	Surf A	7	3.39	
V10	Interm B	1	3.77	3.86
V10	Interm B	1		4.21
V10	Interm B	2	4.34	4.90
V10	Interm B	2	4.55	
V10	Interm B	2	3.91	
V10	Interm B	3	3.63	3.74
V10	Interm B	3	3.99	
V10	Interm B	3	2.54	2.66
V10	Interm B	*4*	*4.14*	*3.71*
V10	Interm B	*4*	*4.58*	
V10	Interm B	*4*	*3.43*	*3.23*
V10	Interm B	*4*	*4.69*	
V10	Interm B	*4*	*3.50*	
V10	Interm B	*5*	*4.37*	
V10	Interm B	*5*	*4.38*	
V10	Interm B	*5*	*4.66*	
V10	Interm B	*5*	*4.55*	
V10	Interm B	6	4.06	
V10	Interm B	6	3.74	
V10	Interm B	6	4.30	
V10	Interm B	7	3.76	3.40
V10	Interm B	7	4.92	
V10	Interm B	7	4.55	4.55

Table D.2. Air Voids Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT	Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V10	Interm B	7		3.08					
V10	Interm B	8	4.35	3.49					
V10	Interm B	8		5.15					
V10	Interm B	8	3.89						
V10	Interm B	4	4.14	3.71					
V10	Interm B	4	4.58						
V10	Interm B	4	3.43	3.23					
V10	Interm B	4	4.69						
V10	Interm B	4	3.50						
V10	Interm B	5	4.37						
V10	Interm B	5	4.38						
V10	Interm B	5	4.66						
V10	Interm B	5	4.55						
V10	Surf A	1	5.30	5.72					
V10	Surf A	1	5.42	5.58					
V10	Surf A	1	4.63	4.52					
V10	Surf A	1	4.67						
V10	Surf A	2	3.91						
V10	Surf A	2	4.09	4.44					
V10	Surf A	2	4.24	4.59					
V10	Surf A	2	4.68						
V10	Surf A	3	3.82						
V10	Surf A	3	3.50						
V10	Surf A	3	3.56	3.52					
V10	Surf A	3	3.37	2.86					
V10	Surf A	4	5.01						
V10	Surf A	4	4.61						
V10	Surf A	4	4.47	3.51					
V10	Surf A	4	3.97						
V10	Surf A	5	4.83	5.03					
V10	Surf A	5	4.66						
V10	Surf A	5	4.83						
V10	Surf A	6	4.65	3.34					
V10	Surf A	6	4.05	3.01					
V10	Surf A	6	3.03	3.08					
V10	Surf A	7	3.80	3.80					
V10	Surf A	7		3.37					
V10	Surf A	3	3.82						
V10	Surf A	3	3.50						
V10	Surf A	3	3.56	3.52					
V10	Surf A	3	3.37	2.86					
V10	Surf A	4	5.01						
V10	Surf A	4	4.61						
V10	Surf A	4	4.47	3.51					
V10	Surf A	4	3.97						
V10	Surf A	5	4.83	5.03					
V10	Surf A	5	4.66						
V10	Surf A	5	4.83						

Table D.3. VMA Verification Test Results Data

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V01	Interm B	1	14.30	13.93
V01	Interm B	1	14.69	
V01	Interm B	1	15.29	
V01	Interm B	1	14.45	14.40
V01	Interm B	1	15.36	15.12
V01	Interm B	1	15.24	
V01	Interm B	1	14.43	
V01	Interm B	1	15.21	
V01	Interm B	2	14.28	
V01	Interm B	2	14.49	15.24
V01	Interm B	2	14.75	14.82
V01	Interm B	2	14.34	15.33
V01	Interm B	2	15.19	
V01	Interm B	3	14.59	
V01	Interm B	3	13.87	
V01	Interm B	3	14.94	
V01	Interm B	3	14.41	
V01	Interm B	4	14.23	14.86
V01	Interm B	4	14.89	
V01	Surf A	1	14.89	14.15
V01	Surf A	1	14.92	14.30
V01	Surf A	1	14.29	14.29
V01	Surf A	2	14.27	13.85
V01	Surf A	3	14.86	15.30
V01	Surf A	4	14.18	
V01	Surf A	5	15.75	14.66
V02	Interm B	1	14.67	
V02	Interm B	2	13.78	13.96
V02	Interm B	2		13.29
V02	Interm B	3	13.46	14.17
V02	Interm B	3	14.52	
V02	Interm B	4	13.62	
V02	Interm B	5	13.80	13.65
V02	Interm B	5	13.57	12.58
V02	Surf A	1	15.05	17.54
V02	Surf A	1	14.17	14.82
V02	Surf A	1	13.56	13.26
V02	Surf A	1		14.07
V02	Surf A	2	14.74	13.72
V02	Surf A	2	14.35	14.15
V02	Surf A	2	13.72	
V02	Surf A	2	13.98	
V02	Surf A	3	13.79	13.43
V02	Surf A	3	13.75	
V02	Surf A	3	13.68	
V02	Surf A	4	14.40	14.83
V02	Surf A	4	13.77	

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V02	Surf A	4	14.70	
V02	Surf A	5	14.27	
V02	Surf A	5	14.83	
V02	Surf A	5	14.22	
V02	Surf A	5	14.25	
V02	Surf A	5	12.78	14.69
V02	Surf A	5	14.69	
V02	Surf A	6	14.51	14.81
V02	Surf A	6	14.25	
V02	Surf A	6	14.11	
V02	Surf A	6	13.78	
V02	Surf A	7	14.55	14.68
V02	Surf A	7	14.58	
V02	Surf A	7	14.74	
V02	Surf A	8	14.73	15.67
V02	Surf A	8	14.14	
V02	Surf A	8	14.33	
V02	Surf A	9	15.11	14.62
V02	Surf A	9	15.34	
V02	Surf A	9	14.70	14.84
V02	Surf A	9	14.57	
V02	Surf A	9	14.48	
V02	Surf A	10	14.57	14.83
V02	Surf A	10	14.16	
V02	Surf A	10	14.07	14.27
V02	Surf A	11	14.18	15.21
V02	Surf A	11	14.75	
V02	Surf A	11	14.79	16.63
V02	Surf A	11	14.18	
V02	Surf A	11	13.91	
V02	Surf A	12	13.71	
V02	Surf A	12	13.73	
V02	Surf A	12	14.01	
V02	Surf A	12	13.96	
V02	Surf A	13	14.58	14.34
V02	Surf A	13	13.82	
V02	Surf A	13	14.01	
V02	Surf A	13	13.80	
V02	Surf A	14	14.24	14.60
V02	Surf A	14	13.45	
V02	Surf A	14	14.23	
V02	Surf A	14	14.07	14.27
V02	Surf A	14	14.39	
V02	Surf A	14	14.11	
V02	Surf A	15	14.08	13.94
V02	Surf A	15	13.65	15.21
V02	Surf A	15	14.68	
V02	Surf A	15	13.88	

Table D.3. VMA Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V02	Surf A	16	14.55	13.60
V02	Surf A	16	13.27	13.76
V02	Surf A	16	14.19	
V02	Surf A	16	13.91	
V02	Surf A	17	14.55	15.14
V02	Surf A	17	14.12	15.35
V02	Surf A	17	14.75	
V02	Surf A	17	13.96	
V02	Surf A	*18*	*13.35*	*15.23*
V02	Surf A	*18*	*14.82*	
V02	Surf A	*18*	*14.62*	*16.13*
V02	Surf A	*18*	*14.71*	
V02	Surf A	*19*	*14.27*	*14.91*
V02	Surf A	*19*	*14.71*	
V02	Surf A	*19*	*15.20*	*15.47*
V02	Surf A	*19*	*14.18*	
V02	Surf A	*20*	*14.33*	*14.59*
V02	Surf A	*20*	*13.58*	
V02	Surf A	*20*	*13.55*	
V02	Surf A	*20*	*14.52*	
V02	Surf A	21	13.95	14.34
V02	Surf A	21	14.55	
V02	Surf A	21	14.54	
V02	Surf A	21	14.54	
V02	Surf A	22	15.18	
V02	Surf A	22	13.51	
V02	Surf A	*18*	*13.35*	*15.23*
V02	Surf A	*18*	*14.82*	
V02	Surf A	*18*	*14.62*	*16.13*
V02	Surf A	*18*	*14.71*	
V02	Surf A	*19*	*14.27*	*14.91*
V02	Surf A	*19*	*14.71*	
V02	Surf A	*19*	*15.20*	*15.47*
V02	Surf A	*19*	*14.18*	
V02	Surf A	*20*	*14.33*	*14.59*
V02	Surf A	*20*	*13.58*	
V02	Surf A	*20*	*13.55*	
V02	Surf A	*20*	*14.52*	
V02	Surf B	1	15.12	15.03
V02	Surf B	1	15.20	
V02	Surf B	1	14.34	14.71
V02	Surf B	1	13.54	
V02	Surf B	2	15.10	15.32
V02	Surf B	2	14.83	
V02	Surf B	2	14.66	16.04
V02	Surf B	2	14.93	14.79
V02	Surf B	2	14.71	

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V02	Surf B	3	14.61	14.58
V02	Surf B	3	14.62	15.20
V02	Surf B	3	15.27	15.36
V02	Surf B	4	14.74	14.20
V02	Surf B	4	14.70	
V02	Surf B	4	14.51	
V02	Surf B	6	13.67	13.79
V02	Surf B	6	14.80	14.66
V02	Surf B	6	13.74	
V02	Surf B	2	14.14	
V02	Surf B	2	15.12	
V02	Surf B	2	14.76	
V02	Surf B	3	14.37	15.97
V02	Surf B	3	14.74	15.93
V02	Surf B	3	14.80	14.21
V02	Surf B	4	14.54	13.50
V02	Surf B	4	14.15	
V02	Surf B	4	14.53	
V02	Surf B	4	14.63	
V02	Surf B	5	15.07	14.55
V02	Surf B	5	15.01	
V02	Surf B	5	14.59	
V02	Surf B	6	14.40	14.70
V02	Surf B	6	14.56	14.32
V02	Surf B	6	14.31	
V02	Surf B	6	14.74	
V02	Surf B	6	14.16	
V02	Surf B	5	14.98	16.24
V02	Surf B	5	14.69	
V02	Surf B	5	14.31	
V02	Surf B	6	14.43	
V02	Surf B	6	13.80	15.20
V02	Surf B	6	14.53	14.33
V02	Surf B	6	14.65	
V02	Surf B	6	14.04	
V02	Surf B	6	13.96	
V02	Surf B	7	14.69	
V02	Surf B	7	14.39	
V02	Surf B	7	13.62	
V02	Surf B	7	14.13	
V02	Surf B	8	14.77	15.13
V02	Surf B	8	14.67	15.00
V02	Surf B	8	14.15	
V02	Surf B	9	15.08	14.59
V02	Surf B	9	14.34	14.28
V02	Surf B	9	13.74	
V02	Surf B	10	15.02	16.08

Table D.3. VMA Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V02	Surf B	10	14.18	16.17
V02	Surf B	10	14.63	
V02	Surf B	11	14.81	
V02	Surf B	11	15.42	
V02	Surf B	11	14.83	
V02	Surf B	12	14.63	16.47
V02	Surf B	12	15.37	
V02	Surf B	12	15.43	
V02	Surf B	12	15.38	
V02	Surf B	13	15.10	
V02	Surf B	7	15.27	15.16
V02	Surf B	7	14.20	15.58
V02	Surf B			15.23
V04	Surf B	1	14.96	15.36
V04	Surf B	1	14.61	15.87
V04	Surf B	1	14.54	
V04	Surf B	1	14.73	14.15
V04	Surf B	1	14.58	
V04	Surf B	2	14.54	15.90
V04	Surf B	2	14.12	
V04	Surf B	2	15.02	
V04	Surf B	2	14.95	
V04	Surf B	3	14.15	14.89
V04	Surf B	3	14.55	14.77
V04	Surf B	3	13.99	14.69
V04	Surf B	3	14.58	
V04	Surf B	4	14.40	14.39
V04	Surf B	4	14.30	
V04	Surf B	4	14.06	
V04	Surf B	5	14.27	14.94
V04	Surf B	5	14.06	13.59
V04	Surf B	5	14.36	
V04	Surf B	5	14.55	
V04	Surf B	6	15.27	16.12
V04	Surf B	6	14.59	
V04	Surf B	6	14.37	
V04	Surf B	6	14.48	
V04	Surf B	6	15.38	
V05	Interm B	2	14.07	16.21
V05	Interm B	2	14.39	
V05	Interm B	2	15.34	16.22
V05	Interm B	2	14.75	
V05	Interm B	3	13.97	15.96
V05	Interm B	3	14.08	
V05	Interm B	3	14.54	
V05	Interm B	4	15.28	
V05	Interm B	4	15.19	17.10
V05	Interm B	4	15.20	

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V05	Interm B	4	14.65	
V05	Interm B	4	13.72	
V05	Interm B	5	15.18	14.89
V05	Interm B	5	14.46	15.34
V05	Interm B	5	14.47	
V05	Interm B	5	14.49	
V05	Interm B	6	14.37	
V05	Interm B	6	14.53	
V05	Interm B	6	14.77	
V05	Interm B	6	13.90	
V05	Interm B	7	14.73	
V05	Interm B	7	15.26	
V05	Interm B	7	14.92	
V05	Interm B	8	14.16	16.43
V05	Interm B	8	13.80	
V05	Interm B	8	14.91	
V05	Interm B	9	14.68	
V05	Interm B	9	14.58	16.17
V05	Interm B	9	14.35	16.95
V05	Interm B	10	14.84	17.15
V05	Interm B	10		15.48
V05	Interm B	*11*	*14.26*	*15.70*
V05	Interm B	*11*	*13.92*	
V05	Interm B	*11*	*14.30*	
V05	Interm B	*11*	*14.32*	
V05	Interm B	12	14.61	16.05
V05	Interm B	12	14.67	
V05	Interm B	12	15.24	15.46
V05	Interm B	12	14.38	
V05	Interm B	13	15.27	15.73
V05	Interm B	13	14.20	
V05	Interm B	13	14.65	
V05	Interm B	14	15.18	16.01
V05	Interm B	14	14.47	16.52
V05	Interm B	14	15.04	
V05	Interm B	15	14.63	
V05	Interm B	*11*	*14.26*	*15.70*
V05	Interm B	*11*	*13.92*	
V05	Interm B	*11*	*14.30*	
V05	Interm B	*11*	*14.32*	
V05	Surf A	1	15.29	
V05	Surf A	1	14.98	
V05	Surf A	2	16.00	17.31
V05	Surf A	2	15.90	
V05	Surf A	2	15.05	15.99
V05	Surf A	2	15.01	
V05	Surf A	2	15.59	

Table D.3. VMA Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V05	Surf A	2	15.40	
V05	Surf A	3	16.10	16.66
V05	Surf A	3	15.71	
V05	Surf A	3	15.87	
V05	Surf A	3	15.52	
V05	Surf A	3	15.73	
V05	Surf A	4	15.99	16.70
V05	Surf A	4	16.08	
V05	Surf A	4	15.33	
V05	Surf A	4	15.41	
V05	Surf A	5	14.90	16.44
V05	Surf A	5	15.20	
V05	Surf A	5	15.71	
V05	Surf A	6	14.62	15.36
V05	Surf A	6	15.28	
V05	Surf A	6	15.54	16.36
V05	Surf A	6	15.42	
V05	Surf A	7	15.42	16.14
V05	Surf A	7	15.17	
V05	Surf A	7	15.63	
V05	Surf A	8	16.00	16.71
V05	Surf A	8	15.84	
V05	Surf A	8	15.07	
V05	Surf A	9	16.44	17.06
V05	Surf A	9	15.83	17.15
V05	Surf A	9	15.86	
V05	Surf A	10	15.72	16.69
V05	Surf A	10	15.96	16.93
V05	Surf A	10	16.42	
V05	Surf A	10	15.31	
V05	Surf A	11	15.67	
V05	Surf A	11	16.43	15.59
V05	Surf A	11	15.66	16.22
V05	Surf A	11	14.65	
V05	Surf A	11	15.62	
V05	Surf A	12	15.67	16.84
V05	Surf A	12	14.81	16.75
V05	Surf A	12	16.00	
V05	Surf A	12	15.33	
V05	Surf A	13	15.45	16.83
V05	Surf A	13	14.80	17.44
V05	Surf A	13	15.02	
V05	Surf A	13	14.78	
V05	Surf A	13	15.25	16.65
V05	Surf A	14	15.37	
V05	Surf A	14	15.36	
V05	Surf A	14	15.31	16.34
V05	Surf A	15	15.19	

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V05	Surf A	15	15.30	16.30
V05	Surf A	15	16.12	
V05	Surf A	15	14.97	
V05	Surf A	15	15.12	15.91
V05	Surf A	16	15.07	
V05	Surf A	16	14.74	15.45
V05	Surf A	16	15.30	
V05	Surf A	16	15.30	
V05	Surf A	16	15.94	16.59
V05	Surf A	17	14.98	
V05	Surf A	17	14.53	
V05	Surf A	17	15.01	16.22
V05	Surf A	17	14.35	
V05	Surf A	17	14.38	
V05	Surf A	18	15.19	
V05	Surf A	18	15.95	
V05	Surf A	18	15.42	15.90
V05	Surf A	18	15.54	
V05	Surf A	18	15.64	15.89
V05	Surf A	19	16.07	
V05	Surf A	19	15.88	16.16
V05	Surf A	19	15.04	15.38
V05	Surf A	20	15.51	16.50
V05	Surf A	20	16.36	
V05	Surf A	20	16.02	15.82
V05	Surf A	20	15.46	
V05	Surf A	20	15.24	
V05	Surf A	21	16.29	16.42
V05	Surf A	21	15.04	
V05	Surf A	21	15.50	
V05	Surf A	22	16.05	
V05	Surf A	22	15.70	16.21
V05	Surf A	22	15.16	15.54
V05	Surf A	23	14.77	16.07
V05	Surf A	23	15.34	
V05	Surf A	23	15.44	
V05	Surf A	23	14.91	
V05	Surf A	24	14.76	15.69
V05	Surf A	24	15.11	
V05	Surf A	24	14.88	
V05	Surf A	25	14.47	
V05	Surf A	25	14.55	
V05	Surf B	1	15.52	
V05	Surf B	1	14.81	
V05	Surf B	1	15.70	17.25
V05	Surf B	1	15.65	
V05	Surf B	1	15.89	

Table D.3. VMA Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V05	Surf B	2	16.16	
V05	Surf B	2	15.83	17.40
V05	Surf B	2	15.73	
V05	Surf B	2	16.04	16.59
V05	Surf B	2	15.33	
V05	Surf B	2	15.08	16.89
V05	Surf B	3	15.25	
V05	Surf B	3	16.10	
V05	Surf B	3	15.11	16.95
V05	Surf B	*4*	*15.25*	
V05	Surf B	*4*	*15.52*	
V05	Surf B	*4*	*15.49*	
V05	Surf B	*5*	*15.05*	*16.86*
V05	Surf B	*5*	*14.74*	*16.44*
V05	Surf B	*5*	*15.18*	
V05	Surf B	*5*	*14.50*	
V05	Surf B	*5*	*15.87*	
V05	Surf B	6	15.17	16.22
V05	Surf B	6	15.46	15.63
V05	Surf B	6	14.37	16.11
V05	Surf B	6	15.09	
V05	Surf B	6	15.22	
V05	Surf B	7	15.17	
V05	Surf B	7	15.03	
V05	Surf B	7	14.96	
V05	Surf B	8	15.41	16.11
V05	Surf B	8	14.62	
V05	Surf B	8	15.29	16.07
V05	Surf B	8	14.98	
V05	Surf B	*4*	*15.25*	
V05	Surf B	*4*	*15.52*	
V05	Surf B	*4*	*15.49*	
V05	Surf B	*5*	*15.05*	*16.86*
V05	Surf B	*5*	*14.74*	*16.44*
V05	Surf B	*5*	*15.18*	
V05	Surf B	*5*	*14.50*	
V05	Surf B	*5*	*15.87*	
V06	Interm C	1	17.08	
V06	Interm C	2	16.94	16.43
V06	Interm C	3	16.20	17.28
V06	Interm C	3		16.52
V06	Interm C	4	16.72	16.72
V06	Interm C	5	17.14	
V06	Interm C	5	17.00	
V09	Surf A	1	14.62	15.45
V09	Surf A	1	14.76	
V09	Surf A	1	14.39	

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V09	Surf A	1	15.07	
V09	Surf A	2	14.64	15.25
V09	Surf A	2	14.44	14.55
V09	Surf A	2	14.28	
V09	Surf A	2	14.59	
V09	Surf A	3	14.71	13.79
V09	Surf A	3	14.83	15.23
V09	Surf A	3	14.67	14.97
V09	Surf A	3	14.95	
V09	Surf A	3	13.87	
V09	Surf A	3	14.91	
V09	Surf A	4	14.19	14.94
V09	Surf A	4	14.89	
V09	Surf A	4	15.64	14.74
V09	Surf A	4	15.24	
V09	Surf A	5	14.62	14.91
V09	Surf A	5	15.03	
V09	Surf A	5	13.96	13.94
V09	Surf A	5	14.46	
V09	Surf A	6	14.31	13.93
V09	Surf A	6	15.21	14.88
V09	Surf A	6	14.74	
V09	Surf A	6	14.40	14.57
V09	Surf A	7	14.11	
V09	Surf A	7	14.24	
V10	Interm B	1	15.07	14.15
V10	Interm B	1		15.55
V10	Interm B	2	14.92	15.00
V10	Interm B	2	14.71	
V10	Interm B	2	15.15	
V10	Interm B	3	13.73	14.85
V10	Interm B	3	13.83	
V10	Interm B	3	14.62	14.36
V10	Interm B	*4*	*14.60*	*15.69*
V10	Interm B	*4*	*14.76*	
V10	Interm B	*4*	*14.79*	*14.46*
V10	Interm B	*4*	*14.90*	
V10	Interm B	*4*	*14.55*	
V10	Interm B	*5*	*15.28*	
V10	Interm B	*5*	*14.16*	
V10	Interm B	*5*	*15.07*	
V10	Interm B	*5*	*15.12*	
V10	Interm B	6	14.74	
V10	Interm B	6	14.70	
V10	Interm B	6	14.79	
V10	Interm B	7	15.33	14.66
V10	Interm B	7	15.49	
V10	Interm B	7	15.07	15.36

Table D.3. VMA Verification Test Results Data (*continued*)

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT
V10	Interm B	7		15.21
V10	Interm B	8	14.60	14.43
V10	Interm B	8		15.72
V10	Interm B	8	14.87	
V10	Interm B	4	14.60	15.69
V10	Interm B	4	14.76	
V10	Interm B	4	14.79	14.46
V10	Interm B	4	14.90	
V10	Interm B	4	14.55	
V10	Interm B	5	15.28	
V10	Interm B	5	14.16	
V10	Interm B	5	15.07	
V10	Interm B	5	15.12	
V10	Surf A	1	15.92	16.55
V10	Surf A	1	15.14	16.84
V10	Surf A	1	15.61	15.41
V10	Surf A	1	14.81	
V10	Surf A	2	14.66	
V10	Surf A	2	15.69	15.06
V10	Surf A	2	15.28	15.67
V10	Surf A	2	15.40	
V10	Surf A	3	15.12	
V10	Surf A	3	15.25	
V10	Surf A	3	15.00	15.44
V10	Surf A	3	14.88	14.83
V10	Surf A	4	15.62	
V10	Surf A	4	15.70	
V10	Surf A	4	14.60	15.34
V10	Surf A	4	15.04	
V10	Surf A	5	14.83	16.12
V10	Surf A	5	15.57	
V10	Surf A	5	15.69	
V10	Surf A	6	15.16	14.83
V10	Surf A	6	15.44	15.63
V10	Surf A	6	15.13	15.98
V10	Surf A	7	15.37	15.30
V10	Surf A	7		14.69
V10	Surf A	3	15.12	
V10	Surf A	3	15.25	
V10	Surf A	3	15.00	15.44
V10	Surf A	3	14.88	14.83
V10	Surf A	4	15.62	
V10	Surf A	4	15.70	
V10	Surf A	4	14.60	15.34
V10	Surf A	4	15.04	
V10	Surf A	5	14.83	16.12
V10	Surf A	5	15.57	
V10	Surf A	5	15.69	

Proj. No.	Mix Type	Lot No.	Contr.	SCDOT

Total Printing Cost	$544.26
Total Number of Documents	30
Cost per Unit	$18.14