Development and Implementation of a Performance-Related Specification for I-65 Tennessee · FINAL REPORT

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CONCRETE PAVEMENT CPTP TECHNOLOGY PROGRAM

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16. Abstract

The development and implementation of a trial performance-related specification (PRS) for concrete pavement construction of I-65 near Nashville, TN, is documented. The work was performed under the FHWA's Concrete Pavement Technology Program Task 7: Field Trial of Performance-Related Specifications (PRS) for PCC Pavement, and was conducted in partnership with the Tennessee Department of Transportation (TDOT). This project continued the field implementation of PRS for concrete pavement construction to more fully determine its benefits and deficiencies. The FHWA methodology (FHWA-RD-98-155, *Guide to Developing Performance-Related Specifications*) and software (PaveSpec 3.0) were used in developing the PRS. Construction went smoothly and following construction the results were evaluated.

Quantitatively, the contractor achieved a higher than target quality PCC pavement as indicated by the level of incentive pay (106 percent average). An independent performance analysis showed that due to the higher quality achieved, the as-constructed pavement would have an increased life of approximately 14 percent. Thus, for an additional 6 percent incentive investment up front, an increased life of 14 percent is expected.

Qualitatively, the following comments were representative of the TDOT staff: "The PRS pay factor would have been worth the effort spent achieving it." "Incentive promotes quality from contractors." "Ultimately it [quality] is up to the contractor and how well they build the road. I think it [PRS] gives the contractor a reason to work harder and do better." Comments from the contractor staff: PRS "promotes quality end product. Promotes payment for actual product received." Comments from the QC representative: PRS "would most likely reduce variability, thus increasing quality." "From testing and inspection viewpoint, don't think any more complicated than current specifications." Thus, for all stakeholders involved, the PRS trial project appears to be successful. Several good suggestions were also received to improve the PRS.

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EXECUTIVE SUMMARY

PURPOSE AND SCOPE OF THE PROJECT

The Tennessee Department of Transportation (TDOT) piloted a performance-related specification (PRS) for portland cement concrete pavement. The trial implementation of this PRS on I-65 in Nashville, Tennessee, was sponsored by the Federal Highway Administration (FHWA). The trial has provided TDOT and the contracting industry with an understanding of the PRS development and implementation processes and the results achieved. The main objective of the PRS is to provide the agency with a methodology to assure that design assumptions are fulfilled, to promote high quality construction, and to protect the agency from poor workmanship. At the same time, the PRS will allow the contractor increased freedom and innovation in deciding how to perform the construction and will provide significant incentives to produce a quality project.

DESCRIPTION OF THE PROJECT

The PRS provides for incentive/disincentive pay to the contractor depending on the level of construction quality achieved in the field, as illustrated in figure ES-1. With PRS, the composite pay adjustment factor for a specific lot of pavement is a calculated value based on the difference between the estimated life-cycle cost (LCC) of the as-designed (target) pavement and the estimated LCC of the as-constructed pavement (lot) as computed by the PaveSpec 3.0 software.

This methodology is defined in the report FHWA-RD-98-155, *Guide to Developing Performance-Related Specifications.* The FHWA Web site provides additional information about PRS and the PaveSpec 3.0 software (www.tfhrc.gov/pavement/pccp/pavespec/pavespec.htm).

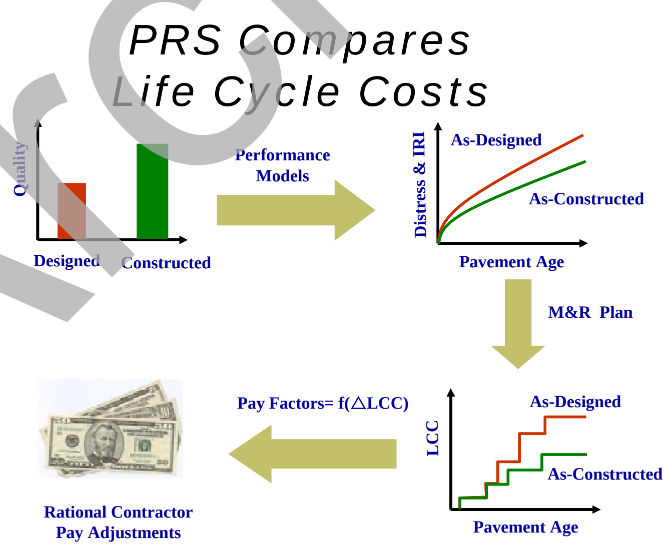


Figure ES-1. Basic concepts of life-cycle-cost–based performance-related specification pay adjustment for a lot.

The *pay adjustment factor* is defined as the percentage of the bid price that the contractor is paid for the construction of a concrete pavement lot and is computed based on the difference between the as-constructed and as-designed LCC. Pay adjustment in these specifications was based on the following key acceptance quality characteristics (AQCs) for the I-65 project:

- Concrete compressive strength at 28 days.
- Slab thickness.
- Initial smoothness (or profile index [PI]).

Other quality characteristics (e.g., consolidation around dowel bar, entrained air content) could have been included if desired. All other acceptance quality characteristics (AQCs) and construction requirements were considered according to TDOT's existing Standard Specifications. Other aspects of the PRS that were established include the following:

- Testing methods were selected for slab thickness, concrete strength, and PI.
- Lots and sublots were defined, and a sampling plan established.
- Pay adjustment curves were computed for thickness, compressive strength, and PI.

RESULTS ACHIEVED

A sample of the results obtained from the construction work for smoothness is shown in figure ES-2. The PI for each lot, plus and minus one standard deviation, is shown. The pay factor associated with each lot is also shown. The southbound exhibited much smoother pavement than the northbound due to use of stringlines, which provided better grade control for the subbase.

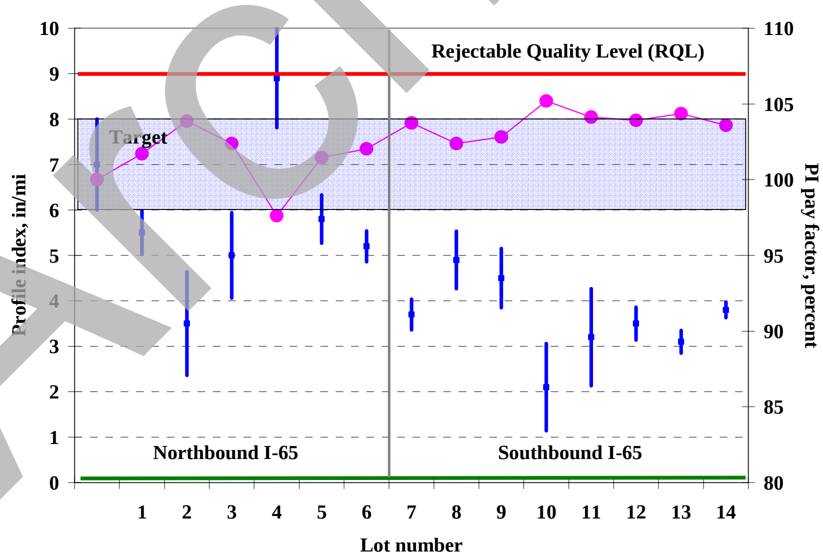


Figure ES-2. Performance-related smoothness specification results for 14 lots.

Figure ES-3 shows a summary of the PRS pay factors for each of the 14 lots used in the analysis. It also includes an overall pay factor, which averages 106.5 percent for the northbound lots and 105.2 percent for the southbound lots.

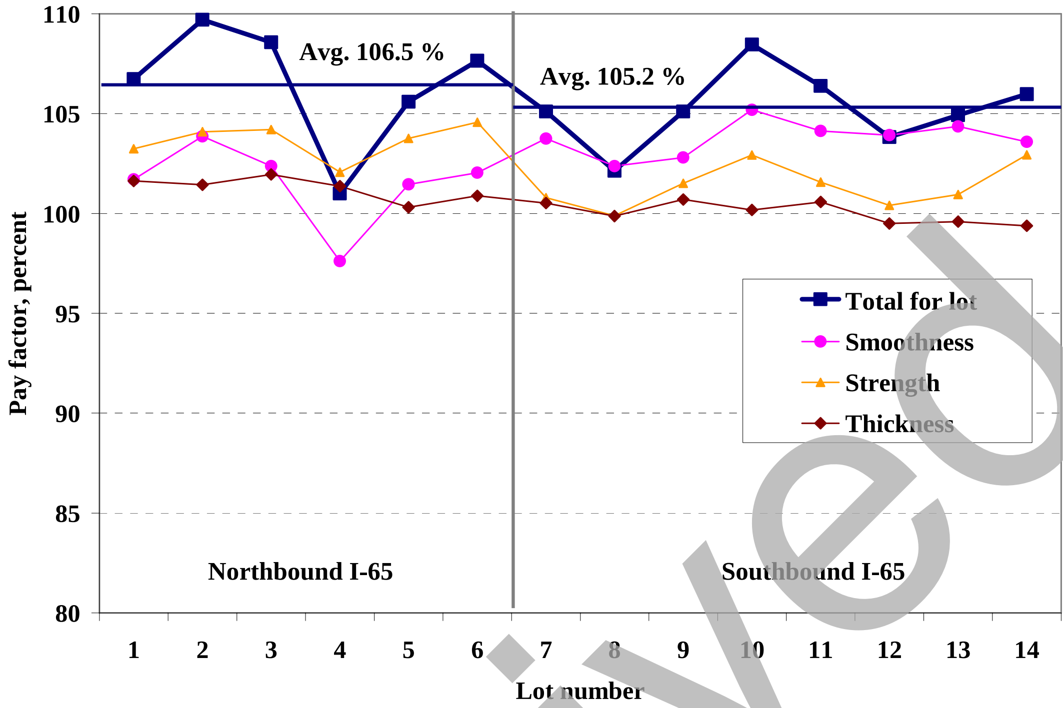


Figure ES-3. Summary of performance-related specification pay factor results.

FINDINGS

The result of using the PRS was that the contractor would receive an average of 106 percent incentive pay for higher quality construction. The following question was posed: will a 6 percent increase in construction cost due to higher quality result in a similar or greater increase in pavement life as well as a lower LCC (on which the pay factor curves are based)? This question was addressed using an independent method to predict pavement life. The NCHRP 1-37A mechanistic–empirical pavement design and analysis software was used to predict the performance of the target (or as-designed) and the as-built lots.

Results showed that the expected life of the target pavement turned out to be in excess of 50 years, which was due in part to the conservatism in the design. The expected life of the as-constructed lots was even longer, by 14 percent, due to the better AQCs. Therefore, for an increase in initial cost of 6 percent (from the positive quality incentives), an even greater percentage increase in pavement life was achieved.

After construction, a meeting was held with the contractors, the quality control (QC) representatives, and the TDOT staff. Independent comments indicated that all three groups supported the PRS approach. A few representative comments from each group are provided below:

Contractor:

- PRS "rewards contractor for exceeding quality of product requested." "Incentive promotes quality control."
- More accurate quality measurements can be achieved because PRS "relates actual product back to anticipated [design] product."
- PRS "promotes quality end product. Promotes payment for actual product received."
- "Need faster answers on test results."
- "Need more tests per sublot."

TDOT:

- "I think it [PRS] leads to elimination of less-quality-oriented contractors."
- "I like the direction it [PRS] takes us."
- "I see the contractor giving us a more concentrated effort to increase the quality of the product he produces."
- PRS "allows greater pay for better materials and quality of construction."
- "Ultimately it [quality] is up to the contractor and how well they build the road. I think it [PRS] gives the contractor a reason to work harder and do better."

QC representative:

- PRS "would most likely reduce variability, thus increasing quality."
- PRS can provide more accurate quality measurements because "with reduced variability, actual test results are more realistic of actual pavement."
- "From testing and inspection viewpoint, don't think a PRS is any more complicated than current specifications."

BENEFITS OF PERFORMANCE-RELATED SPECIFICATION

This project provides strong support for the concept that a PRS that considers those AQCs that relate directly to performance and are under the control of the contractor is practical and can produce a win–win situation for the contractor and the highway agency. Listed below are key benefits of PRS that were demonstrated on this I-65 project:

- Better linkage between design and construction.
- Higher quality pavements (through incentives) and longer pavement life.

- Testing that focuses on key quality characteristics that relate to the pavement long-term performance.
- Incentives and disincentives that are justified through reduction or increase in future LCC.
- Specifications that give the contractors more responsibility and flexibility yet increased accountability, for the potential benefit of both the contractor and owner.
- An environment that allows contractors to be more innovative and more competitive and leads to the success of more quality-oriented contractors.

RECOMMENDATIONS

The trial PRS worked very well on this major I-65 project, and all parties appeared to be supportive of fully implementing a PRS for future projects. Some key recommendations are provided as follows:

- Develop practical definitions of lots and sublots (extremely important).
- Select target means and standard deviations of AQCs to reflect reasonable quality.
- Consider the impacts of pay factor curves derived using PaveSpec on the highway agency and the contractor.
- Consider tightening subgrade and subbase grade requirements and encouraging contractors to better control and monitor these elevations and profiles.
- Provide a methodology to measure PRS pay factor results quickly.
- Consider methods for increasing the sampling rate and reducing the amount of destructive testing such as coring for slab thickness measurement.

CHAPTER 1—INTRODUCTION

This report documents the development and testing of a performance-related specification (PRS) for a section of I-65 near Nashville, Tennessee, in 2004. The study was conducted under the Federal Highway Administration (FHWA) Concrete Pavement Technology Program Task 7: Field Trial of Performance-Related Specifications for Portland Cement Concrete (PCC) Pavement in Tennessee, contract DTFH61-03-C-00109. The work was conducted in partnership with the Tennessee Department of Transportation (TDOT) which, under the leadership of Brian Egan, contributed significantly to the effort.

The purpose of this work was to continue the implementation of PRS for concrete pavement construction to more fully determine the benefits and any problems associated with PRS so that they can be improved for future implementations. Previous trials of PRS for concrete pavement were conducted in Florida and Indiana (two major projects), and shadow trials were conducted in Missouri, Iowa, Wisconsin, and New Mexico (see references 1–4 and 6–9).

PRS for highway pavement construction are similar to quality assurance specifications; however, a key difference is that the measured acceptance quality characteristics (AQCs) are related directly to pavement performance through quantifiable relationships. Performance is defined by key distress types and smoothness and is related to the future maintenance, rehabilitation, and user costs of the highway. This link between measured AQCs and future life-cycle cost (LCC) provides the ability to develop rational and fair contractor pay adjustments that depend on the difference between the as-designed "target LCC" and the as-constructed LCC (figure 1 illustrates these concepts).

The FHWA methodology (FHWA-RD-98-155, *Guide to Developing Performance-Related Specifications*) and software (PaveSpec 3.0) were used in developing the PRS for the Interstate 65 project.[4] As illustrated in figure 1, PaveSpec 3.0 computes pay adjustment (termed pay factor) for a given lot based on the effect of construction quality on the pavement performance and subsequent LCC. The pay adjustment is computed as the difference in LCC between the as-designed "target" pavement and the as-constructed pavement (lot).

A pay adjustment factor (PF) is defined as the percentage of the bid price that the contractor is paid for the construction of a pavement lot and is computed based on the difference between the as-constructed and as-designed LCC (in present worth dollars) as follows:

$$PF = 100(BID + [LCC_{des} - LCC_{con}]) / BID \qquad (1)$$

Where:

BID = Contractor's bid price
LCC_{des} = As-designed life-cycle cost
LCC_{con} = As-constructed life-cycle cost

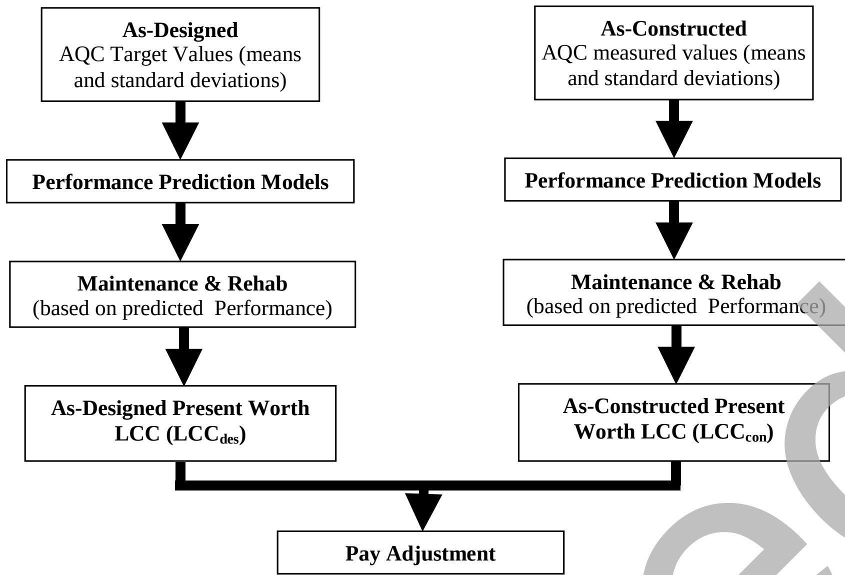


Figure 1. Basis for pay adjustment in performance-related specification.

For jointed plain concrete pavement (JPCP), the LCC is computed using prediction models for slab cracking, joint spalling, joint faulting, and pavement smoothness. A key aspect of using LCC to define the PFs is that the LCC of the as-constructed lot essentially represents the overall measure of quality, providing a rational way to develop an overall pay adjustment factor for the lot.

During the selection of this project for PRS implementation, it was intended to be a full test of PRS, where the contractor would be subject to the PRS in all of the concrete paving work. However, the best available project had just been bid and awarded. TDOT and the contractor agreed to a plan to place the northbound lanes under the existing TDOT method specifications (data were also to be collected on the northbound lanes using PRS procedures). Plans were for the contractor to be subjected to the PRS specifications for the southbound lanes and remaining inside lanes. After the PRS was developed and construction was underway on the northbound lanes (which included complete PRS data collection), other issues, unrelated to the PRS, arose between TDOT and the contractor that resulted in the contractor continuing work under the TDOT method specification. However, southbound PRS data were collected and analyzed. The PRS data from both the northbound and southbound paving are reported herein. These results are not a true independent test of the PRS implementation from beginning to end but provide results that would likely have been achieved under a full PRS implementation.

This report describes the PRS concept and provides an overview of the Tennessee I-65 project. The development of the PRS for the I-65 project is then described in detail, followed by a description of the implementation of the PRS on the I-65 project. The results from the construction monitoring are then presented. An evaluation of the PRS for this project is presented as judged by the resulting quality, the TDOT staff, the quality control (QC) representative, and the contractor staff comments. Finally, a summary and conclusions are provided. The specification is provided in appendix A, the data measured on the project in appendix B, and the expected pay charts for the PRS in appendix C.

CHAPTER 2—OVERVIEW OF THE TENNESSEE I-65 PROJECT

This project is located in Nashville, Tennessee, and is a section of suburban freeway reconstruction of I-65 from Old Hickory Boulevard at LM 91.55 to CSX Railroad at LM 95.03. The overall project is 3.487 mi (5.612 km) long and consists of five lanes in each direction. Data from only two lanes in each direction are included. The design of the pavement is as follows:

- JPCP.
- 13-in. (330 mm) slab (design thickness).
- 15-ft (4.6 m) transverse joint spacing.
- 1.625-in. (41.28 mm) dowel bars spaced at 12-in. (304.8 mm) at transverse joints.
- 4-in. (101.6 mm) permeable asphalt base course and drainage layer.
- 4-in. (101.6 mm) granular separation layer.
- Tied concrete shoulders.

To begin the development process, the project team collected and reviewed much information about the TDOT's existing specifications, design criteria, construction sampling and testing techniques, pavement performance measures, and typical maintenance and rehabilitation (M&R) strategies and costs. This information, along with data specific to the I-65 project and feedback from TDOT staff, was used to create the framework for the specifications and provide the necessary inputs to the PaveSpec 3.0 program.[1,2,3,4] The PRS development process, including the data gathering and analysis, started in 2003 and was completed in April 2004. The process included meetings with TDOT staff and several teleconferences and e-mail exchanges. Several TDOT staff members provided previous concrete pavement project data and feedback pertaining to these specifications. Details of the PRS development are provided in chapter 3.

CHAPTER 3—DEVELOPMENT OF THE PERFORMANCE-RELATED SPECIFICATION

SELECTION OF ACCEPTANCE QUALITY CHARACTERISTICS

The following AQCs can be considered directly in the PaveSpec PRS methodology for JPCPs:

- Concrete strength.
- Slab thickness.
- Initial smoothness.
- Entrained-air content.
- Percent consolidation around dowel bars.

These AQCs were found to affect pavement performance and are under the control of the paving contractor. TDOT includes concrete strength, slab thickness, initial smoothness, and entrained-air content in their existing method specifications. After significant discussion, TDOT decided to use the following AQCs and test methods in the PRS for I-65:

- Concrete strength: The compressive strength at 28 days is the standard quality characteristic used, and this was the logical value to use in the PRS.
- Slab thickness: Typically measured by cores, and TDOT had an interest in specifying the impact echo procedure for this project.
- Initial smoothness: The Rainhart profilograph with a 0.1-in. (2.5 mm) blanking band is specified for use on this project.

TDOT CONCRETE PAVEMENT SPECIFICATIONS

The current method specifications include the following items:

- Slab thickness: Measured by coring the pavement at 1,000-ft (304.8 m) intervals.
- PCC strength: Measured by taking cylinders at the paving site and curing them for 28 days to determine their compressive strength. One batch of PCC is taken each 400 yd^3 (305.8 m^3), for a minimum of two cylinders.
- Smoothness/profile: Measured by testing each wheelpath using the Rainhart profilograph with a 0.1-in. (2.5 mm) blanking band.

Details of measurement and pay are provided later in this chapter.

ESTABLISHMENT OF AS-DESIGNED TARGET VALUES

PRS differs from other QC specifications in that target means and standard deviations are specified, not minimums. The target means and standard deviations of the AQCs are those values that, if achieved by the contractor for an as-constructed lot, will be paid for at 100 percent of the bid price. Considerable discussion went into the selection of the as-designed target values. Since this would be the first PRS project conducted in Tennessee, it was decided that the target levels set in the specification should not significantly exceed the level of quality being achieved under the current method specification. Given the magnitude of incentives, it was considered that the contractor may exceed the targets, but forcing an increase in quality by raising the target quality level (e.g., increasing PCC strength target) was not desired in this project. Of course, depending on the results of this project, TDOT may modify the target values in the future.

To determine the level of quality currently being achieved, historical data from three projects were obtained. A summary is given in table 1. These results show the following:

- Compressive strength of PCC ranged from 5,247 to 6,432 lbf/in^2 (36.18 to 44.35 MPa) with a mean of 5,908 lbf/in^2 (40.73 MPa).
- Compressive strength standard deviation of PCC ranged from 315 to 892 lbf/in^2 (2,171.8 kPa to 6,150.1 kPa) with a mean (computed from the mean of the variances) of 655 lbf/in^2 (4,516.1 kPa).
- Slab thickness data were not sufficient to analyze.
- Slab thickness standard deviation was available on one project with a value of 0.11 in. (2.8 mm).
- Profile index (PI) ranged from 2.53 to 2.55 in./mi (39.91 to 40.23 mm/km) with a mean of 2.54 in./mi (40.07 mm/km) (may have been measured after diamond grinding).
- PI standard deviation of thickness ranged from 0.71 to 0.88 in./mi (11.20 to 13.88 mm/km) with a mean of 0.8 in./mi (12.62 mm/km).

If the TDOT mean and standard deviation targets for each of the AQCs used for pay adjustment are met, the agency will pay 100 percent of the bid price. Table 2 shows target quality levels (mean and standard deviations) selected after examination of results achieved on previous PCC projects and significant discussion about the impacts of selection of AQC target levels.

Slab Thickness. The logical target mean is the design thickness (13 in. [330.2 mm]). Specification of anything different would be inappropriate because this is what is called for in the design at a given level of reliability. Requiring more than the mean thickness would artificially add reliability to the design and is not recommended. The target standard deviation of thickness was set at 0.5 in. (12.7 mm), which is higher variability than a previous project target that appeared to be unreasonably low (0.11 in. [2.8 mm]).

PCC Strength. Compressive strength being achieved on previous projects is shown in table 1. The typical values presented previously were considered, and a somewhat lower value of 4,500 lbf/in^2 (31.03 MPa) was selected as representing the quality level desired by TDOT at 100 percent of PF. The standard deviation of PCC compressive strength was set slightly lower, at 500 lbf/in^2 (3,447 kPa), than past historical data indicated (655 lbf/in^2 [4,516 kPa]).

Smoothness (or Profile Index). Values of the PI achieved on two previous projects showed approximately 2.5 in./mi (39.44 mm/km) using the Rainhart profilograph with a 0.1-in. (2.5 mm) blanking band. This value was considered too low, and may require significant, undesirable grinding. Therefore, a value of 7.0 in. (177.8 mm) was selected as the target mean. The standard deviation of PI was set at 1.0 in./mi (15.78 mm/km), slightly higher than past data (0.8 in./mi [12.6 mm/km]).

Table 1. Summary of Data From Three Previous Portland Cement Concrete Projects

Attribute		**Project #1**	**Project #2**	**Project #3**
Tennessee Department of Transportation Identification		S.P. 33003-4154-04	IM-40-2(71)87, 57001-8172-44.	NH-I-75-1(95)3, 33005-3161-44
Location		I-24, Hamilton County	I-40, Madison and Henderson Counties	I-75, Hamilton County
Approximate length, mi		2.76	8.02	3.2
Project period		1997–2000	1997	1999–2001
28-day compressive strength, lbf/in^2	Field average	6,432	5,247	6,046
	Field standard deviation	892	315	625
	Specifications	Min. 3,000	Min. 3,000	Min. 3,000
Thickness, in.	Field average	NA	NA	12.04
	Field standard deviation	NA	NA	0.11
	Specifications	NA	NA	12
Air content, %	Field average	5.46	5.11	5.14
	Field standard deviation	0.51	0.11	0.44
	Specifications	3 to 8	3 to 8	3 to 8
Profile index, in./mi	Field average	2.55	NA	2.53
	Field standard deviation	0.88	NA	0.71
	Specifications	5	NA	4

1 mi = 1.61 km; 1 lbf/in^2 = 6.89 kPa; 1 in. = 25.4 mm; 1 in./mi = 16 mm/km

Table 2. Lot Acceptance Quality Characteristic Target Lot Mean and Standard Deviation Selected for I-65 Project

Acceptance Quality Characteristic	**Lot Target Values**	
	Mean	**Standard Deviation**
Slab thickness, in.	13.0	0.5[(1)]
Compressive strength: 28-days, lbf/in^2	4,500	500[(2)]
Initial profile index (with 0.1 in. blanking band), in./mi	7.0	1.0[(3)]

1 in. = 25.4 mm; 1 lbf/in2 = 6.89 kPa; 1 in./mi = 16 mm/km

(1) Thickness: mean and standard deviation computed from independent cores (one core per sublot).

(2) Compressive strength: mean and standard deviation computed from averages of two replicate cylinders taken at one location per sublot.

(3) Profile index: mean and standard deviation computed from averages of inside and outside wheelpaths of each 500-ft (152.4 m) section in the lot measured prior to any grinding.

TDOT PAVEMENT PERFORMANCE INDICATORS

The PaveSpec PRS uses inputs from the as-designed target lot and predicts performance over a designated analysis period. The key performance indicators included in PaveSpec are the following for JPCP:

- Slab transverse fatigue cracking, percent slabs.
- Joint faulting, inches.
- Joint spalling, percent joints.
- PI (at 0.1-in. [2.5 mm] blanking band).

Definitions of these distress types are provided in reference 4.

INPUTS USED FOR PAVESPEC 3.0

The following section provides information on the critical terminal values for use in PaveSpec 3.0 analysis of pavement life.

General Information.

Project Number: I-65 from Old Hickory Boulevard at LM 91.55 to CSX Railroad at LM 95.03
Location: Nashville, Tennessee
Project length: 3.478 miles
Number of lanes: Five in each direction

Pavement Design Features. Table 3 shows the design feature inputs used in PaveSpec 3.0.

Traffic Loadings. Table 4 shows the traffic loading inputs used in PaveSpec 3.0. The listed traffic inputs result in a projected 92 million equivalent single-axle loads (ESALs) in the design lane over the 20-year analysis period.

Climate. Table 5 shows the climatic inputs used in PaveSpec**.**

Table 3. Design Feature Inputs Used in PaveSpec 3.0

Design Feature	Value	Data Source/ Comment
Design life	20	Ok
Pavement type	Jointed plain concrete	Ok
Dowel bar diameter	1.625 in.	Ok
Transverse joint spacing	15 ft	Ok
PCC modulus of elasticity	4,461,750 lbf/in^2	Ok
Transverse joint sealant type	Silicone	Ok
Modulus of subgrade reaction (k-value)	126 lbf/in^2/in.	Ok
Water–cementitious materials ratio	0.42	Ok
% Subgrade material pass sieve #200	75	Ok
Base type	Permeable-asphalt-treated aggregate	Ok
Base permeability	Yes	Ok
Base thickness	4-in. asphalt-treated permeable over 4-in. aggregate separator layer	Ok
Base modulus of elasticity	100,000 lbf/in^2 typ. at 70 °F	Ok
PCC-Base Interface	Bonded	Ok
Base erodibility factor (1= totally non-erodable material, 5=granular)	1.5 permeable	Ok

1 in. = 25.4 mm; 1 ft = 0.305 m; 1 lbf/in^2 = 6.89 kPa

Table 4. Traffic Inputs Used in PaveSpec

Item	Value	Data Source/ Comment
Average daily traffic (both directions)	98,770	2004 estimate
Growth type	Linear	Ok
Growth rate	2.7%	Ok
Directional factor	50%	Ok
Percent trucks	20%	Ok
Percent trucks in outer lane	60%	Ok
Avg. truck-load equivalency factor	1.78 ESALs/truck	Ok

ESAL = equivalent single-axle load

Table 5. Climatic Inputs Used in PaveSpec 3.0

Item	Value	Data Source/ Comment
Average annual freezing index	226 per degree F	Ok
Average annual precipitation	56 in.	Ok
Average annual air freeze–thaw cycles	60 air freeze–thaw cycles	Ok
Average annual # of days > 90 °F	42 days	Ok
Climate zone	Wet–freeze	Ok

1 in. = 25.4 mm; 1 ft = 0.305 m; 1 lbf/in^2 = 6.89 kPa

M&R Plan. The following M&R activities were established based on discussions with TDOT staff.

Maintenance Plan Summary:

- Reseal 50 percent of the transverse joints every 10 years.
- Reseal 100 percent of the longitudinal joints every 10 years.
- Seal 100 percent of the transverse cracks every 5 years.

Localized Rehabilitation Plan Summary:

- Always apply 100 percent slab replacements to cracked slabs.
- If spalled joints exceed 30 percent, then apply partial-depth repairs to 100 percent of slabs.

Sublot Failure Thresholds:

- Consider the sublot failed if cumulative percent cracked slabs exceeds 20 percent.
- Consider the sublot failed if average transverse joint faulting exceeds 0.15 in. (3.8 mm).
- Consider the sublot failed if International Roughness Index (IRI) exceeds 175 in./mi (2,760 mm/km).
- Consider the sublot failed if cumulative percent joints spalled exceeds 30 percent.

If 20 percent of the sublots are failed, apply the global rehabilitation activities in table 6.

Table 6. Global Rehabilitation Activities If 20 Percent of Sublots Are Failed

Global Rehabilitation Activity	**Activities**
Prior to Phase I	Repair 100% of outstanding spalled joints with partial-depth repairs. Repair 100% of outstanding cracked slabs with full slab replacements
Phase I (diamond grinding)	Assumed life: 10 years Starting IRI: 50 in./mi Ending IRI: 175 in./mi
Phase II (diamond grinding)	Assumed life: 10 years Starting IRI: 50 in./mi Ending IRI: 175 in./mi
Phase III (asphalt concrete overlay)	Assumed Life: 10 years Starting IRI: 50 in./mi Ending IRI: 175 in./mi
Phase IV (asphalt concrete overlay)	Assumed life: 10 years Starting IRI: 50 in./mi Ending IRI: 175 in./mi

1 in./mi = 16 mm/km

This selection of 20 percent is important in that it triggers overall lot rehabilitation if 20 percent of the sublots reach a terminal cracking, faulting, or IRI. Thus, more variability within the project will result in 20 percent of sublots failing in cracking, faulting, or IRI earlier.

Unit Costs. Table 7 shows the unit costs estimated for this project used in PaveSpec.

Table 7. Design Feature Inputs Used in PaveSpec 3.0

Cost Item	Cost (in 2004 Dollars)
Transverse joint sealing	1.20 per ft
Longitudinal joint sealing	0.80 per ft
Transverse crack sealing	1.20 per ft
Local: Partial-depth repairs of transverse joints*	70.00 per yd^2
Local: Full slab replacements	75.00 per yd^2
Local: Partial slab replacements	105.00 per yd^2
Global: Asphalt concrete overlay	9.00 per yd^2
Global: Diamond grinding	5.25 per yd^2
% user cost	2 (provides about the right amount of user impact on pay factor)
Estimated bid price	$31.95 per yd^2 (contractors bid for 13-in. jointed plain concrete pavement)

1 in. = 25.4 mm; 1 ft = 0.305 m; 1 yd^2 = 0.836 m^2

*Width of partial-depth repair of transverse joints = 6 in. across joint.

DEFINITIONS OF LOTS AND SUBLOTS

The PRS AQCs of thickness, strength, and PI are measured within each sublot. All values measured within the lot are combined to compute a mean and standard deviation of the lot. The pay adjustment for a given lot is then computed from these values. Pay is determined on a lot-by-lot basis, not by the sublot.

There must be precise and easily understood definitions of lots and sublots, as ambiguity can cause significant problems in the field. These definitions required perhaps more discussion among the TDOT and project staff than any other item. Thus, sublots were set at a constant 500-ft (152.4 m) interval to provide simple, consistent testing methods. Sublot boundaries are marked and maintained until finalizing the payment computation. Each lot is divided into a minimum of three sublots for sampling and testing purposes. Markers are placed every 500 ft (152.4 m) along the mainline traffic lanes to aid in determining the lot and sublot limits.

The definitions of lot, sublot, and sampling frequency for thickness, concrete strength, and initial PI are presented below.

Lot Definition

- Each lot is one paving pass in width. This width can be equal to one, two, or more traffic lanes (see below for consideration of concrete shoulders).

- A lot consists of a minimum of three sublots that are each 500 ft (152.4 m) in length, and they all exist consecutively (longitudinally) along the same paving width. A lot cannot be divided between two adjacent or separated paving lanes.
- Therefore, the minimum length of a lot is 1,500 ft (457.2 m) along the same paving lane(s), and this lot can include work from 1 or more days of paving.
- The maximum lot length is defined as 1 day's production of one paving pass, or 4,500 ft (1,371.6 m) in length, whichever is less. If the 1-day production is longer than 4,500 ft (1,371.6 m), the engineer will divide the 1-day production into multiple lots that meet the minimum lot length as defined above. The engineer may terminate the lot if there is any reason to believe that a special cause affected the process and resulted in a significant shift in the mean or standard deviation of thickness, PI, or strength (AQCs).
- If the contractor builds a paving pass in a given day that is less than 1,500 ft (457.2 m), this is defined as a partial lot. A partial lot is combined with the previous or next day's paving to produce a full lot with a minimum length of 1,500 ft (457.2 m) and a maximum length of 4,500 ft (1,371.6 m). If the combined length of paving of a partial lot and the current lot being paved is greater than 4,500 ft (1,371.6 m), the lot will be limited to 4,500 ft (1,371.6 m) and another partial lot identified to be added to the next day's paving.
- If a section of paving has been designated as a partial lot but cannot be combined with the adjacent lot (e.g., a single lane of widening or tapered paving that is less than 1,500 ft (457.2 m), or if it is the last lot in the paving project and is less than 1,500 ft (457.2 m), it may be grouped with a previous lot. This will be allowed even if it results in a lot that is greater than 4,500 ft (1,371.6 m). This type of flexibility must be included to make the field management of the PRS data collection feasible and efficient.
- Concrete shoulders can be included along with adjacent paved traffic lane(s), or by themselves if paved separately. If concrete shoulders are paved with a traffic lane (a paving width includes one or more traffic lanes and a concrete shoulder), the traffic lane is tested for all AQCs (PI, strength, and thickness) but the shoulder is tested for strength and thickness only. The pay factor is computed using only the PI values obtained from the traffic lane(s). If the lot width includes only a concrete shoulder, the shoulder is tested for concrete strength and slab thickness, and PI is assumed to be at the target values of 7.0-in. (177.8 mm) mean and 1.0-in. (25.4 mm) standard deviation.

Sublot Definition

- The sublot length is established at a constant 500 ft (152.4 m) so that the PI can be measured, as well as for field location expediency and consistency.
- The width of the sublot is the paving width.
- There shall be a minimum of three sublots in each lot. The maximum is nine sublots within a maximum lot size of 4,500 ft (1,371.6 m).
- If there is a sublot that is not tested for concrete strength for whatever reason, this section shall be cored as specified and tested for compressive strength at 28 days after

placement. The cores shall be tested for compressive strength according to procedures required in table 8.

Table 8. Testing Procedures Used for Performance-Related Specification Evaluation

Acceptance Quality Characteristic	**Test Method[1]**
Slab thickness	AASHTO T148
Compressive strength	Concrete cylinders: AASHTO T23 and AASHTO T22. Concrete cores: AASHTO T24 for sublots with missing strength data.
Initial Profile Index	ASTM E 1274

Sampling Frequency Within Sublots

The sampling frequencies for slab thickness, concrete strength, and PI within a given 500-ft (152.4 m) sublot are described below.

Slab Thickness: A thickness measurement for each sublot is determined by taking one core through the slab at one random location in the sublot.

Concrete Strength: The concrete strength for each sublot is determined as the average of the 28-day compression tests of two replicates taken from one random batch of concrete from each sublot. Thus, the concrete strength sample size is one per sublot and the number of replicates per sample is two.

Initial Smoothness (PI): A longitudinal profile trace will be taken in each 500-ft (152.4 m) length within the wheelpaths (inside and outside wheelpaths located 3 ft [0.91 m] from the edge of the slab for conventional width lanes, or 3 ft [0.91 m] from the paint stripe for widened slabs) for each traffic lane included within the sublot. The mean PI for each 500-ft (152.4 m) section within the sublot will be computed. The number of replicates per pass location equals the number of wheelpaths per traffic lane. Smoothness measurement will terminate not less than 50 ft (15.2 m) from the bridge approach joint.

Existing Tennessee Pay Factor Curves

The existing TDOT pay factor curves are provided in chapter 5 and compared with the final PRS pay factor curves. The main difference in the curves is that there are no incentives available with the existing TDOT pay factor curves, only disincentives.

DEVELOPMENT OF PAY FACTOR CURVES USING PAVESPEC 3.0

A PRS recognizes that higher quality products have additional value; and, the PRS provides payment adjustment for this higher quality up to a maximum value. A PRS also recognizes that marginal quality products have reduced value and advocates payment reduction instead of requiring complete removal, unless the pavement is so deficient that replacement or corrective action is warranted.

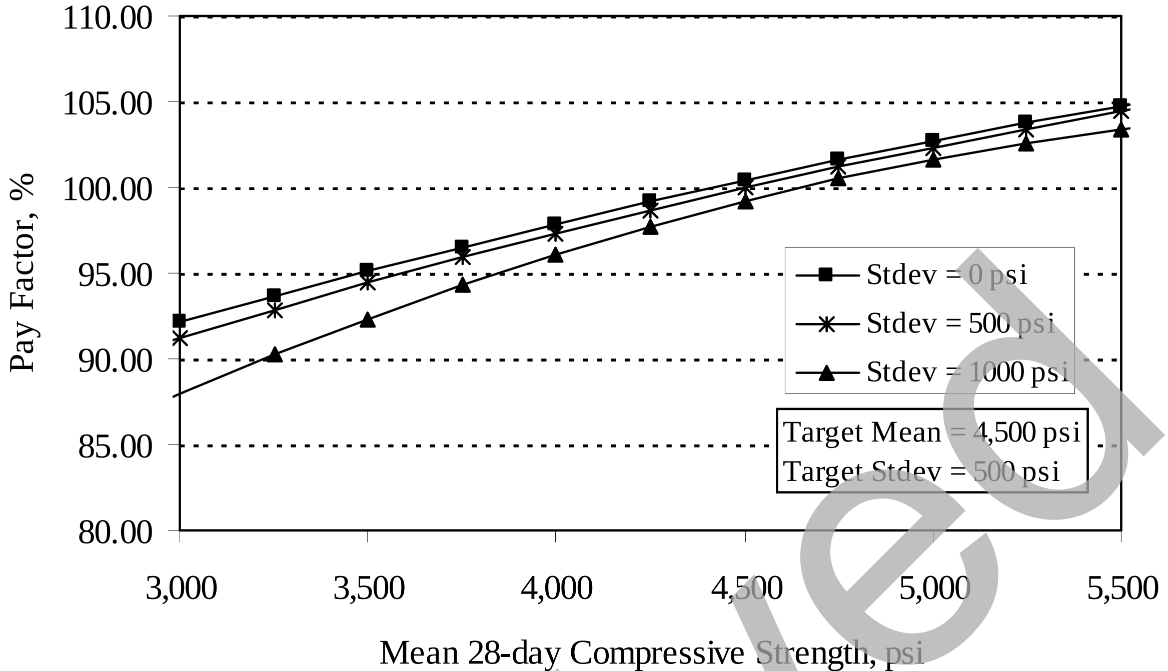
Individual Pay Adjustment Factors

Individual pay adjustment factors for slab thickness, comprehensive strength, and initial PI shall be determined using the pay factor curves shown in figures 2 through 4 or tables 9 through 11. These curves and tables were developed using the PaveSpec 3.0 software and account for the mean and standard deviation of the AQCs for the subject pavement project. Linear interpolation or extrapolation shall be used between the values shown in these tables, if needed.

Figure 2 and table 9 show that as strength increases within the specified limits, the pay factor increases due to greater resistance to fatigue cracking from repeated truck loadings, resulting in fewer cracked slabs and lower rehabilitation costs. Also, the lower the variability (as indicated by standard deviation) of strength, the higher the pay factor. This is caused by fewer slabs containing low-strength concrete.

Figure 3 and table 10 show that as slab thickness increases within the specified limits, the pay factor increases. This is due to greater resistance to fatigue cracking from repeated truck loadings, resulting in fewer cracked slabs and lower rehabilitation costs. Also, the lower the variability (as indicated by standard deviation) of thickness, the higher is the pay factor. This results from having fewer thin slabs. One very interesting item to note from figure 3 is that as the slab thickness decreases from 13 in. (330.2 mm), the loss in pay factor is not very significant within the range shown because of the very conservative thickness design used (13 in. [330.2 mm], as determined by AASHTO at high level of reliability). The slab cracking model in PRS is predicting that a reduced slab thickness to, say, 12 in. (304.8 mm) is not showing a drastic reduction in performance. For thinner pavement designs (e.g., 9 to 11 in. [228.6 to 279.4 mm]), this drop-off would be much more dramatic.

Figure 4 and table 11 show that as initial PI decreases within the specified limits, the pay factor increases. This is due to longer pavement life from better initial smoothness (smoother pavements last longer). Also, lower variability (as indicated by standard deviation) of the PI results in a higher pay factor. The cause is that fewer sublots are reaching a terminal PI level and there are lower rehabilitation costs.



1 psi = 6.89 kPa

Figure 2. Pay adjustment curve for 28-day compressive strength of concrete.

Table 9. Compressive Strength Pay Adjustment Table (PF, %)

Lot Mean, lbf/in^2**	**Lot Standard Deviation (computed using means of 2 tests)**		
	0 lbf/in^2	**500 lbf/in^2***	**1,000 lbf/in^2**
3,000	92.17	91.28	87.92
3,250	93.68	92.89	90.22
3,500	95.14	94.43	92.36
3,750	96.54	95.91	94.33
4,000	97.88	97.32	96.13
4,250	99.17	98.67	97.76
4,500*	100.41	100.00	99.23
4,750	101.58	101.18	100.52
5,000	102.71	102.33	101.65
5,250	103.78	103.42	102.62
5,500	104.79	104.45	103.41

1 lbf/in^2 = 6.89 kPa

*Targets

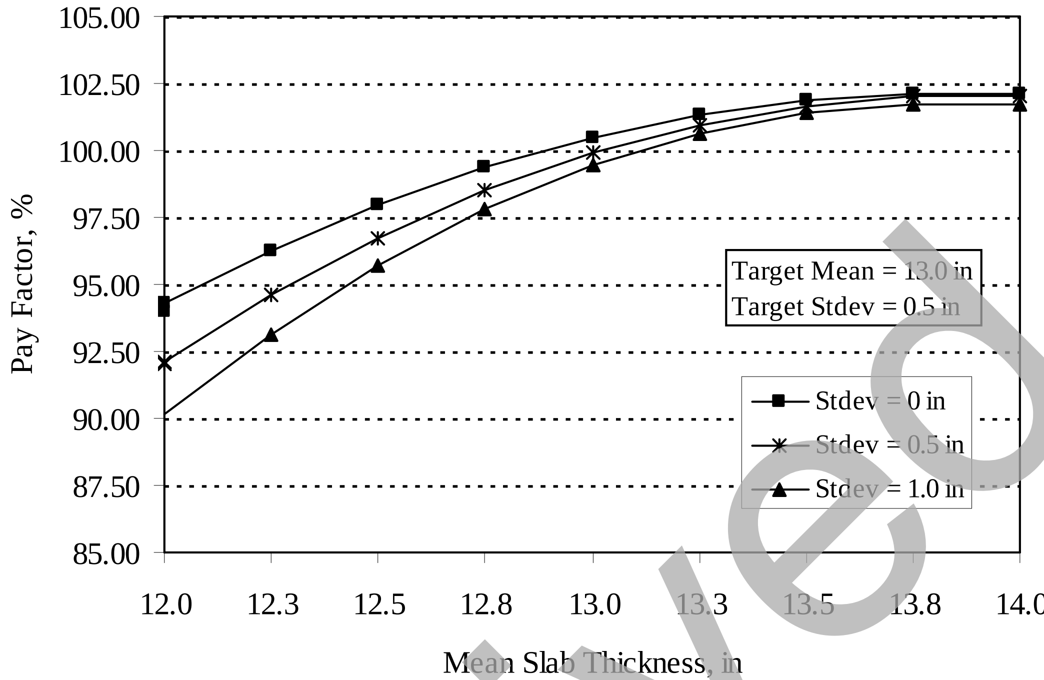
**Pay adjustment for Lot Mean less than 3,000 lbf/in^2 are as follows:

<3,000 to 2,751 lbf/in^2 = 85.00 percent

2,750 to 2,501 lbf/in^2 = 70.00 percent

2,500 to 2,251 lbf/in^2 = 50.00 percent

2,250 to 2,000 lbf/in^2 = 25.00 percent



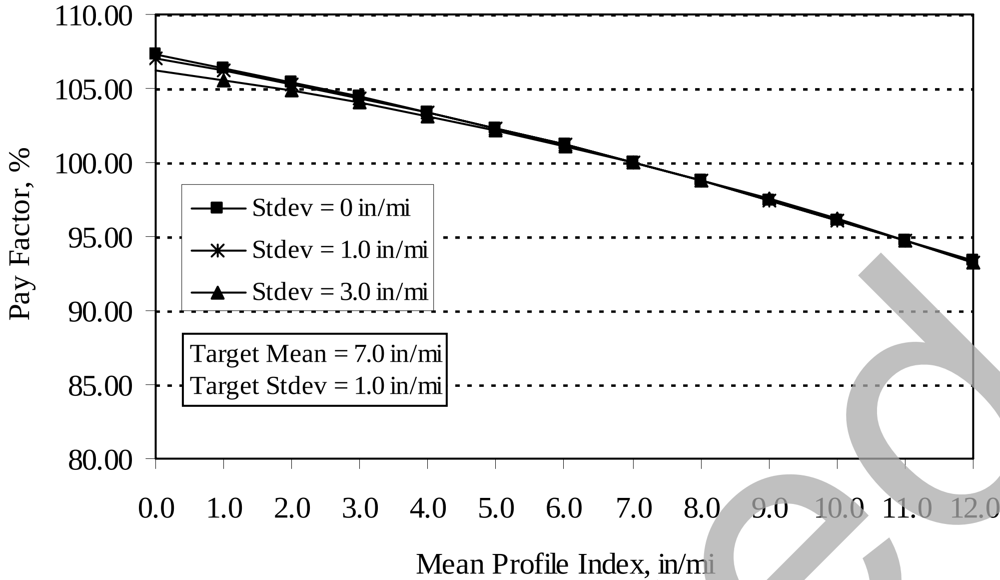
1 in. = 25.4 mm

Figure 3. Slab thickness pay adjustment curve.

Table 10. Slab Thickness Pay Adjustment Table (PF, %)

Lot Mean Slab Thickness, in.	**Lot Standard Deviation (computed from independent cores), in.**		
	0	**0.5-in.***	**1.0-in.**
12.0	94.26	92.14	90.19
12.25	96.24	94.62	93.16
12.5	97.94	96.74	95.69
12.75	99.35	98.51	97.78
13.00*	100.47	100.00	99.43
13.25	101.31	100.97	100.64
13.50	101.86	101.67	101.41
13.75	102.12	102.02	101.75
14.00	102.11	102.01	101.64

1 in. = 25.4 mm
*Targets



1 in./mi = 16 mm/km

Figure 4. Initial profile index pay adjustment curve.

Table 11. Initial Profile Index Pay Adjustment Table (PF, %)

Lot Mean Profile Index (PI), in./mi**	Lot Standard Deviation (computed using means of 2 wheelpaths' PIs per lane), in./mi		
	0	1.0 in./mi*	3.00 in./mi
0	107.29	107.02	106.26
1	106.39	106.20	105.60
2	105.44	105.32	104.86
3	104.44	104.38	104.04
4	103.39	103.38	103.15
5	102.30	102.33	102.18
6	101.16	101.21	101.13
7*	99.97	100.00	100.00
8	98.73	98.79	98.80
9	97.45	97.50	97.52
10	96.12	96.14	96.17
11	94.74	94.72	94.73
12	93.32	93.25	93.22

1 in./mi = 16 mm/km

*Targets

**Measured prior to any grinding.

***If PI is > 9 in./mi, grinding is required. The PF is determined for the PI prior to grinding for > 9 to 12 in./mi. If PI > 12 in./mi, the pay factor for 12 is used.

COMPUTATION OF AQC MEAN AND STANDARD DEVIATION

The determination of individual pay factors from figures 2 through 4 or tables 9 through 11 requires computing the mean and standard deviation of the slab thickness, compressive strength, and initial PI for the as-constructed lot based on the field testing results. These statistics are calculated as follows.

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} \quad (2)$$

Where

$\overline{X}$ = Mean of n random samples of the AQC under consideration for the lot

X_i = Sample measurement (for PI and strength, X_i is a mean of multiple replicates, and for thickness is the individual core)

n = Sample size per lot, n for each AQC is as follows:

Compressive strength: n = number of sublots (mean of two replicate cylinders produced from each batch in sublot)

Thickness: n = number of sublots (one core per sublot, no replicates)

PI: n = number of sublots multiplied by number of traffic lanes in lot (each profile test consists of measurement of a 500-ft [152.4 m] continuous wheelpath section, mean of two replicates [the two wheelpaths in each lane are considered replicates])

The lot thickness standard deviation (where number of replicates = 1) is computed as follows:

$$s = \frac{\sqrt{\dfrac{\sum (X_i - \overline{X})^2}{(n-1)}}}{C_{SD}} \quad (3)$$

The compressive strength and PI unbiased lot standard deviation (where more than one replicate per sample are used) is computed as follows.

$$s = \frac{\sqrt{\dfrac{\sum (X_i - \overline{X})^2}{(n-1)m}}}{C_{SD}} \quad (4)$$

Where

m = Number of replicates per sample, m, for compressive strength and PI are as follows:

Compressive strength: *m* = 2 replicates (i.e., two tests per batch sublot)

PI: m = 2 replicates per lane (i.e., two wheelpaths per lane) multiplied by number of lanes in lot.

C_{SD} = Correction factor (based on the total sample size, *n*) used to obtain unbiased estimates of the actual lot sample standard deviation. Appropriate C_{SD} values are determined using table 12.

Table 12. Correction Factors Used to Obtain Unbiased Estimates of the Actual Standard Deviation

Number of Samples, *n*	**Correction Factor, C_{SD}**
2	0.7979
3	0.8862
4	0.9213
5	0.9399
6	0.9515
7	0.9594
8	0.9650
9	0.9693
10	0.9726
30	0.9915

CHAPTER 4—IMPLEMENTATION OF THE PERFORMANCE-RELATED SPECIFICATION

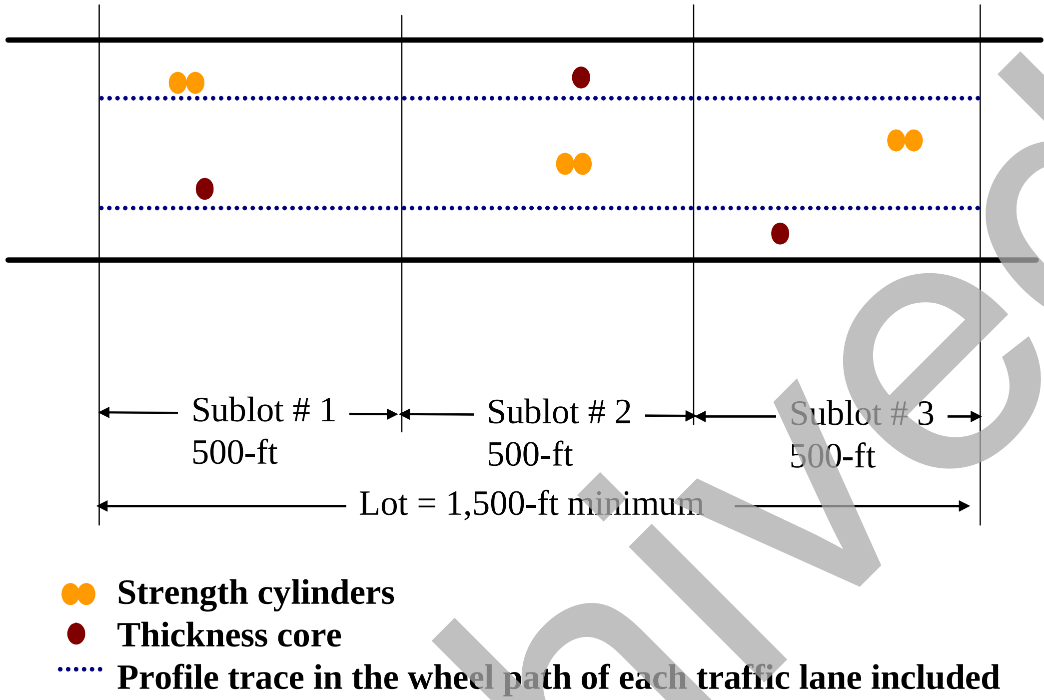
The evaluated I-65 construction work was completed between May and October 2004. It included two outside lanes in both the northbound and southbound directions. Fourteen lots (24 ft [7.3 m] wide) were placed, ranging in length from 1,180 to 2,380 ft (359.7 to 725.4 m). Photos of the PCC pavement placement are shown in figures 5 and 6.

Figure 5. General view of concrete pavement construction on northbound I-65.

Figure 6. General view of concrete pavement construction on northbound I-65.

LAYOUT OF LOTS AND SUBLOTS

The layout and sampling of typical sublots within a lot are shown in figure 7. The width of the lot is the width of paving: one, two, or more traffic lanes, typically. Sampling is random within each sublot.



1 ft = 0.3 m

Figure 7. Layout and sampling of typical sublots.

PAY ADJUSTMENT COMPUTATION EQUATIONS

The lot composite (overall) pay factor is computed as follows.

$$PF_{composite} = (PF_{PI} * PF_{strength} * PF_{thickness})/10000 \qquad (5)$$

Where

$PF_{composite}$	= Composite (overall) pay factor, %
$PF_{strength}$	= Compressive strength pay factor (obtain from table 9), %
$PF_{thickness}$	= Slab thickness pay factor (obtain from table 10), %
PF_{PI}	= Initial PI pay factor (obtain from table 11), %

Averaging of pay factors from each AQC could have also been used; however, the multiplicative model is believed to more closely approximate actual performance and LCC analysis.

The actual pay adjustment for an as-constructed lot is computed using the lot composite pay factor as follows. Pay adjustments will be made only on the individual lots.

$$PAYADJ_{Lot} = BID * AREA_{Lot} * (PF_{composite} - 100)/100 \quad (6)$$

Where

$PAYADJ_{Lot}$ = Pay increase (+) or decrease (-), $

BID = Contractor bid price for pay item (31.95, $/yd^2)

$AREA_{Lot}$ = Measured actual area of the as-constructed lot, yd^2

$PF_{composite}$ = Composite pay factor (from equation 5), percent (e.g., 101 percent is expressed as 101.0)

$$PAY_{Lot} = BID * AREA_{Lot} + PAYADJ_{Lot} \quad (7)$$

Where

PAY_{Lot} = Adjusted payment for the as-constructed lot, $

The absolute minimum value of the Composite Pay Adjustment Factor for a given lot was limited to 80 percent, and the absolute maximum value was limited to 110 percent.

TESTING AND CALCULATIONS OF PAY FACTORS

Samples were collected and tests were run, as required, for each sublot and lot. The results were recorded in a spreadsheet. The example shown in figure 8 contains results for a typical lot with four sublots. The pay factors were calculated for thickness, strength, and smoothness separately. The overall lot pay factor was then determined, and the contractor pay for the lot was calculated as shown. Results from all 14 lots are provided in appendix B.

A set of expected pay charts are provided in appendix C.

LOT INFORMATION

Lot Number	10		Project No.	
Bid Price, $/sq yd	31.95		Begin Station	535+15
Lot Length, feet	1823	Check Stations	End Station	553+38
Lot Width, feet	24		Lane No's.	4 & 5
Resulting Lot Area, sq yds	4861.33		Paving Date(s)	

THICKNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Thickness Core 1, in	12.9	12.9	13	13					
Thickness IE 1 (avg of 3), in									
Sublot Thickness, in	12.9	12.9	13	13					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in	13.0
Lot Thickness Mean, in	13.0	Lot RQL, in	12.0
Lot Thickness Mean Acceptable?	Yes	Lot MQL, in	14.0
Notes on Lot Thickness Mean:	Lot mean thickness is between RQL and MQL.		
Notes on Sublot Thickness Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9213		
Lot Thickness Std. Dev., in	0.06267		
Resulting Pay Factor:	**100.18%**		

STRENGTH

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Strength cylinder 1, psi	5,320	5,240	4,910	4,640					
Strength cylinder 2, psi	5,775	5,340	4,830	4,760					
Sublot Strength, psi	5547.5	5290	4870	4700					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, psi	4500
Replicates per lot (m)	2.0	Lot RQL, psi	3000
Lot Strength Mean, psi	5101.9	Lot MQL, psi	5500
Lot Strength Mean Acceptable?	Yes		
Notes on Lot Strength Mean:	Lot mean strength is between RQL and MQL.		
Notes on Sublot Strength Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9213		
Lot Strength Std. Dev., psi	297.00		
Resulting Pay Factor:	**102.93%**		

SMOOTHNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
PI for Pass 1, in/mi	4.22	1.9	0.9	2.1					
PI for Pass 2, in/mi	4.75	1.9	0.4	1					
PI for Pass 3, in/mi	4.75	1.7	1.1	1.5					
PI for Pass 4, in/mi	4.23	2.6	1.9	4.9					
Sublot Mean PI, in/mi	4.49	2.03	1.08	2.38					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in/mi	7.0
Replicates per lot (m)	4.0	Lot RQL, in/mi	9.0
Lot PI Mean, psi	2.1	Lot MQL, in/mi	0.0
Lot PI Mean Acceptable?	Yes		
Notes on Lot Smoothness Mean:	Lot mean smoothness is between RQL and MQL.		
Notes on Sublot Smoothness Mean:	All sublots are at or below RQL.		
Std. Dev. Correction Factor	0.9213		
Lot Smoothness Std. Dev., in/mi	0.96		
Resulting Pay Factor:	**105.19%**		

RESULTS

All Pay Factors Determined?	Yes
Equal Number of Sublots?	Yes
PF Thickness	100.18%
PF Strength	102.93%
PF Smoothness	105.19%
PF Composite	**108.46%**
Payadj (lot)	**$13,135.12**
Pay (lot)	**$168,454.72**

Figure 8. Spreadsheet used for calculating pay factors for thickness, strength, and smoothness for each sublot; overall lot pay factor; and contractor pay.

CHAPTER 5—EVALUATION OF THE PERFORMANCE-RELATED SPECIFICATION

Both a quantitative assessment (from results of the AQCs and pay factors for each lot) and qualitative assessment (from results from surveys of the contractor, TDOT staff, and QC representative) are provided in this chapter. Expected pay charts for the PRS are provided in appendix C.

QUANTITATIVE ASSESSMENT

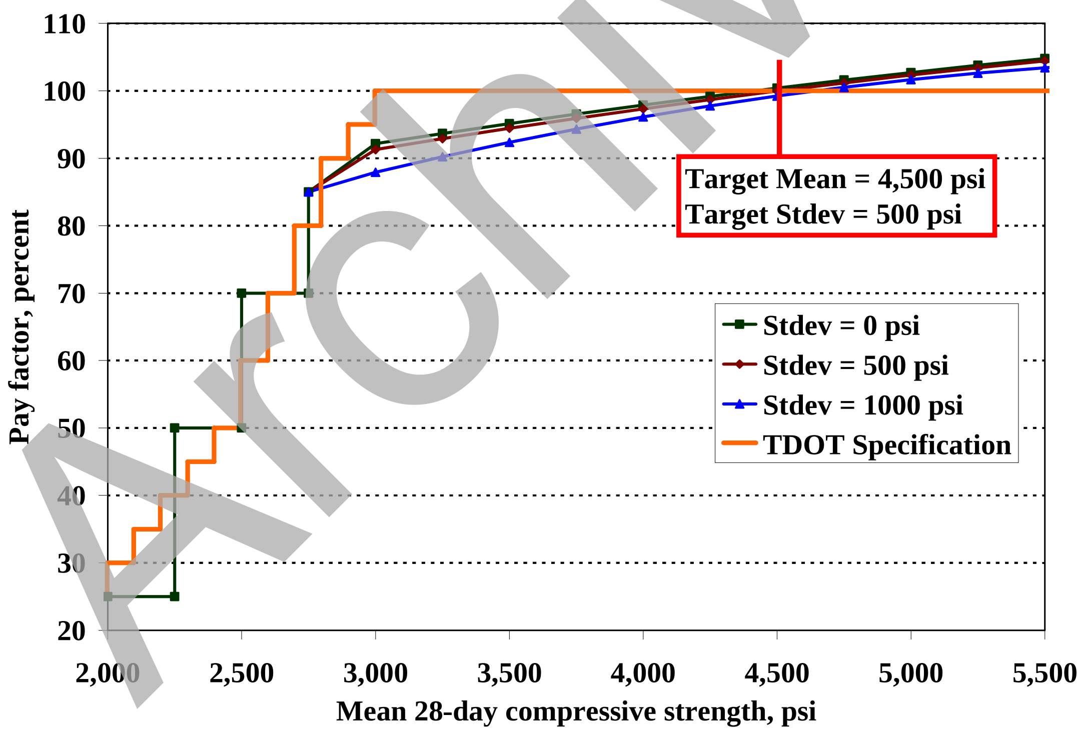
Quantitative assessments of the results achieved through use of the PRS specification can be made by comparing the final PRS pay factors and payments to those of the standard TDOT specification. Table 13 summarizes the PRS and standard TDOT quality requirements for strength, thickness, and smoothness. By design, they are similar. However, the pay factor curves for PRS are based on the expected change in LCC associated with actual variation in performance from the as-design target properties. The TDOT pay factors are based on the judgment of engineers regarding the incentives or disincentives for the contractor.

The differences in the PRS and TDOT pay factor curves for strength, thickness, and smoothness are shown in figures 9 through 11. TDOT specifications provide disincentives for below-standard quality levels. The PRS specification includes both incentives and disincentives, based on the expected level of the as-constructed quality values. In both specifications, concrete that does not develop compressive strength of 3,000 lbf/in^2 (20.68 MPa) in 28 days must either be removed and replaced or accepted at reduced pay. The TDOT standard pay factors for thickness decline significantly more than the PRS pay factors for thicknesses between 12.0 and 12.8 in. (305 and 324 mm). For thinner pavement designs (e.g., 9 to 11 in. [229 to 279 mm]), these curves might be more similar, as thickness greatly affects performance. However, as previously discussed, because of the very conservative thickness design used (as determined by AASHTO at a high level of reliability), the PRS pay factors indicate that the pavement LCC is reduced only by about 10 percent when the thickness is reduced to 12.0 in. (300 mm). The target Rainhart PI (0.1-in. [2.5 mm] blanking band) that was used for PRS specification development was 7.0 in./mi (111 mm/km). Target values used by TDOT during the project included 10 in./mi (158 mm/km), 3.5 in./mi (55 mm/km), and 7.0 in./mi (111 mm/km).

Table 13. Quality Requirements for the Performance-Related Specification (PRS) and Tennessee Department of Transportation (TDOT) Standard Method Specifications

Factor	Detail	PRS	TDOT
Strength	Test methods	AASHTO T23, T22	AASHTO T23, T22
	Lot AQC mean (std. deviation), lbf/in^2	4,500 (500)	4,000
	Lot RQL, lbf/in^2 *	3,000	3,000
	Lot MQL, lbf/in^2 **	5,500	-
Thickness	Test methods	AASHTO T 148	AASHTO T 148
	Lot AQC mean (std. deviation), in.	13.0 (0.5)	13.0
	Lot RQL, in.	12.0	12.0
	Lot MQL, in.	14.0	13.25
Smoothness	Test methods	Rainhart 0.1-in. blanking band	Rainhart 0.1-in. blanking band
	AQC mean (std. deviation), in./mi	7.0 (1.0)	10.0
	Lot RQL, in./mi	9.0	10.0
	Lot MQL, in./mi	0.0	0.0

AQC = acceptable quality characteristic; 1 lbf/in.^{2} = 6.89 kPa; 1 in. = 25.4 mm; 1 in./mi = 16 mm/km.
* RQL (rejectable quality limit)—Agency-chosen minimum limit for acceptable AQC specimen sample quality.
** MQL (maximum quality limit)—Agency-chosen maximum limit for acceptable AQC specimen sample quality.



1 psi = 6.89 kPa

Figure 9. Comparison of Performance-Related Specification and Tennessee Department of Transportation (TDOT) strength specifications.

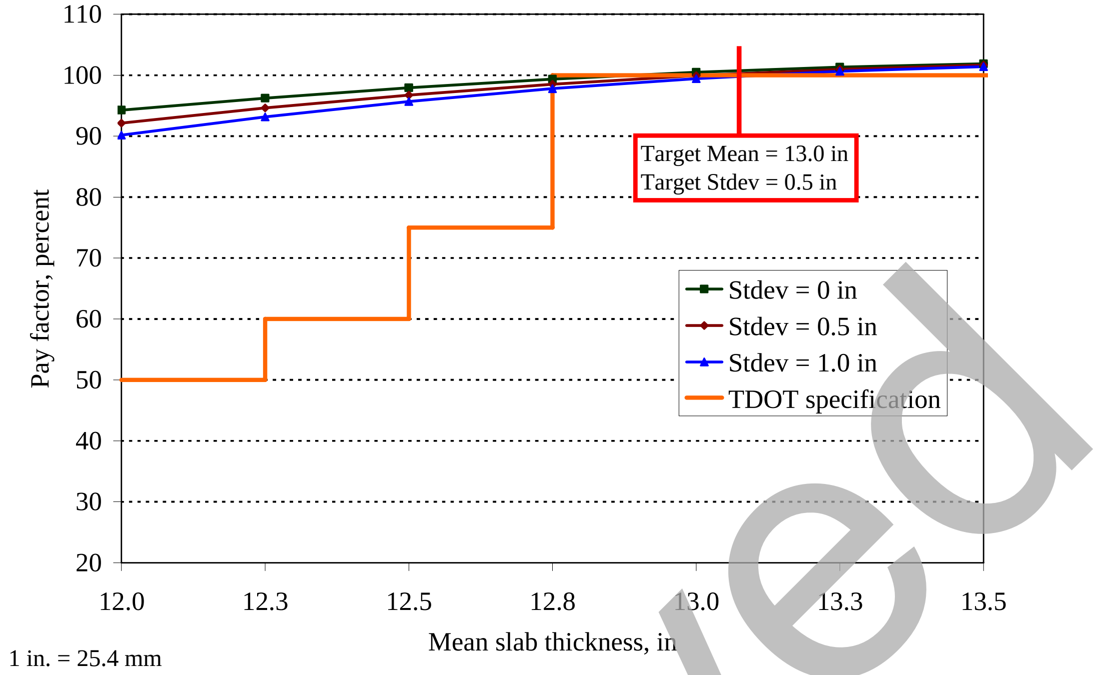


Figure 10. Comparison of Performance-Related Specification and Tennessee Department of Transportation (TDOT) thickness specifications.

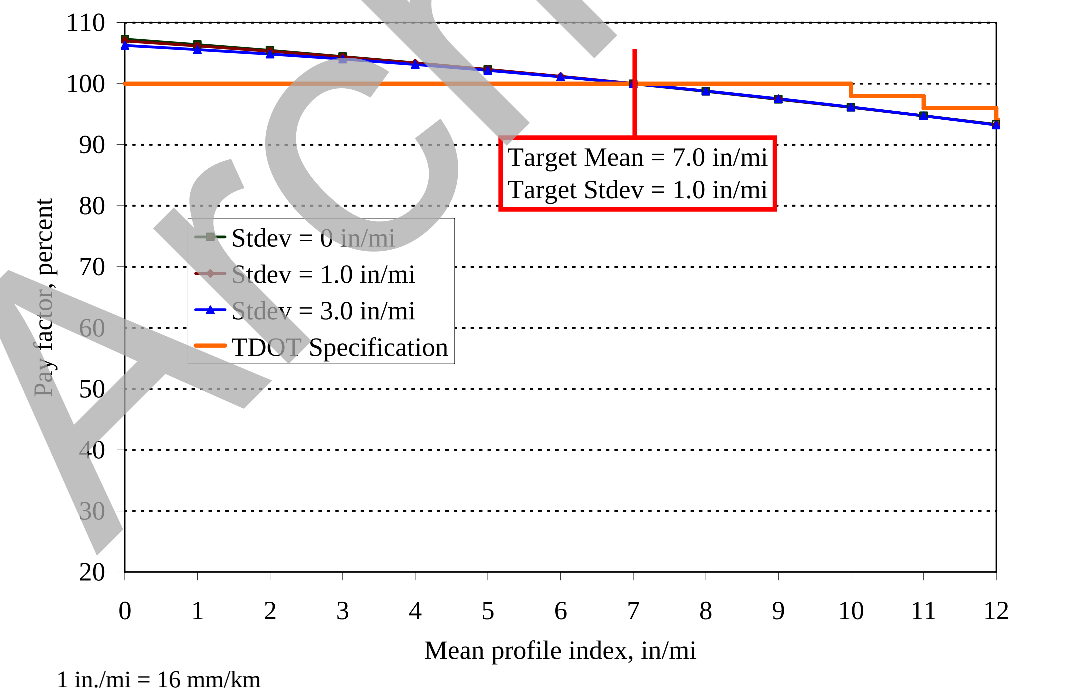


Figure 11. Comparison of Performance-Related Specification and Tennessee Department of Transportation (TDOT) smoothness specifications.

PRS pay factors for the as-constructed northbound and southbound lane lots indicate that the pavement in both directions was constructed to a quality above the design level. Lot quality levels and pay factors for strength, thickness, and smoothness in the northbound lane are shown in table 14. Table 15 includes the quality levels and pay factors for the southbound lanes.

Table 14. PRS Lot Quality and Pay Factors (PF) for the Northbound Lanes

		Northbound Lot Number					
Item	**Target**	**1**	**2**	**3**	**4**	**5**	**6**
Sample Units		3	4	4	4	3	5
Thick (mean), in	13.0	13.4	13.3	13.6	13.3	13.1	13.1
Thick (st. dev)	0.50	0.17	0.05	0.00	0.09	0.59	0.06
Thick PF (%)	**100.00**	**101.63**	**101.44**	**101.96**	**101.37**	**100.31**	**100.89**
Strength (mean), lbf/in^2	4500	5177	5366	5321	4885	5292	5485
Strength (st. dev), lbf/in^2	500	300	205	74	153	274	240
Strength PF (%)	**100.00**	**103.25**	**104.1**	**104.2**	**102.07**	**103.76**	**104.57**
Profile (mean), in/mi	7.0	5.5	3.5	5.0	8.9	5.8	5.2
Profile (st. dev), in./mi	1.0	0.48	1.14	0.94	1.09	0.53	0.34
Profile PF (%)	**100.00**	**101.71**	**103.87**	**102.38**	**97.62**	**101.46**	**102.04**
Lot PF (%)	**100.00**	**106.73**	**109.7**	**108.58**	**101.00**	**105.60**	**107.65**

Table 15. Performance-Related Specification Lot Quality and Pay Factors (PF) for the Southbound Lanes

		Southbound Lot Number							
Item	**Target**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Sample Units		3	5	5	4	4	4	4	3
Thick (mean), in.	13.0	13.0	12.9	13.1	13.0	13.1	12.9	12.9	12.9
Thick (st. dev)	0.50	0.065	0.20	0.048	0.063	0.063	0.311	0.140	0.363
Thick PF (%)	**100.00**	**100.52**	**99.87**	**100.70**	**100.18**	**100.58**	**99.50**	**99.60**	**99.39**
Strength (mean), lbf/in^2	4500	4676.7	4411.0	4766.5	5101.9	4761.3	4573.1	4631.3	5100.0
Strength (st. dev), lbf/in^2	500	531.81	83.53	166.02	297.00	72.30	415.64	89.36	267.3
Strength PF (%)	**100.00**	**100.79**	**99.89**	**101.52**	**102.93**	**101.57**	**100.41**	**100.95**	**102.94**
Profile (mean), in./mi	7.0	3.7	4.9	4.5	2.1	3.2	3.5	3.1	3.8
Profile (st. dev), in./mi	1.0	0.34	0.63	0.65	0.96	1.07	0.36	0.25	0.17
Profile PF (%)	**100.00**	**103.75**	**102.38**	**102.81**	**105.19**	**104.13**	**103.92**	**104.36**	**103.59**
Lot PF (%)	**100.00**	**105.11**	**102.14**	**105.11**	**108.46**	**106.39**	**103.83**	**104.93**	**105.98**

A closer look at the values and pay factors provides additional insight. There appears to have been a dialing down by the contractor of the strength and thickness mean values as the project progressed from lot 1 to lot 14. Figures 12 and 13 both indicate this trend of the contractor beginning the project with conservative properties. Pay factors for both of these items also decreased as the project progressed.

Another interesting aspect is that the contractor reported that grade control for the northbound lots was accomplished using the adjacent pavement. In the southbound lanes, stringlines and better subbase grade control were used. The results are evident in figure 14, which shows reduction in both the average PI values and a trend toward reduced variability within the lots in the southbound lanes.

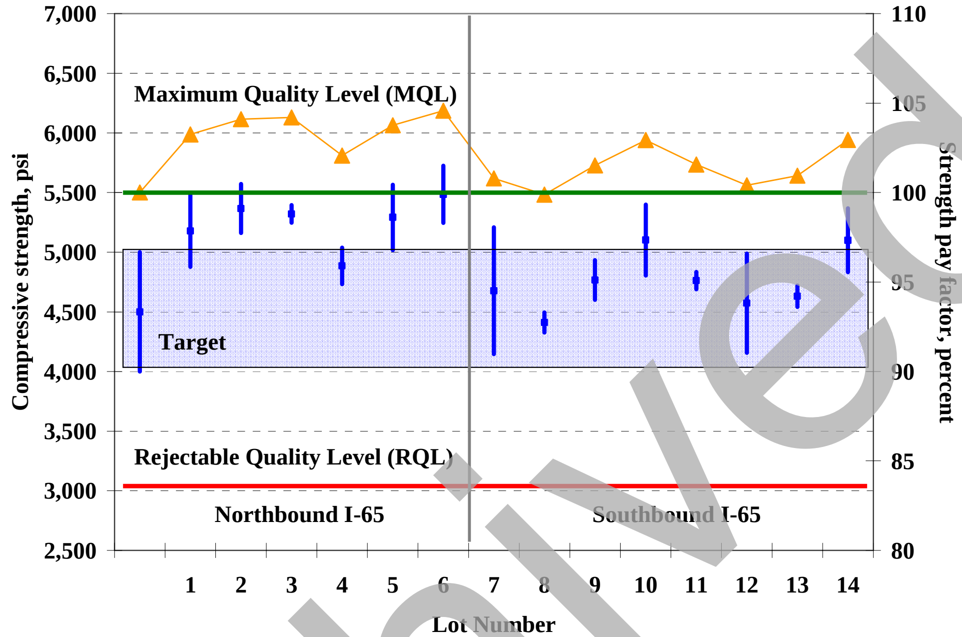


Figure 12. Comparison of Performance-Related Specification strength specifications and results.

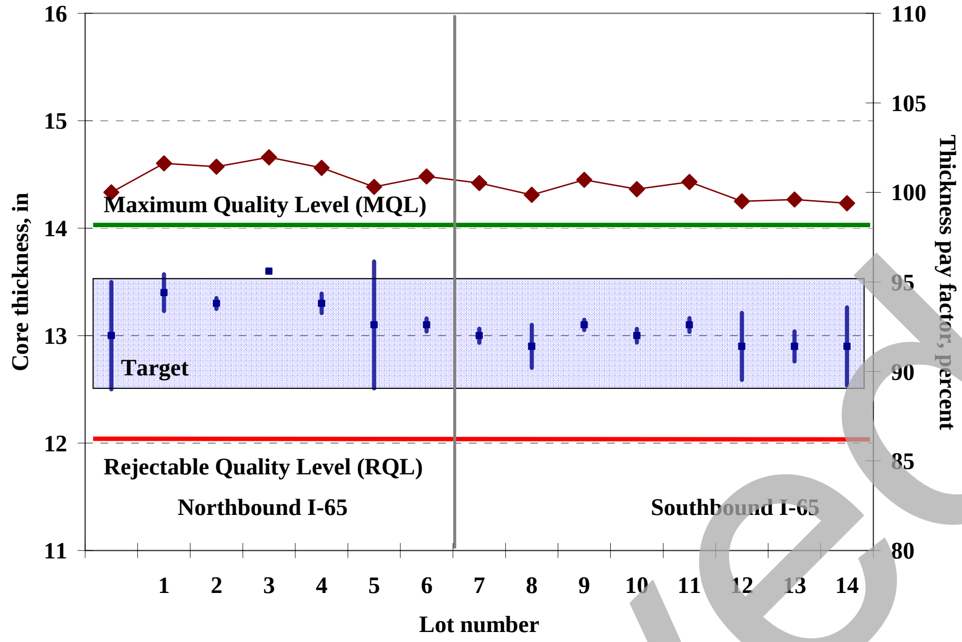


Figure 13. Comparison of Performance-Related Specification thickness specifications and results.

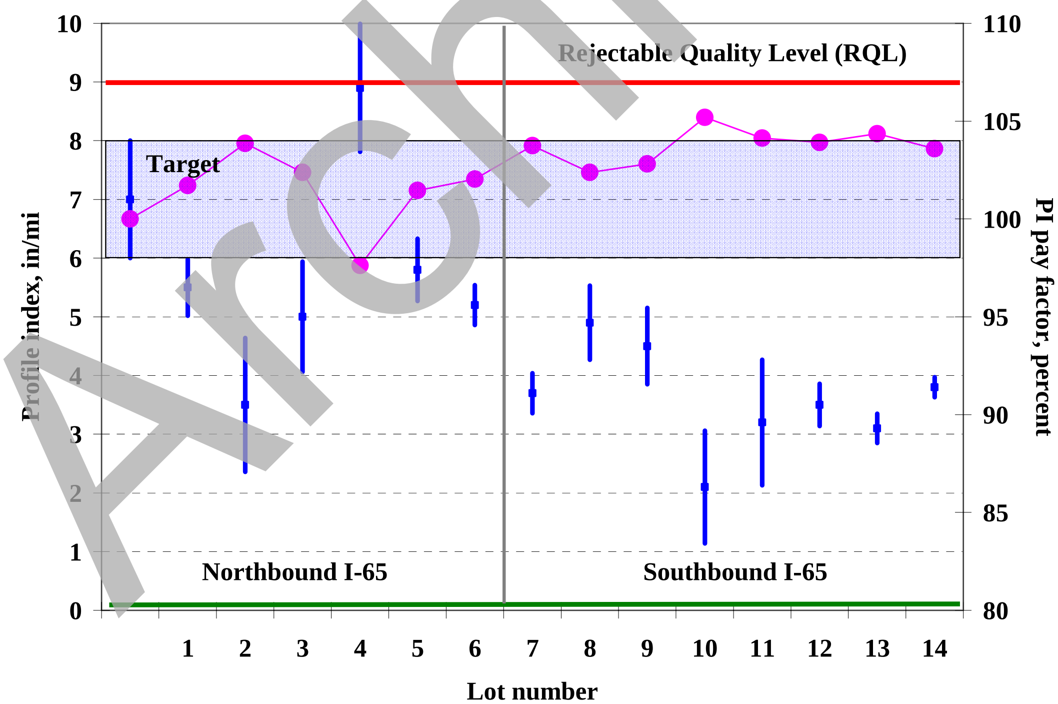


Figure 14. Comparison of PRS smoothness specifications and results.

Figure 15 shows a summary of the PRS pay factors for each of the 14 lots used in the analysis. It also includes an overall pay factor, which averages 106.5 percent for the northbound lots and 105.2 percent for the southbound lots. High strength and thickness levels are the primary cause of increased pay factors in the northbound lanes. Although these values were reduced in the southbound lanes, the smoothness values increased, offsetting most of the pay factor reduction from strength and thickness.

COMPARISON WITH EXISTING TDOT PAY FACTOR CURVES

The PRS pay factor curves provide for incentives and disincentives for strength, thickness, and profile. The PRS curves are based on economic analysis of LCC, indicating that there will be changes in pavement performance depending on the level of quality achieved during construction of these three acceptance quality characteristics. It is believed that the PRS pay factor curves will provide the contractor with more opportunity to achieve incentive pay and to avoid disincentives, thereby providing a pavement with a longer life and lower LCC.

A comparison of TDOT with PRS pay factors using data from each lot separately shows that the TDOT specification would provide 100 percent of the bid price. The PRS would provide for a positive incentive on the order of 106 percent.

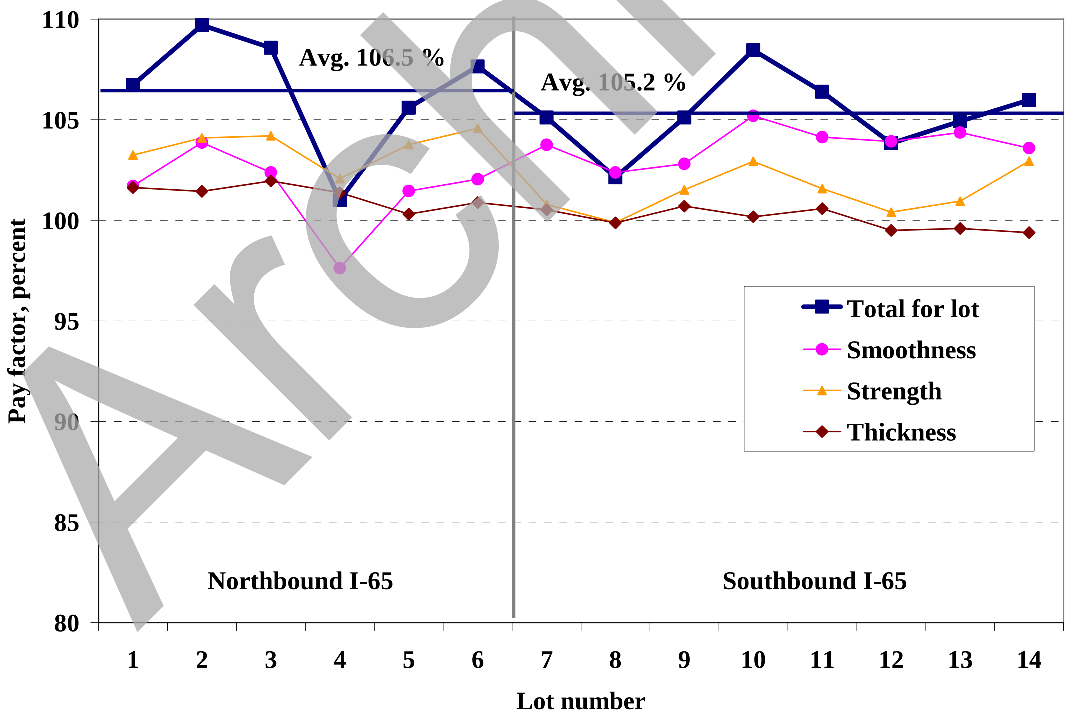


Figure 15. Summary of performance-related specification pay factor results.

IMPACT OF QUALITY ON PAVEMENT LIFE

The result of the PRS was that the contractor would receive an average of 106 percent incentive pay for higher quality construction of all 14 lots. As was shown, this was due to PCC strength, PCC slab thickness, and initial PI being of general higher quality than the specified target values. The mean values were as shown in table 16 for comparison. The standard deviations of most of the AQCs were also of higher quality than the target values.

Table 16. Target and As-built Acceptance Quality Character Values

Acceptance Quality Characteristic	**Target**	**As-Built**
PCC compressive strength, lbf/in^2	4,500	4,967
PCC slab thickness, in.	13.0	13.1
Profile Index (Rainhart 0.1-in. blanking band), in./mi	7.0	4.5

1 lbf/in^2 = 6.89 kPa; 1 in. = 25.4 mm; 1/in./mi = 16 mm/km

In assessing benefits of the PRS, the following could be asked: will a 6 percent increase in construction cost due to higher quality result in a similar or greater increase in pavement life? This question was addressed using an independent method to predict pavement life for both the target and the as-built lot mean AQCs. The NCHRP 1-37A mechanistic-empirical pavement design and analysis software was used to predict the performance of the target (or as-designed) and the as-built JPCP.[(10)] The distress and smoothness models were nationally calibrated under NCHRP 1-37A and should be reasonably applicable to the Nashville, Tennessee, area. All inputs were estimated and the program run to provide an estimate of the target and as-built pavements expected life. The program predicts three main performance characteristics: slab cracking, joint faulting, and IRI and terminal levels of each were selected at which rehabilitation would be needed.

Results showed that the expected life of the target pavement turned out to be in excess of 50 years, which was due to the conservatism in the design. The expected life of the as-constructed lots was even longer, approximately 14 percent longer. Over the long predicted pavement life the IRI was the controlling factor (very low amounts of cracking and joint faulting were predicted) but eventually the pavements roughness increased. Therefore, for an increase in initial cost of 6 percent (from the positive quality incentives), an even greater percentage (over twice) increase in pavement life was achieved.

QUALITATIVE ASSESSMENT

A meeting was held at the end of construction to obtain responses by the contractor, the QC consultant, and TDOT staff regarding the PRS implementation project. During the meeting, the results from the project were presented and explained, and questions were addressed. Then survey forms were provided to the contractors, the construction QC representatives, and TDOT personnel who participated in the PRS implementation. Included in the survey were questions assessing the functionality of the PRS, any related problems encountered in the process, and changes that were made in response to the PRS. Results of general questions are summarized in table 17, which indicates that the PRS documents were adequate, the PRS concept is desirable, and PRS implementation was not difficult. Additional detailed questions were asked of the contractors, QC managers, and TDOT personnel. Their responses are provided in the following sections.

Table 17. General Survey Responses

No.	Question	Contractors			Quality Control Representatives			TDOT		
		Yes	Maybe	No	Yes	Maybe	No	Yes	Maybe	No
1	Do you think the responsibilities and roles of the contractors and TDOT are well defined in the PRS document?	1	2		1	1		3	1	
2	Do you think PRS (including the incentives) would improve the quality of concrete pavements in Tennessee?	3			3			3	1	
3	Do you think that the PRS testing and sampling plan can lead to more accurate measurement of the quality of TDOT PCC pavements?	3			3			2	2	
4	Did you think that the PRS process was complicated and difficult?			2			3		1	3
5	Would you like to see PRS implemented on more Tennessee PCC pavement projects?	2	1		3			3	1	

PRS = performance-related specification; TDOT = Tennessee Department of Transportation

Contractor Assessment

Surveys were completed with representatives of the prime contractor (LoJac, Inc.) and the paving contractor (APAC, Inc.). Their responses are shown in the following tables.

6. What average cumulative pay factor did you expect to receive for the PRS sections prior to construction?

Pay Factor, %	Reason for this estimate
108 to 112	Money saved for future construction, jobs are different.
105 to 108	Reasonable pay for additional control.
108	

7. Was the pay factor you received worth the effort you spent achieving it?

Yes	Maybe	No	Comments and suggestions
☐	☒	☐	Could include more pay factors like permeable base.
☒	☐	☐	Incentive promotes quality from the contractor.

8. **What problems did you see or encounter in preparing for and constructing the I-65 PRS sections?**

Problem encountered in:	Description and suggestions
Discussing the PRS specification with TDOT	OK.
Understanding the PRS specification	OK.
Adjusting processes to meet the PRS specification	OK.
Preparing subgrade and base	Involved extra work to control grades.
Setting grade stakes and string lines	Need strandline for permeable base.
Placing and finishing the concrete surface	OK.
Sampling and testing for strength, thickness, and smoothness	Need faster turnaround on results.
Understanding the PRS pay factors	OK.
Resolving any conflicts related to PRS	Everyone willing to discuss.
Other related activities	None.

9. **What changes did you make or in the design and construction process to avoid penalties or receive bonuses under the PRS?**

Activities affected:	Description of any changes
Mix design	
Subgrade and base preparation	(1) Yes. (2) Better control.
Grade stakes and stringlines	(1) Yes. (2) Used more often.
PCC batch mixing	
PCC hauling to paver	
PCC transfer to paver	
Paving machine type and setup	
PCC placement methods	
Pavement surface finishing	
Pavement curing	
Surface grinding	

10. What changes might you make in the design and construction process under similar PRS projects?

Possible changes:	Description of any changes
1. Mix design	Add over design factor in initial mix design.
2. Subgrade and base	(1) Monitor and maintain a smooth, consistent subgrade. (2) Better control of base.
3. Grade stakes and stringlines	Use wire for stringline. Base and paving contractor use the same stringline.
4. PCC batch mixing	Monitor mix for consistency.
4. PCC placement methods	Use a spreader in the paving train.

Other comments that were received included the following:

- PRS "rewards contractor for exceeding product requested." "Incentive promotes quality control."
- More accurate quality measurements can be achieved because PRS "relates actual product back to anticipated [design] product."
- PRS "promotes quality end product. Promotes payment for actual product received."
- The pay factor would have been worth the effort spent achieving it. "Incentive promotes quality from contractors."
- PRS provides "better pay for better work."
- "Need faster answers on test results."
- "Need more tests per sublot."
- "Incentives good—procurement process."
- PRS "eliminates low quality contractors."
- "Immediate feedback – yes!"
- Contractor started strength high in the first 2 weeks of northbound paving and adjusted down to optimal strength in the southbound paving.
- Contractors need 5 to 10 percent incentive to provide enough incentive for the necessary changes in construction processes.
- If the incentive is greater than 10 percent, the target should be reset.

- A smoothness specification for the permeable base would be helpful.

- "There was more grade variability in the northbound sections. This affects smoothness and thickness."

- Northbound paving matched the existing PCC grade line. Southbound paving was tied to a stringline.

Construction QC Contractor Assessment

Surveys were received from the QC contractor, Florence & Hutcheson, Inc. of Nashville, Tennessee. Their comments are included in the following tables.

6. What problems did you see or encounter in developing or implementing the I-65 performance related specification?

Problem encountered in:	**Descriptions and suggestions**
Collecting data for PRS input	(1) None.
Selecting pay factor limits	(1) Some judgment and subjectivity involved.
Introducing PRS to contractors	(1) I think they are receptive.
Completing the PRS sampling	(1) Based on square yards rather than lineal feet. Smoothness is fixed.
Completing the PRS testing	(1) None.
Determining the PRS pay factor values	(1) None.
Informing contractors of bonus or penalty values	(1) None, they know what is required up front.
Resolving conflicts over payments	(1) None, they know what is required up front.
Other PRS activities	(1) (2) Subgrade and permeable base grades.

7. What other possible problems do you foresee in future performance related specification use?

Potential problems	Descriptions and suggestions
1. Grades	TDOT needs to tighten specifications for subgrade and permeable base (elevations).

These engineers also provided several additional comments:

- No real problems were encountered in CE1 services.

- PRS "would most likely reduce variability, thus increasing quality."

- PRS can provide more accurate quality measurements because “with reduced variability, actual test results are more realistic of actual pavement.”

- “From testing and inspection viewpoint, don’t think any more complicated than current specifications.”

- “Testing frequency is affected too much by pavement width; 24 ft versus 12 ft doubles testing.”

- “Incentive versus disincentive should result in a better product.”

- “Contractors can ‘go for’ an incentive rather [than] just focusing on not getting hit with a penalty, resulting in a higher quality of pavement.”

- “The same data is obtained in the previous specification. More compilation of the data is required, but once the TDOT office is familiar with the software, it should not be complicated or lengthy.”

TDOT Assessment

TDOT engineers who had participated in the design, implementation, and management of the PRS project responded to the survey and followup interviews with generally positive responses. Following are their responses:

6. What problems did you see or encounter in developing or implementing the I-65 performance-related specification (PRS)?

Problem encountered in:	Descriptions and suggestions
Collecting data for PRS input	(1) Smoothness data (for instance) was difficult to obtain in short sections. Road profiler was used. (3) It would have been very beneficial to use the impact echo device (for slab thickness).
Selecting pay factor limits	(1) Wanted to be fair with contractor and State so pay limits should reward appropriately. (2) How low do you go, or how high?
Introducing PRS to contractors	(1) The contractors seemed interested and helpful because of the potential plus incentives. (2) I think it is important to show that incentives can be earned by using ‘everyday’ practices.
Completing the PRS sampling	(1) This was a little difficult because it required additional samples to be taken. (2) I think it was good to define the sublot stationing up front, so that sampling could be easily tracked. (3) It’s hard to tell the contractor that we want to take 3 cores in their new pavement every 1,500 ft (e.g., 1 per 500 ft).

Problem encountered in:	Descriptions and suggestions
Completing the PRS testing	(2) Somewhat problematic with relating smoothness lengths to cubic yards.
Determining the PRS pay factor values	(2) Spreadsheet very good (for summarizing data and computing pay factors).
Informing contractors of bonus or penalty values	
Resolving conflicts over payments	
Other PRS activities	(2) Increased sampling and testing leads to increase in field personnel responsibilities. This could be an issue in an understaffed office.

7. What other possible problems do you foresee in future performance related specification use?

Potential problems	Descriptions and suggestions
1. Payment deduction issues	If a penalty is levied by the data, concrete contractor will possibly look to place blame on permeable base and/or grading contractors.
2. Sublot/lot size	If two lanes paving 500-ft sublot—good. If single lane, then two times as much testing.

Additional comments provided by TDOT engineers included the following:

- "I think it [PRS] leads to elimination of less-quality-oriented contractors."
- "The number of tests could be questionable in being accurate."
- "Compared to the discussion of all other specifications we deal with, the process was more straightforward and not as much time spent in discussion."
- "I like the direction it [PRS] takes us."
- "I see the contractor giving us a more concentrated effort to increase the quality of the product he produces."
- PRS "allows greater pay for better materials and quality of construction."
- "Since being involved with the process, it was not complicated. However, those who were not involved during the process may have seen it as complicated."

- "This trial shows that using everyday practices can lead to incentives, provided a quality, consistent approach is used."

- "Ultimately it [quality] is up to the contractor and how well they build the road. I think it [PRS] gives the contractor a reason to work harder and do better."

Suggestions to Improve PRS for Concrete Pavement

Several suggestions for improvement of the specification and methodology can be gleaned from these comments:

- Consider aiming for 10 percent maximum incentive. If this is exceeded, consider changing the specified requirements (e.g., modifying the AQC target values).

- Consider tightening subgrade and subbase grade requirements, encouraging contractors to better control these elevations, or adding incentives.

- Provide a mechanism for contractor to have PRS pay factor results quickly. More rapid testing would be one solution, such as a reduction in coring by use of alternative method to determine slab thickness (possibly the Wisconsin method of probing the plastic concrete).

- Reconsider the required increased testing when paving width is one 12-ft lane rather than the normal two or three.

- Adjust smoothness-sampling lengths or modify smoothness data analysis method to easily report PI for short lengths.

- Consider methods for increasing the sampling rate and reducing the amount of destructive testing (this comment likely refers to coring to determine slab thickness).

CHAPTER 6—SUMMARY AND RECOMMENDATIONS

SUMMARY

This trial implementation of a PRS on I-65 in Nashville, Tennessee, was sponsored by the FHWA in full cooperation and assistance by TDOT. The trial implementation has provided TDOT and the contracting industry with an understanding of the PRS development and implementation process and results achieved. It also has provided useful information for developing future PRS projects by TDOT and other agencies.

The researchers, FHWA research contract manager, and TDOT staff made significant efforts in advance of the implementation to develop a practical and effective PRS. Valuable input from the contractor staff was also received. Three AQCs were selected for consideration in the PRS: PCC strength, slab thickness, and smoothness (or PI). Acceptance levels that were selected for these characteristics are shown in table 2. Inputs listed in chapter 3 were used to develop pay factor curves using the PaveSpec 3.0 software available from the FHWA. These pay factor curves were based on economic justification, not opinion as to the impact of changes in AQCs on a project. A detailed but practical plan for field sampling and testing was prepared. The PRS is included in appendix A.

The I-65 PCC paving used to test the PRS was completed between May and October in 2004. Time limitations required that the PRS be applied first to the northbound lanes as a shadow specification, requiring field sampling according to both standard TDOT and PRS formats. The PRS was to be applied formally to the southbound lane paving, but factors unrelated to the PRS precluded this opportunity. The southbound lanes were then constructed according to TDOT specifications, but the strength, thickness, and smoothness data were taken such that they could be readily converted to the PRS sublots and sampling methods. The results of 14 lots were obtained from the northbound and southbound paved lanes, and these data were analyzed using the PRS procedure. Pay factors were determined for all lots and summarized in tables and graphs.

The average pay factor was 106 percent for the project, which indicates that the contractor exceeded the target quality significantly. To determine the impact of exceeding targets on performance independently of the PaveSpec models, the new Mechanistic–Empirical Design Guide program was used as developed under NCHRP 1-37A.[10] This procedure predicts joint faulting, slab cracking, and IRI over time for a given set of inputs for JPCP. All inputs associated with the target JPCP (target strength, thickness, and smoothness) were used to predict the life of the pavement. Then all inputs associated with the as-built (average as-built strength, thickness, and smoothness) were input and used to predict the life of the pavement. The as-built JPCP showed a 14 percent longer life (due to the higher quality AQCs) than the target JPCP. Thus, for the additional 6 percent invested in incentives at construction, the pavement life is expected to increase approximately 14 percent, which is a significant benefit.

At a meeting held after construction of the north- and southbound lanes, the results from the PRS were presented and discussed. Many interesting comments were received from the contractors, QC representatives, and TDOT staff involved. Comments (provided in chapter 5) indicated that all three groups were very supportive of the PRS approach. A few representative comments from each group are provided below:

- Contractor:
    - PRS "rewards contractor for exceeding product requested." "Incentive promotes quality control."
    - More accurate quality measurements can be achieved because PRS "relates actual product back to anticipated [design] product."
    - PRS "promotes quality end product. Promotes payment for actual product received."
    - "Need faster answers on test results."
    - "Need more tests per sublot."
- Tennessee DOT:
    - "I think it [PRS] leads to elimination of less-quality-oriented contractors."
    - "I like the direction it [PRS] takes us."
    - "I see the contractor giving us a more concentrated effort to increase the quality of the product he produces."
    - PRS "allows greater pay for better materials and quality of construction."
    - "Ultimately it [quality] is up to the contractor and how well they build the road. I think it [PRS] gives the contractor a reason to work harder and do better."
- QC representative:
    - PRS "would most likely reduce variability, thus increasing quality."
    - PRS can provide more accurate quality measurements because "with reduced variability, actual test results are more realistic of actual pavement."
    - "From testing and inspection viewpoint, don't think any more complicated than current specifications."

This project provides strong support for the concept that a PRS that considers those AQCs that relate directly to performance and are under the control of the contractor is practical and can produce a win–win situation for the contractor and the highway agency.

RECOMMENDATIONS

The trial PRS worked very well on this major I-65 project, and all parties appeared to be supportive of constructing future projects fully under PRS. Some key recommendations are provided as follows:

- Carefully define lots and sublots (extremely important).
    - Must define lots and sublots very carefully to meet the technical requirements of the PRS. This includes clear definition of the sublots and the sampling of all AQCs from each sublot, which are then used to compute the means and standard deviations for the lots and, finally, the cost pay factor.
    - Must also allow for flexibility of unusual situations in the field, such as partial sublots and lots.
    - The definitions of lots and sublots developed for I-65 appeared to meet technical requirements and to be practical in the field.
- Carefully select target means and standard deviations of AQCs.
    - Carefully consider these selections so that the level of quality for the project is as desired by the owning agency at the 100 percent pay level.
    - Determine if the agency wishes to increase the quality level, decrease the quality level, or specify a quality level similar to previous contracts that performed well. Given the typical incentive level provided by the economic analysis, the level of quality will likely increase over that of previous projects.
- Carefully consider impacts of pay factor curves derived using PaveSpec on the highway agency and the contractor.
    - The incentives and disincentives must be sufficient to cause the contractor to take actions to consider appropriate AQC targets, but not too large to cause management and political concerns. (Comments indicated that 10 percent was the maximum needed, and if this is exceeded, a change in the specified requirements should be considered.)
    - Limits must be placed on each AQC above which no further incentive is paid (MQL) and below which the lot acceptance is decided through other means than pay reduction (RQL). These limits are absolutely essential to avoid problems.
    - A small percentage of user cost is needed in the PRS. The level used to develop the PRS pay factor curves was 2 percent. If this is not included, the smoothness curve can be very flat when a conservative JPCP design is used.
    - Some practical adjustment may be needed in some of the theoretical, economic-based, pay factor curves to meet the desires of the highway agency.
- Consider tightening subgrade and subbase grade requirements, and encourage contractors to better control and monitor these elevations and profiles. The southbound lanes, paved with stringline, were much smoother than the northbound lanes, where the existing

pavement was used as the paving guide. The northbound PI was 5.65 in./mi (88.45 mm/km) versus 3.6 in./mi (56.80 mm/km) in the southbound lanes, indicating a 36 percent reduction was achieved using stringline.

- Provide a methodology to measure PRS pay factor results quickly. More rapid and nondestructive testing for slab thickness would be one solution. Note that Tennessee had done some significant research into using the impact echo procedure for slab thickness, and this procedure was further tested on this project. (However, it was not used in the official measurements of thickness due to problems in identifying the boundary with the permeable asphalt base.) Another technique is used successfully in Wisconsin: a thin metal circular plate is placed on the top of the base, and a probe is inserted into the plastic concrete to determine thickness.
- Adjust smoothness sampling lengths or modify smoothness data analysis method to easily report PI for short lengths.
- Consider methods for increasing the sampling rate and reducing the amount of destructive testing such as the coring for slab thickness measurement.

BENEFITS OF PERFORMANCE-RELATED SPECIFICATION

The clear and rational approach of PRS, with well-defined quality levels that are understandable to the contractor, are expected to lead to significantly improved highway construction quality, improved pavement performance, and a reduction in LCC. The full possibility of PRS may also offer the opportunity to optimize the design and construction process to provide acceptable performance for lower LCCs. Key benefits of PRS are listed below, some of which were demonstrated on this I-65 project:

- Better linkage between design and construction. The very conservative design of I-65 was evident in relatively flat pay factor curve for thickness.
- Higher quality pavements (through incentives). The overall pay factor was 106 percent, which indicates a significantly higher quality level of construction. The true effect of lower variability (all AQCs had lower standard deviations than the target) may also have benefits that are not known at this time.
- Testing that focuses on key quality characteristics that relate to the pavement's long-term performance. Any factor that is measured and paid by incentive will receive a lot of attention and focus on the project. Other AQCs such as dowel alignment, tie bar alignment, and consolidation around dowels, would add to the comprehensiveness of a PRS project and avoid a disastrous situation where something (such as tie bar location) is not measured until well into the project only to discover that it is out of specifications.
- Incentives and disincentives that are justified through reduction or increase in future LCC. The PaveSpec program provided reasonable pay factors for I-65. An independent estimate of increased life of approximately 14 percent represents a very significant benefit to highway users.

- Specifications that give the contractors more responsibility and flexibility yet increased accountability may benefit both the contractor and owner. Additional full PRS projects are needed to prove this possibility.
- Allow contractors to be more innovative and more competitive.
- Both the contractor and State staff felt that PRS may lead to the elimination of less-quality-oriented contractors.

• PRS may provide a lower “fear factor” for contractors and less administrative complexity and work over the long term for the agency than warrantee specifications.

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APPENDIX A—Final Performance-Related Specification

PROJECT NO. 19012-3154-44 IM-65-3(104)91
ROUTE I-65
DAVIDSON COUNTY 3.47 MILES

TECHNICAL SPECIAL PROVISIONS
FOR
PERFORMANCE-RELATED SPECIFICATIONS for
RIGID PAVEMENT

Prepared for Review By:

Task Group Developing the I-65 Project PRS

Drafted By:

Applied Research Associates, Inc.
505 W. University Ave.
Champaign, IL 61820

April 12, 2004

LIST OF ABBREVIATIONS

AQC:	Acceptance Quality Characteristic
$AREA_{Lot}$:	Area of the As-Constructed Lot
BID:	Contractor Bid Price of Concrete Slab
LCC:	Life Cycle Cost
LCC_{con}:	As-Constructed Life Cycle Cost
LCC_{des}:	As-Designed Life Cycle Cost
MQL:	Maximum Quality Limit
PAY_{Lot}:	Adjusted Payment for the As-Constructed Lot
$PAYADJ_{Lot}$:	Lot Pay Increase (+) or Decrease (-)
$PF_{composite}$:	Composite Pay Factor for Lot
PF_{PI}:	Initial Smoothness (or Profile Index, PI) Pay Factor
$PF_{strength}$:	28-Day Strength Pay Factor
$PF_{thickness}$:	Slab Thickness Pay Factor
$PI_{0.1}$:	Profile Index with 0.1-in Blanking Band
PRS:	Performance-Related Specifications
RQL:	Rejectable Quality Limit

This Technical Special provision applies to 13-in mainline Portland cement concrete pavement on I-65 Project 19012-3154-44 IM-65-3(104)91 from Old Hickory Boulevard to CSX Railroad as shown in the plans.

INTRODUCTION

Tennessee Department of Transportation (TDOT) will pilot performance-related specifications (PRS) for Portland cement concrete pavement as a part of this project. The PRS provides for incentive/disincentive pay to the contractor depending on the level of construction quality achieved in the field. The Composite Pay Adjustment Factor for a specific lot of pavement is based on the difference between the estimated long-term life-cycle cost (LCC) of the as-designed (target) pavement and the estimated long term LCC of the as-constructed pavement (lot) as computed by the PaveSpec 3.0 software on a lot basis. This methodology is defined in the report "FHWA-RD-98-155, Guide to Developing Performance-Related Specifications." The Composite Pay Adjustment Factor will apply to TDOT pay item number 501-01.06 (13-in mainline pavement including the cost of joints). The Composite Pay Adjustment Factor is based on three individual lot pay factors: concrete slab thickness, concrete compressive strength, and initial smoothness (or Profile Index). The absolute minimum value of the Composite Pay Adjustment Factor for a given lot shall be limited to 80 percent and the absolute maximum value shall be limited to 110 percent.

BACKGROUND

The main objective of these performance-related specifications (PRS) is to provide the agency with a methodology to assure that the design assumptions are being fulfilled, promote high quality construction, and to protect the agency from poor workmanship. At the same time it allows the contractor the increased freedom and innovation in deciding how to perform the construction and provides significant incentives to produce a quality project. PRS provides a rational method for contract price adjustment based on the difference between the long-term as-designed and as-constructed life-cycle costs of the pavement.

The proposed PRS incentive pay schedules were developed using the FHWA methodology as defined in the report "FHWA-RD-98-155, *Guide to Developing Performance-Related Specifications for PCC Pavements,"* and implemented in the PaveSpec 3.0 software. PRS employ distress prediction models to relate the acceptance quality characteristics (AQCs) to future pavement performance and associated LCC. Figure 1 illustrates how the PRS methodology works. The FHWA Web site provides additional information about PRS and the PaveSpec 3.0 software (www.tfhrc.gov/pavement/pccp/pavespec/pavespec.htm).

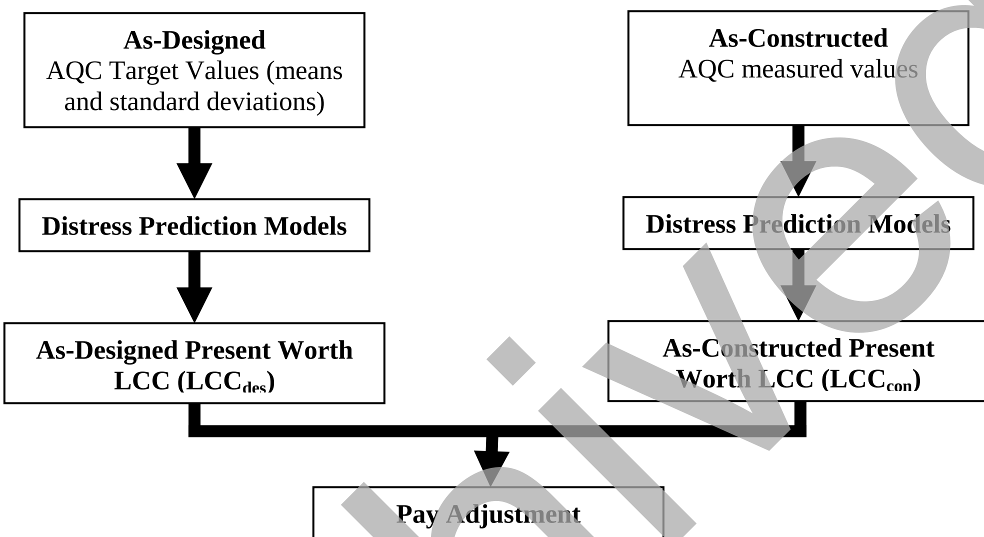


Figure A-1. Basic concepts of LCC-based PRS pay adjustment for a lot.

The *pay adjustment factor* (PF) is defined as the percentage of the bid price that the contractor is paid for the construction of a concrete pavement lot and is computed based on the difference between the as-constructed and as-designed LCC (in present worth dollars) as follows:

$$PF^* = 100(BID + [LCC_{des} - LCC_{con}]) / BID \quad (1)$$

Where:

BID = Contractor's bid price
LCC_{des} = As-designed life cycle cost
LCC_{cons} = As-constructed life cycle cost
* The pay adjustment factor (PF) will be applied to pay item 506-01.06 only.

The LCC is computed using future maintenance and rehabilitation activities that are determined based on prediction models for slab cracking, joint spalling, joint faulting, and pavement PI. A key aspect of using LCC to define the PF's is that the LCC of the as-constructed lot is the overall measure of quality, providing a rational way to develop an overall pay adjustment factor for the lot. The PF's computed by this procedure have been adjusted slightly for practical application by TDOT.

ACCEPTANCE QUALITY CHARACTERISTICS

Pay adjustment in these specifications is based on the following key acceptance quality characteristics (AQC) only:

- Concrete compressive strength at 28-days.
- Slab thickness.
- Initial smoothness (or Profile Index).

Several other quality characteristics (e.g., slump, dowel placement, tie bar placement, aggregate gradation, aggregate quality, surface friction) are very important but are not described in these PRS. These quality characteristics and construction requirements are considered according to TDOT's existing Standard Specifications.

TARGET QUALITY LEVELS

If the TDOT mean and standard deviation targets for each of the AQCs used for pay adjustment are met, the agency will pay 100 percent of the bid price. Table 1 shows target quality levels (mean and standard deviations) at which TDOT will pay 100 percent of the bid price.

Table A-1. Lot AQC target lot mean and standard deviation.

AQC	Lot Target Values	
	Mean	**Standard Deviation**
Slab Thickness, in	13.0	0.5(1)
Compressive strength: 28-days, lbf/in^2	4,500	500(2)
Initial Profile Index (with 0.1 Blanking Band), in/mi	7.0	1.0(3)

(1) Thickness: mean and standard deviation computed from independent cores (1 core per sublot). Alternatively using a combination of ASTM C 1383-98a Impact Echo and independent cores (1 core per odd numbered sublot)

(2) Compressive strength: mean and standard deviation computed from averages of 2 replicate cylinders taken at one location per sublot.

(3) Profile Index (PI): mean and standard deviation computed from averages of inside and outside wheelpaths of each 500-ft section in the lot measured prior to any grinding.

REJECTABLE QUALITY LEVELS

Rejectable quality level (RQL) is the level of quality below which for thickness and compressive strength or above which for PI of the pavement is deficient enough that a corrective action or remove-and-replace is warranted. Table 2 shows the RQLs (lot mean values) for each of the AQCs used for pay adjustment in these PRS.

Table A-2. Mean AQC rejectable quality levels for lots.

AQC	RQL (Lot Mean)
Slab Thickness, in	12.0
Compressive strength, lbf/in^2	3,000
Initial Profile Index (with 0.1 blanking band), in/mile	>9.0 (must grind to ≤ 9.0)

If the quality of the as-constructed lot (as measured by the acceptance test results) of *any* of the AQCs is below the RQL, the Engineer will determine the appropriate corrective actions as follows.

When the thickness of the as-constructed lot is less than 12 in and the judgment of the Engineer is that the area of such deficiency does not warrant removal and the Contractor elects not to remove the pavement, there will be no payment for the area retained.

The Engineer may elect to use Impact Echo methods to identify the boundaries of the deficient thickness.

Concrete that fails to develop a compressive strength of 3,000 lbf/in^2 within 28 days shall be removed and replaced at the Contractor's expense or accepted at a reduced pay adjustment, as described in section 6 of this supplemental specification.

All surface profile areas represented by high points having deviations in excess of 0.4 in per 25 ft or less shall be corrected. If after these corrections are made, the average profile index of any sublot is greater than the RQL, corrective action shall be taken to reduce the profile index to the target value shown in table 1.

MAXIMUM QUALITY LEVELS

Maximum quality level (MQL) is the level of quality at which the pavement is unnecessarily more conservative than the design so that no further pay increase will be provided. Table 3 shows the MQLs (lot mean values) for each of the AQCs used for pay adjustment in these PRS.

If the quality of the as-constructed lot (as measured by the acceptance test results) of *any* of the AQCs is higher for thickness or compressive strength or lower for PI than the MQL, the pay factor at the MQL will be used for computing the composite PF and adjusting the payment. The actual values will be used to compute the standard deviation.

Table A-3. Lot AQC maximum quality levels.

AQC	MQL (Lot Mean)
Slab Thickness, in	14.0
Compressive strength (28-days), lbf/in^2	5,500
Initial Profile Index (with 0.1-in Blanking Band), in/mile	0.0 (Minimum)

TESTING METHODS

Table 4 lists the testing methods for slab thickness, concrete strength, and Profile Index. The testing methods for these AQCs are discussed further in the following sections.

Table A-4. Testing methods.

AQC	Test Method[1]
Slab Thickness	AASHTO T148
Compressive Strength	Concrete Cylinders: AASHTO T23 and AASHTO T22 Concrete Cores: AASHTO T24 for sublots with missing compression strength data.
Initial Profile Index	ASTM E 1274

(1) Note that all AQCs must be measured within the same sublot limits.

Slab Thickness

The thickness of cores drilled in conformance with AASHTO T148, shall be used for determining slab thickness. Core shall be taken from one randomly selected location within each sublot and be a minimum of 4-in diameter. The slab thickness at a cored location shall be recorded to the nearest 0.1-in, as the average of nine caliper measurements of the core length. Individual caliper measurements shall be recorded to the nearest 0.1-in.

As designated by the Engineer, alternatively the ASTM C1383-98a Impact Echo method of measuring pavement thickness shall be used. Impact Echo thicknesses shall be measured at one random location within each sublot, as designated by the Engineer. Cores shall be extracted from the same location in the odd numbered sublots, and thicknesses shall be measured. If the Impact Echo measurement on even numbered sublots is less than the RQL, confirmation cores shall be extracted from the same location. Core thickness shall be measured and used in the pay factor computation.

Initial Smoothness (or Profile Index)

The contractor shall collect pavement surface profile index values as soon as practical and prior to sealing joints and opening to traffic. Profile Index shall be collected in the presence of the Engineer using a computerized Rainhart profilograph in conformance with ASTM E 1274-03. The blanking band shall be set to 0.1 in and the bump limit shall be set to 0.4 in per 25 ft. Vertical measurement accuracy of each profilograph shall be demonstrated to the Engineer upon request. Profile measurement accuracy of each profilograph shall be demonstrated immediately prior to initial profile collection and following final profile collection through comparison with the TDOT high-speed profiler. The contractor shall identify and lay out a 1,000-ft long PCC section with PI values between 5 and 7 in/mi. The average PI from of three profilograph runs shall be within +/-”1” in/mi of the average of five runs collected using the TDOT high-speed profiler. If the PI comparisons are acceptable, the profilograph PI values will be used for pay factor computation.

If the average of the three post-construction PI values measured by the profilograph does not meet this requirement, any equipment and operator problems shall be assessed and resolved. Five additional runs shall be completed using both the contractor's profilograph and the TDOT high-speed profiler. If the supplemental PI comparisons are acceptable, the profilograph PI values will be used for pay factor computation. Otherwise, PI values measured using the TDOT high-speed profiler will be used in pay factor determination.

Compressive Strength

The required strength cylinders shall be cast from a randomly selected concrete truck within the sublot. The cylindrical specimens shall be molded and cured in accordance with AASHTO T23 and tested in accordance with AASHTO T22 standard test methods.

A strength test for each sublot is determined as the average of the 28-day compressive strength of two cylinders cast from a sample of concrete from the sublot. In the case of partial lots, the strength cylinders can be supplemented by cores. Thus, the strength sample size is one per sublot and the number of replicates per sample is two.

SAMPLING PLAN AND ADJUSTMENTS

The PRS Acceptance Quality Characteristics (AQC) of thickness, strength, and PI are measured within each sublot. All values measured within the lot are combined to compute a mean and standard deviation of the lot. The pay adjustment for a given lot is computed from these values. Pay is determined on a lot-by-lot basis, not by the sublot.

Sublot boundaries must be marked and maintained until finalizing the payment computation. The lot shall be divided into a minimum of three sublots for sampling and testing purposes. Markers shall be placed every 500-ft along the mainline traffic lanes to aid in determining the lot and sublot limits.

The definitions of lot, sublot, sampling frequency for thickness, concrete strength, and initial PI are presented.

Pavement Lot

Contract pay for concrete paving is determined on a lot-by-lot basis. A paving lot has the following characteristics:

1. Each lot is one paving pass in width. This width can be equal to one, two, or more traffic lanes (see below for consideration of concrete shoulders).
2. A lot consists of a minimum of three sublots, which are each 500-ft in length, and they all exist consecutively (longitudinally) along the same paving width. A lot cannot be divided between two adjacent or separated paving lanes.
3. Therefore, the minimum length of a lot is 1500-ft along the same paving lane(s) and this lot can include work from one or more days of paving.
4. The maximum lot length is defined as 1-day production of one paving pass, or 4500-ft in length; whichever is less. If the 1-day production is longer than 4500-ft, the Engineer

shall divide the 1-day production into multiple lots that meet the minimum lot length from #3. The Engineer may terminate the lot if there is any reason to believe that a special cause affected the process and resulted in a significant shift in the mean or standard deviation of thickness, PI, or strength (AQCs).

5. Partial lots: if the contractor builds a paving pass in a given day that for whatever reason is less than 1500-ft, this is defined as a partial lot. A partial lot is combined with the previous or next day's paving to produce a full lot with a minimum length of 1500-ft and a maximum length of 4500-ft. If the combined length of paving of a partial lot and the current lot being paved is greater than 4500-ft, the lot shall still be limited to 4500-ft and another partial lot identified to be added to the next day's paving.
6. If a section of paving has been designated as a partial lot but cannot be combined with the adjacent lot described under #2 (e.g., a single lane of widening or tapered paving that is less than 1500-ft), or if it is the last lot in the paving project and is less than 1500-ft, they shall allowed to be grouped with a previous lot. This will be allowed even if it results in a lot that is greater than 4500-ft.
7. Concrete shoulders can be included along with adjacent paved traffic lane(s), or by themselves if paved separately. If concrete shoulders are paved with a traffic lane (a paving width includes one or more traffic lanes and a concrete shoulder), the traffic lane is tested for all AQCs (PI, strength, and thickness but the shoulder is only tested for strength and thickness). The pay factor is computed using only the PI values obtained from the traffic lane(s). If the lot width includes only a concrete shoulder, the shoulder is tested for concrete strength and slab thickness and PI is assumed to be at the target values of 7.0-in mean and 1.0-in standard deviation.

Pavement Sublot

Each lot is divided into discrete sublots and that sampling for each AQC be conducted randomly in each sublot. This means that thickness, concrete strength, and PI shall be measured within each sublot boundary.

1. The sublot length is established at a constant 500-ft so that the PI can be measured and also for field location expediency.
2. The width of the sublot is the paving width.
3. There shall be a minimum of three sublots in each lot. The maximum is nine (9) sublots within a maximum lot size of 4500-ft.
4. If there is a sublot that is not tested for concrete strength for whatever reason, this section shall be cored as specified and tested for compressive strength at 28-days after placement. The cores shall be tested for compressive strength according to procedures required in Table 4.

Sampling Frequency Within Sublots

The sampling frequencies for slab thickness, concrete strength, and PI within a given 500-ft sublot are described below.

Slab Thickness

A thickness measurement for each sublot is determined by taking one core through the slab at one random location in the sublot. Alternatively, the Engineer may allow thickness measurements in the even numbered sublots to be measured using the ASTM C 1383 equipment and methods. Thus, the thickness sample size is one per sublot and the number of replicates per sample is one.

Concrete Strength

The concrete strength for each sublot is determined as the average of the 28-day compression tests of two replicates taken from one random batch of concrete from each sublot. Thus, the concrete strength sample size is one per sublot and the number of replicates per sample is two.

Initial Smoothness (Profile Index)

A longitudinal profile trace shall be taken in each 500-ft length along the wheelpaths (inside and outside wheelpaths located 3-ft from the edge of the slab for conventional width lanes, or 3-ft from the paint stripe for widened slabs) for each traffic lane included within the sublot. The mean PI for each discrete 500-ft section within the sublot shall be computed. The number of replicates per pass location for a paving width equals 2, the number of wheelpaths per traffic lane). Smoothness measurement shall terminate not less than 50-ft from the bridge approach joint.

PAY ADJUSTMENTS

PRS recognize that higher quality products have additional value and provide payment adjustment for this higher quality up to a maximum value. PRS also recognize that marginal quality products have reduced value and advocate payment reduction instead of requiring complete removal unless the pavement is so deficient that replacement or correction action is warranted (i.e., at the RQL).

INDIVIDUAL PAY ADJUSTMENT CURVES

Individual pay adjustment factors for slab thickness, comprehensive strength, and initial PI shall be determined using the pay factor curves shown in figures 2, 3, and 4 or tables 5, 6, and 7. These curves and tables were developed using the PaveSpec 3.0 PRS software and account for the mean and standard deviation of the AQCs for the subject pavement project. Linear interpolation or extrapolation shall be used between the values shown in these tables, if needed. Some adjustment was made to the curves to provide a more practical incentive and disincentive.

The determination of individual pay factors from figures 2, 3, and 4 or tables 5, 6, and 7 requires computing the mean and standard deviation of the slab thickness, compressive strength, and initial PI for the as-constructed lot based on the field testing results. These statistics shall be calculated as follows.

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} \tag{2}$$

Where

$\overline{X}$ = Mean of n random samples of the AQC under consideration for the lot

X_i = Sample measurement (for PI and strength, X_i is a mean of multiple replicates, and for thickness is the individual core)

n = Sample size per lot, n for each AQC is as follows:

Compressive strength: n = number of sublots (mean of 2 replicate cylinders produced from each batch in sublot)

Thickness: n = number of sublots (no replicates)

PI: n = number of sublots multiplied by number of traffic lanes in lot (each profile test consists of measurement of a 500-ft continuous wheelpath section, mean of 2 replicates (the two wheelpaths in each lane are considered replicates)

The lot thickness standard deviation (where number of replicates = 1) is computed as follows:

$$s = \frac{\sqrt{\frac{\sum (X_i - \overline{X})^2}{(n-1)}}}{C_{SD}} \quad (3)$$

The compressive strength and PI unbiased lot standard deviation (where more than one replicate per sample are used) is computed as follows.

$$s = \frac{\sqrt{\frac{\sum (X_i - \overline{X})^2}{(n-1)m}}}{C_{SD}} \quad (4)$$

Where

m = Number of replicates per sample, m, for compressive strength and PI are as follows:

Compressive strength: m = 2 replicates (i.e., 2 tests per batch sublot)

PI: m = 2 replicates per lane (i.e., 2 wheelpaths per lane) multiplied by number of lanes in lot.

C_{SD} = Correction factor (based on the total sample size, n) used to obtain unbiased estimates of the actual lot sample standard deviation. Appropriate C_{SD} values are determined using table 5.

Table A-5. Correction factors used to obtain unbiased estimates of the actual standard deviation.

Number of Samples, n	**Correction Factor, C_{SD}**
2	0.7979
3	0.8862
4	0.9213
5	0.9399
6	0.9515
7	0.9594
8	0.9650
9	0.9693
10	0.9726
30	0.9915

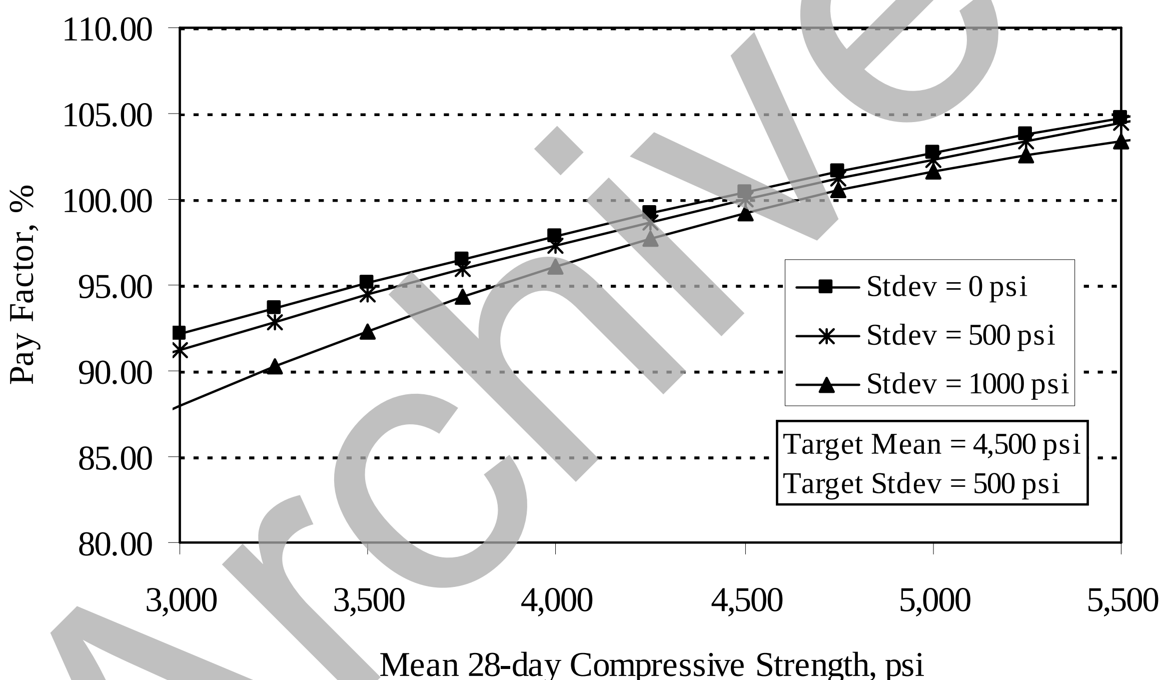


Figure A-2. 28-day compressive strength of concrete pay adjustment curve.

Table A-6. Compressive strength pay adjustment table (PF, %).

Lot Mean, Lbf/in^2**	Lot standard deviation (computed using means of 2 tests)		
	0 lbf/in^2	500 lbf/in^2*	1000 lbf/in^2
3,000	92.17	91.28	87.92
3,250	93.68	92.89	90.22
3,500	95.14	94.43	92.36
3,750	96.54	95.91	94.33
4,000	97.88	97.32	96.13
4,250	99.17	98.67	97.76
4,500*	100.41	100.00	99.23
4,750	101.58	101.18	100.52
5,000	102.71	102.33	101.65
5,250	103.78	103.42	102.62
5,500	104.79	104.45	103.41

*Targets

**Pay adjustment for Lot Mean less than 3,000 lbf/in^2 are as follows:

<3,000 to 2,751 lbf/in^2 = 85.00 percent

2,750 to 2,501 lbf/in^2 = 70.00 percent

2,500 to 2,251 lbf/in^2 = 50.00 percent

2,250 to 2,000 lbf/in^2 = 25.00 percent

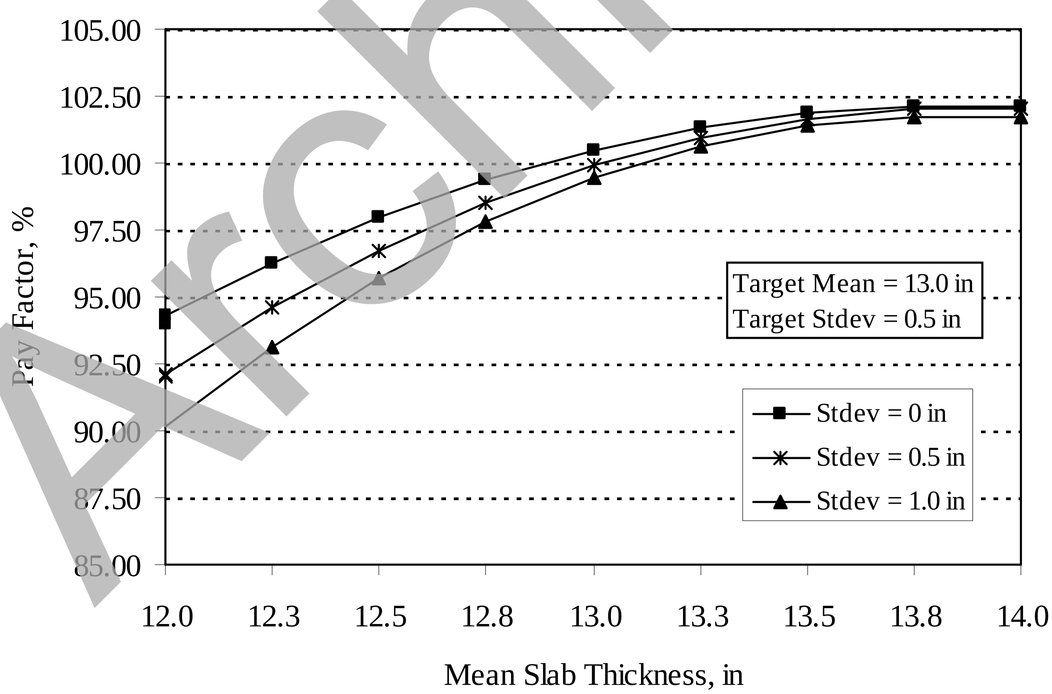


Figure A-3. Slab thickness pay adjustment curve.

Table A-7. Slab thickness pay adjustment table (PF, %).

Lot mean slab thickness, in	Lot standard deviation (computed from independent cores), in		
	0	0.5-in*	1.0-in
12.0	94.26	92.14	90.19
12.25	96.24	94.62	93.16
12.5	97.94	96.74	95.69
12.75	99.35	98.51	97.78
13.00*	100.47	100.00	99.43
13.25	101.31	100.97	100.64
13.50	101.86	101.67	101.41
13.75	102.12	102.02	101.75
14.00	102.11	102.01	101.64

*Targets

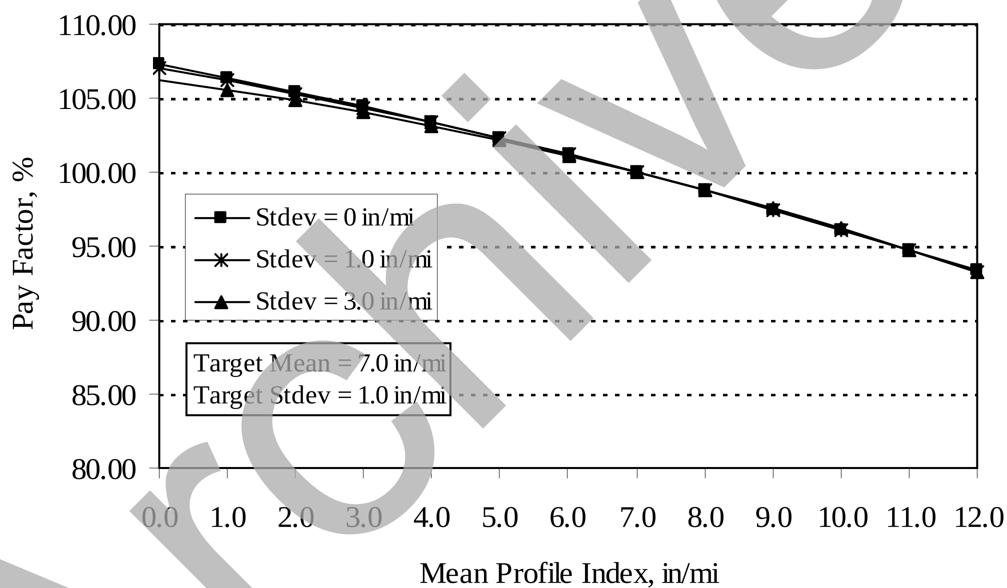


Figure A-4. Initial PI pay adjustment curve.

Table A-8. Initial PI pay adjustment table (PF, %).

Lot Mean PI, in/mi**	Lot standard deviation (computed using means of 2 wheelpaths PI's per lane), in/mi		
	0	1.0-in/mi*	3.00-in/mi
0	107.29	107.02	106.26
1	106.39	106.20	105.60
2	105.44	105.32	104.86
3	104.44	104.38	104.04
4	103.39	103.38	103.15
5	102.30	102.33	102.18
6	101.16	101.21	101.13
7*	99.97	100.00	100.00
8	98.73	98.79	98.80
9	97.45	97.50	97.52
10	96.12	96.14	96.17
11	94.74	94.72	94.73
12	93.32	93.25	93.22

*Targets
**Measured prior to any grinding
***If PI is > 9-in/mi, grinding is required. The PF is determined for the PI prior to grinding for > 9 to 12-in/mi. If PI > 12-in/mi, the pay factor for 12 is used.

Computation of Pay Adjustment

The lot composite (overall) pay factor is computed as follows.

$$PF_{composite} = (PF_{PI} * PF_{strength} * PF_{thickness})/10000 \quad (5)$$

Where

$PF_{composite}$ = Composite (overall) pay factor, %
$PF_{strength}$ = Compressive strength (obtain from table 5), %
$PF_{thickness}$ = Slab thickness pay factor (obtain from table 6), %
PF_{PI} = Initial PI pay factor (obtain from table 7), %

The actual pay adjustment for an as-constructed lot is computed using the lot composite pay factor as follows. Pay adjustments will be made only on the individual lots.

$$PAYADJ_{Lot} = BID * AREA_{Lot} * (PF_{composite} - 100)/100 \quad (6)$$

Where

$PAYADJ_{Lot}$ = Pay increase (+) or decrease (-), $
BID = Contractor bid price for pay item (31.95, $/yd^2)
$AREA_{Lot}$ = Measured actual area of the as-constructed lot, yd^2
$PF_{composite}$ = Composite pay factor (from equation 5), percent (e.g., 101 percent is expressed as 101.0)

$$PAY_{Lot} = BID * AREA_{Lot} + PAYADJ_{Lot} \quad (7)$$

Where

PAY_{Lot} = Adjusted payment for the as-constructed lot, $

The absolute minimum value of the Composite Pay Adjustment Factor for a given lot shall be limited to 80 percent and the absolute maximum value shall be limited to 110 percent.

APPENDIX B—Summary of All Data in Computational Spreadsheet Format

Table B-1. Northbound Lot 1 PRS Computation Results

LOT INFORMATION

Lot Number	1 (1-3)		Project No.	
Bid Price, $/sq yd	31.95		Begin Station	600+00
Lot Length, feet	1770	Check Stations	End Station	617+70
Lot Width, feet	24		Lane No's.	4 & 5
Resulting Lot Area, sq yds	4720.00		Paving Date(s)	

THICKNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Thickness Core 1, in	13.6	13.3	13.4						
Thickness IE 1 (avg of 3), in									
Sublot Thickness, in	13.6	13.3	13.4						

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	3	Lot AQL, in	13.0
Lot Thickness Mean, in	13.4	Lot RQL, in	12.0
Lot Thickness Mean Acceptable?	Yes	Lot MQL, in	14.0
Notes on Lot Thickness Mean:	Lot mean thickness is between RQL and MQL.		
Notes on Sublot Thickness Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.8862		
Lot Thickness Std. Dev., in	0.17237		
Resulting Pay Factor:	**101.63%**		

STRENGTH

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Strength cylinder 1, psi	5,182	4,290	5,605						
Strength cylinder 2, psi	5,605	5,195	5,183						
Sublot Strength, psi	5393.5	4742.5	5394						

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	3	Lot AQL, psi	4500
Replicates per lot (m)	2.0	Lot RQL, psi	3000
Lot Strength Mean, psi	5176.7	Lot MQL, psi	5500
Lot Strength Mean Acceptable?	Yes		
Notes on Lot Strength Mean:	Lot mean strength is between RQL and MQL.		
Notes on Sublot Strength Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.8862		
Lot Strength Std. Dev., psi	300.01		
Resulting Pay Factor:	**103.25%**		

SMOOTHNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
PI for Pass 1, in/mi	4.12	2.32	7.66						
PI for Pass 2, in/mi	8.45	6.44	4.21						
PI for Pass 3, in/mi	4.86	5.17	4.23						
PI for Pass 4, in/mi	6.86	3.59	4.69						
Sublot Mean PI, in/mi	6.07	4.38	5.20						

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	3	Lot AQL, in/mi	7.0
Replicates per lot (m)	4.0	Lot RQL, in/mi	9.0
Lot PI Mean, psi	5.5	Lot MQL, in/mi	0.0
Lot PI Mean Acceptable?	Yes		
Notes on Lot Smoothness Mean:	Lot mean smoothness is between RQL and MQL.		

Table B-2. Northbound Lot 2 PRS Computation Results

LOT INFORMATION

Lot Number	2 (4-7)	Project No.	
Bid Price, $/sq yd	31.95	Begin Station	580+00
Lot Length, feet	2000	End Station	600+00
Lot Width, feet	24	Lane No's.	4 & 5
Resulting Lot Area, sq yds	5333.33	Paving Date(s)	

THICKNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Thickness Core 1, in	13.4	13.3	13.3	13.3					
Thickness IE 1 (avg of 3), in									
Sublot Thickness, in	13.4	13.3	13.3	13.3					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in	13.0
Lot Thickness Mean, in	13.3	Lot RQL, in	12.0
Lot Thickness Mean Acceptable?	Yes	Lot MQL, in	14.0
Notes on Lot Thickness Mean:	Lot mean thickness is between RQL and MQL.		
Notes on Sublot Thickness Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9213		
Lot Thickness Std. Dev., in	0.05427		
Resulting Pay Factor:	**101.44%**		

STRENGTH

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Strength cylinder 1, psi	5,380	4,740	4,740	5,502					
Strength cylinder 2, psi	6,000	5,713	5,425	5,425					
Sublot Strength, psi	5690	5226.5	5082.5	5463.5					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, psi	4500
Replicates per lot (m)	2.0	Lot RQL, psi	3000
Lot Strength Mean, psi	5365.6	Lot MQL, psi	5500
Lot Strength Mean Acceptable?	Yes		
Notes on Lot Strength Mean:	Lot mean strength is between RQL and MQL.		
Notes on Sublot Strength Mean:	All sublots are at or above RQL.		
Std. Dev. Correction Factor	0.9213		
Lot Strength Std. Dev., psi	205.14		
Resulting Pay Factor:	**104.10%**		

SMOOTHNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
PI for Pass 1, in/mi	2.75	2.01	2.96	2.64					
PI for Pass 2, in/mi	7.92	3.38	2.01	4.22					
PI for Pass 3, in/mi	6.76	5.7	1.16	5.49					
PI for Pass 4, in/mi	6.65	7.92	1.48	3.38					
Sublot Mean PI, in/mi	6.02	4.75	1.90	3.93					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in/mi	7.0
Replicates per lot (m)	4.0	Lot RQL, in/mi	9.0
Lot PI Mean, psi	3.5	Lot MQL, in/mi	0.0
Lot PI Mean Acceptable?	Yes		
Notes on Lot Smoothness Mean:	Lot mean smoothness is between RQL and MQL.		

Table B-3. Northbound Lot 3 PRS Computation Results

LOT INFORMATION

Lot Number	3 (8-11)	Project No.	
Bid Price, $/sq yd	31.95	Begin Station	560+00
Lot Length, feet	2000	End Station	580+00
Lot Width, feet	24	Lane No's.	4 & 5
Resulting Lot Area, sq yds	5333.33	Paving Date(s)	

THICKNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Thickness Core 1, in	13.6	13.6	13.6	13.6					
Thickness IE 1 (avg of 3), in									
Sublot Thickness, in	13.6	13.6	13.6	13.6					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in	13.0
Lot Thickness Mean, in	13.6	Lot RQL, in	12.0
Lot Thickness Mean Acceptable?	Yes	Lot MQL, in	14.0
Notes on Lot Thickness Mean:	Lot mean thickness is between RQL and MQL.		
Notes on Sublot Thickness Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9213		
Lot Thickness Std. Dev., in	0.00000		
Resulting Pay Factor:	**101.96%**		

STRENGTH

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Strength cylinder 1, psi	5,380	5,190	5,190	5,295					
Strength cylinder 2, psi	5,155	5,270	5,710	5,380					
Sublot Strength, psi	5267.5	5230	5450	5337.5					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, psi	4500
Replicates per lot (m)	2.0	Lot RQL, psi	3000
Lot Strength Mean, psi	5321.3	Lot MQL, psi	5500
Lot Strength Mean Acceptable?	Yes		
Notes on Lot Strength Mean:	Lot mean strength is between RQL and MQL.		
Notes on Sublot Strength Mean:	All sublots are at or above RQL.		
Std. Dev. Correction Factor	0.9213		
Lot Strength Std. Dev., psi	74.22		
Resulting Pay Factor:	**104.02%**		

SMOOTHNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
PI for Pass 1, in/mi	7.08	3.59	3.7	5.49					
PI for Pass 2, in/mi	6.23	5.28	4.75	3.48					
PI for Pass 3, in/mi	10.67	5.81	5.81	3.91					
PI for Pass 4, in/mi	7.39	3.27	7.39	2.75					
Sublot Mean PI, in/mi	7.84	4.49	5.41	3.91					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in/mi	7.0
Replicates per lot (m)	4.0	Lot RQL, in/mi	9.0
Lot PI Mean, psi	5.0	Lot MQL, in/mi	0.0
Lot PI Mean Acceptable?	Yes		
Notes on Lot Smoothness Mean:	Lot mean smoothness is between RQL and MQL.		

Table B-4. Northbound Lot 4 PRS Computation Results

LOT INFORMATION

Lot Number	4 (12-15)		Project No.	
Bid Price, $/sq yd	31.95		Begin Station	536+30
Lot Length, feet	2370	Check Stations	End Station	560+00
Lot Width, feet	24		Lane No's.	4 & 5
Resulting Lot Area, sq yds	6320.00		Paving Date(s)	

THICKNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Thickness Core 1, in	13.4	13.2	13.3	13.3					
Thickness IE 1 (avg of 3), in									
Sublot Thickness, in	13.4	13.2	13.3	13.3					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in	13.0
Lot Thickness Mean, in	13.3	Lot RQL, in	12.0
Lot Thickness Mean Acceptable?	Yes	Lot MQL, in	14.0
Notes on Lot Thickness Mean:	Lot mean thickness is between RQL and MQL.		
Notes on Sublot Thickness Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9213		
Lot Thickness Std. Dev., in	0.08862		
Resulting Pay Factor:	**101.37%**		

STRENGTH

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Strength cylinder 1, psi	4,515	5,075	4,955	5,173					
Strength cylinder 2, psi	5,015	4,260	5,135	4,955					
Sublot Strength, psi	4765	4667.5	5045	5064					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, psi	4500
Replicates per lot (m)	2.0	Lot RQL, psi	3000
Lot Strength Mean, psi	4885.4	Lot MQL, psi	5500
Lot Strength Mean Acceptable?	Yes		
Notes on Lot Strength Mean:	Lot mean strength is between RQL and MQL.		
Notes on Sublot Strength Mean:	All sublots are at or above RQL.		
Std. Dev. Correction Factor	0.9213		
Lot Strength Std. Dev., psi	153.08		
Resulting Pay Factor:	**102.07%**		

SMOOTHNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
PI for Pass 1, in/mi	2.75	8.24	9.19	6.86					
PI for Pass 2, in/mi	9.4	17.53	9.19	8.13					
PI for Pass 3, in/mi	6.12	7.81	7.39	9.4					
PI for Pass 4, in/mi	4.12	4.65	7.18	8.34					
Sublot Mean PI, in/mi	5.60	9.56	8.24	8.18					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in/mi	7.0
Replicates per lot (m)	4.0	Lot RQL, in/mi	9.0
Lot PI Mean, psi	8.9	Lot MQL, in/mi	0.0
Lot PI Mean Acceptable?	Yes		
Notes on Lot Smoothness Mean:	Lot mean smoothness is between RQL and MQL.		

Table B-5. Northbound Lot 5 PRS Computation Results

LOT INFORMATION

Lot Number	5 (16-18)		Project No.	
Bid Price, $/sq yd	31.95		Begin Station	515+00
Lot Length, feet	1870	Check Stations	End Station	533+70
Lot Width, feet	24		Lane No's.	4 & 5
Resulting Lot Area, sq yds	4986.67		Paving Date(s)	

THICKNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Thickness Core 1, in	12.5	13.4	13.4						
Thickness IE 1 (avg of 3), in									
Sublot Thickness, in	12.5	13.4	13.4						

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	3	Lot AQL, in	13.0
Lot Thickness Mean, in	13.1	Lot RQL, in	12.0
Lot Thickness Mean Acceptable?	Yes	Lot MQL, in	14.0
Notes on Lot Thickness Mean:	Lot mean thickness is between RQL and MQL.		
Notes on Sublot Thickness Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.8862		
Lot Thickness Std. Dev., in	0.58634		
Resulting Pay Factor:	**100.31%**		

STRENGTH

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Strength cylinder 1, psi	5,725	4,820	5,100						
Strength cylinder 2, psi	5,565	5,725	4,820						
Sublot Strength, psi	5645	5272.5	4960						

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	3	Lot AQL, psi	4500
Replicates per lot (m)	2.0	Lot RQL, psi	3000
Lot Strength Mean, psi	5292.5	Lot MQL, psi	5500
Lot Strength Mean Acceptable?	Yes		
Notes on Lot Strength Mean:	Lot mean strength is between RQL and MQL.		
Notes on Sublot Strength Mean:	All sublots are at or above RQL.		
Std. Dev. Correction Factor	0.8862		
Lot Strength Std. Dev., psi	273.63		
Resulting Pay Factor:	**103.76%**		

SMOOTHNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
PI for Pass 1, in/mi	3.59	4.65	4.98						
PI for Pass 2, in/mi	5.39	7.71	8.21						
PI for Pass 3, in/mi	6.02	4.96	8.86						
PI for Pass 4, in/mi	7.6	4.75	6.74						
Sublot Mean PI, in/mi	5.65	5.52	7.20						

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	3	Lot AQL, in/mi	7.0
Replicates per lot (m)	4.0	Lot RQL, in/mi	9.0
Lot PI Mean, psi	5.8	Lot MQL, in/mi	0.0
Lot PI Mean Acceptable?	Yes		
Notes on Lot Smoothness Mean:	Lot mean smoothness is between RQL and MQL.		

Table B-6. Northbound Lot 6 PRS Computation Results

LOT INFORMATION

Lot Number	6 (19-23)		Project No.	
Bid Price, $/sq yd	31.95		Begin Station	489+20
Lot Length, feet	2380	Check Stations	End Station	515+00
Lot Width, feet	24		Lane No's.	4 & 5
Resulting Lot Area, sq yds	6346.67		Paving Date(s)	

THICKNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Thickness Core 1, in	13.1	13.1	13.2	13.1	13.2				
Thickness IE 1 (avg of 3), in									
Sublot Thickness, in	**13.1**	**13.1**	**13.2**	**13.1**	**13.2**				

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	5	Lot AQL, in	13.0
Lot Thickness Mean, in	13.1	Lot RQL, in	12.0
Lot Thickness Mean Acceptable?	Yes	Lot MQL, in	14.0
Notes on Lot Thickness Mean:	Lot mean thickness is between RQL and MQL.		
Notes on Sublot Thickness Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9399		
Lot Thickness Std. Dev., in	0.05827		
Resulting Pay Factor:	**100.89%**		

STRENGTH

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Strength cylinder 1, psi	6,015	5,970	5,265	5,265	5,240				
Strength cylinder 2, psi	5,625	5,635	5,635	5,175	5,025				
Sublot Strength, psi	**5820**	**5802.5**	**5450**	**5220**	**5132.5**				

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	5	Lot AQL, psi	4500
Replicates per lot (m)	2.0	Lot RQL, psi	3000
Lot Strength Mean, psi	5485.0	Lot MQL, psi	5500
Lot Strength Mean Acceptable?	Yes		
Notes on Lot Strength Mean:	Lot mean strength is between RQL and MQL.		
Notes on Sublot Strength Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9399		
Lot Strength Std. Dev., psi	240.49		
Resulting Pay Factor:	**104.57%**		

SMOOTHNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
PI for Pass 1, in/mi	3.38	6.55	3.48	3.17	4.22				
PI for Pass 2, in/mi	7.39	9.19	5.81	2.85	6.34				
PI for Pass 3, in/mi	7.39	5.7	7.08	2.96	5.28				
PI for Pass 4, in/mi	6.97	4.96	5.07	3.7	7.5				
Sublot Mean PI, in/mi	**6.28**	**6.60**	**5.36**	**3.17**	**5.84**				

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	5	Lot AQL, in/mi	7.0
Replicates per lot (m)	4.0	Lot RQL, in/mi	9.0
Lot PI Mean, psi	5.2	Lot MQL, in/mi	0.0
Lot PI Mean Acceptable?	Yes		
Notes on Lot Smoothness Mean:	Lot mean smoothness is between RQL and MQL.		

Table B-7. Southbound Lot 7 PRS Computation Results

LOT INFORMATION

Lot Number	7		Project No.	
Bid Price, $/sq yd	31.95		Begin Station	475+67
Lot Length, feet	1180	Check Stations	End Station	487+47
Lot Width, feet	24		Lane No's.	4 & 5
Resulting Lot Area, sq yds	3146.67		Paving Date(s)	

THICKNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Thickness Core 1, in	13.1	13	13						
Thickness IE 1 (avg of 3), in									
Sublot Thickness, in	13.1	13	13						

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	3	Lot AQL, in	13.0
Lot Thickness Mean, in	13.0	Lot RQL, in	12.0
Lot Thickness Mean Acceptable?	Yes	Lot MQL, in	14.0
Notes on Lot Thickness Mean:	Lot mean thickness is between RQL and MQL.		
Notes on Sublot Thickness Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.8862		
Lot Thickness Std. Dev., in	0.06515		
Resulting Pay Factor:	**100.52%**		

STRENGTH

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Strength cylinder 1, psi	4,260	5,520	4,170						
Strength cylinder 2, psi	4,500	5,360	4,250						
Sublot Strength, psi	4380	5440	4210						

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	3	Lot AQL, psi	4500
Replicates per lot (m)	2.0	Lot RQL, psi	3000
Lot Strength Mean, psi	4676.7	Lot MQL, psi	5500
Lot Strength Mean Acceptable?	Yes		
Notes on Lot Strength Mean:	Lot mean strength is between RQL and MQL.		
Notes on Sublot Strength Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.8862		
Lot Strength Std. Dev., psi	531.81		
Resulting Pay Factor:	**100.79%**		

SMOOTHNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
PI for Pass 1, in/mi	4.4	2.85	0						
PI for Pass 2, in/mi	4.8	6.15	3.7						
PI for Pass 3, in/mi	5.3	1.95	7.65						
PI for Pass 4, in/mi	4.4	3.15	5.55						
Sublot Mean PI, in/mi	4.73	3.53	4.23						

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	3	Lot AQL, in/mi	7.0
Replicates per lot (m)	4.0	Lot RQL, in/mi	9.0
Lot PI Mean, psi	3.7	Lot MQL, in/mi	0.0
Lot PI Mean Acceptable?	Yes		
Notes on Lot Smoothness Mean:	Lot mean smoothness is between RQL and MQL.		
Notes on Sublot Smoothness Mean:	All sublots are at or below RQL.		
Std. Dev. Correction Factor	0.8862		
Lot Smoothness Std. Dev., in/mi	0.34		
Resulting Pay Factor:	**103.75%**		

RESULTS

All Pay Factors Determined?	Yes
Equal Number of Sublots?	Yes
PF Thickness	100.52%
PF Strength	100.79%
PF Smoothness	103.75%
PF Composite	**105.11%**
Payadj (lot)	**$5,141.89**
Pay (lot)	**$105,677.89**

Table B-8. Southbound Lot 8 PRS Computation Results

LOT INFORMATION

Lot Number	8		Project No.	
Bid Price, $/sq yd	31.95		Begin Station	489+02
Lot Length, feet	2173	Check Stations	End Station	510+75
Lot Width, feet	24		Lane No's.	4 & 5
Resulting Lot Area, sq yds	5794.67		Paving Date(s)	

THICKNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Thickness Core 1, in	13.1	12.6	13	13	12.9				
Thickness IE 1 (avg of 3), in									
Sublot Thickness, in	13.1	12.6	13	13	12.9				

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	5	Lot AQL, in	13.0
Lot Thickness Mean, in	12.9	Lot RQL, in	12.0
Lot Thickness Mean Acceptable?	Yes	Lot MQL, in	14.0
Notes on Lot Thickness Mean:	Lot mean thickness is between RQL and MQL.		
Notes on Sublot Thickness Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9399		
Lot Thickness Std. Dev., in	0.20465		
Resulting Pay Factor:	**99.87%**		

STRENGTH

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Strength cylinder 1, psi	4,340	4,440	4,260	4,390	4,605				
Strength cylinder 2, psi	4,535	4,630	4,200	4,460	4,250				
Sublot Strength, psi	4437.5	4535	4230	4425	4427.5				

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	5	Lot AQL, psi	4500
Replicates per lot (m)	2.0	Lot RQL, psi	3000
Lot Strength Mean, psi	4411.0	Lot MQL, psi	5500
Lot Strength Mean Acceptable?	Yes		
Notes on Lot Strength Mean:	Lot mean strength is between RQL and MQL.		
Notes on Sublot Strength Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9399		
Lot Strength Std. Dev., psi	83.53		
Resulting Pay Factor:	**99.89%**		

SMOOTHNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
PI for Pass 1, in/mi	6.96	2.6	5.3	4.8	3.7				
PI for Pass 2, in/mi	5.57	3.9	6.3	4.4	5.9				
PI for Pass 3, in/mi	4.88	2.9	3.9	2.8	7.5				
PI for Pass 4, in/mi	0	3.5	6.8	1.2	6.3				
Sublot Mean PI, in/mi	4.35	3.23	5.58	3.30	5.85				

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	5	Lot AQL, in/mi	7.0
Replicates per lot (m)	4.0	Lot RQL, in/mi	9.0
Lot PI Mean, psi	4.9	Lot MQL, in/mi	0.0
Lot PI Mean Acceptable?	Yes		
Notes on Lot Smoothness Mean:	Lot mean smoothness is between RQL and MQL.		
Notes on Sublot Smoothness Mean:	All sublots are at or below RQL.		
Std. Dev. Correction Factor	0.9399		
Lot Smoothness Std. Dev., in/mi	0.63		
Resulting Pay Factor:	**102.38%**		

RESULTS

All Pay Factors Determined?	Yes
Equal Number of Sublots?	Yes
PF Thickness	99.87%
PF Strength	99.89%
PF Smoothness	102.38%
PF Composite	**102.14%**
Payadj (lot)	**$3,961.06**
Pay (lot)	**$189,100.66**

Table B-9. Southbound Lot 9 PRS Computation Results

LOT INFORMATION

Lot Number	9		Project No.	
Bid Price, $/sq yd	31.95		Begin Station	510+75
Lot Length, feet	2280	Check Stations	End Station	533+55
Lot Width, feet	24		Lane No's.	4 & 5
Resulting Lot Area, sq yds	6080.00		Paving Date(s)	

THICKNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Thickness Core 1, in	13.1	13	13.1	13.1	13.1				
Thickness IE 1 (avg of 3), in									
Sublot Thickness, in	13.1	13	13.1	13.1	13.1				

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	5	Lot AQL, in	13.0
Lot Thickness Mean, in	13.1	Lot RQL, in	12.0
Lot Thickness Mean Acceptable?	Yes	Lot MQL, in	14.0
Notes on Lot Thickness Mean:	Lot mean thickness is between RQL and MQL.		
Notes on Sublot Thickness Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9399		
Lot Thickness Std. Dev., in	0.04758		
Resulting Pay Factor:	**100.70%**		

STRENGTH

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Strength cylinder 1, psi	4,765	4,710	5,080	4,720	4,160				
Strength cylinder 2, psi	4,735	4,760	5,180	4,650	4,905				
Sublot Strength, psi	4750	4735	5130	4685	4532.5				

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	5	Lot AQL, psi	4500
Replicates per lot (m)	2.0	Lot RQL, psi	3000
Lot Strength Mean, psi	4766.5	Lot MQL, psi	5500
Lot Strength Mean Acceptable?	Yes		
Notes on Lot Strength Mean:	Lot mean strength is between RQL and MQL.		
Notes on Sublot Strength Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9399		
Lot Strength Std. Dev., psi	166.02		
Resulting Pay Factor:	**101.52%**		

SMOOTHNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
PI for Pass 1, in/mi	1.4	3.2	2.3	0	9.68				
PI for Pass 2, in/mi	1.9	3.9	3.8	1.39	17.78				
PI for Pass 3, in/mi	2	3.2	5.2	0.67	7.92				
PI for Pass 4, in/mi	1.6	4.6	4.4	1.78	9.51				
Sublot Mean PI, in/mi	1.73	3.73	3.93	0.96	11.22				

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	5	Lot AQL, in/mi	7.0
Replicates per lot (m)	4.0	Lot RQL, in/mi	9.0
Lot PI Mean, psi	4.5	Lot MQL, in/mi	0.0
Lot PI Mean Acceptable?	Yes		
Notes on Lot Smoothness Mean:	Lot mean smoothness is between RQL and MQL.		
Notes on Sublot Smoothness Mean:	Sublot(s) above RQL		
Std. Dev. Correction Factor	0.9399		
Lot Smoothness Std. Dev., in/mi	0.65		
Resulting Pay Factor:	**102.81%**		

RESULTS

All Pay Factors Determined?	Yes
Equal Number of Sublots?	Yes
PF Thickness	100.70%
PF Strength	101.52%
PF Smoothness	102.81%
PF Composite	**105.11%**
Payadj (lot)	**$9,922.34**
Pay (lot)	**$204,178.34**

Table B-10. Southbound Lot 10 PRS Computation Results

LOT INFORMATION

Lot Number	10		Project No.	
Bid Price, $/sq yd	31.95		Begin Station	535+15
Lot Length, feet	1823	Check Stations	End Station	553+38
Lot Width, feet	24		Lane No's.	4 & 5
Resulting Lot Area, sq yds	4861.33		Paving Date(s)	

THICKNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Thickness Core 1, in	12.9	12.9	13	13					
Thickness IE 1 (avg of 3), in									
Sublot Thickness, in	12.9	12.9	13	13					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in	13.0
Lot Thickness Mean, in	13.0	Lot RQL, in	12.0
Lot Thickness Mean Acceptable?	Yes	Lot MQL, in	14.0
Notes on Lot Thickness Mean:	Lot mean thickness is between RQL and MQL.		
Notes on Sublot Thickness Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9213		
Lot Thickness Std. Dev., in	0.06267		
Resulting Pay Factor:	**100.18%**		

STRENGTH

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Strength cylinder 1, psi	5,320	5,240	4,910	4,640					
Strength cylinder 2, psi	5,775	5,340	4,830	4,760					
Sublot Strength, psi	5547.5	5290	4870	4700					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, psi	4500
Replicates per lot (m)	2.0	Lot RQL, psi	3000
Lot Strength Mean, psi	5101.9	Lot MQL, psi	5500
Lot Strength Mean Acceptable?	Yes		
Notes on Lot Strength Mean:	Lot mean strength is between RQL and MQL.		
Notes on Sublot Strength Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9213		
Lot Strength Std. Dev., psi	297.00		
Resulting Pay Factor:	**102.93%**		

SMOOTHNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
PI for Pass 1, in/mi	4.22	1.9	0.9	2.1					
PI for Pass 2, in/mi	4.75	1.9	0.4	1					
PI for Pass 3, in/mi	4.75	1.7	1.1	1.5					
PI for Pass 4, in/mi	4.23	2.6	1.9	4.9					
Sublot Mean PI, in/mi	4.49	2.03	1.08	2.38					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in/mi	7.0
Replicates per lot (m)	4.0	Lot RQL, in/mi	9.0
Lot PI Mean, psi	2.1	Lot MQL, in/mi	0.0
Lot PI Mean Acceptable?	Yes		
Notes on Lot Smoothness Mean:	Lot mean smoothness is between RQL and MQL.		
Notes on Sublot Smoothness Mean:	All sublots are at or below RQL.		
Std. Dev. Correction Factor	0.9213		
Lot Smoothness Std. Dev., in/mi	0.96		
Resulting Pay Factor:	**105.19%**		

RESULTS

All Pay Factors Determined?	Yes
Equal Number of Sublots?	Yes
PF Thickness	100.18%
PF Strength	102.93%
PF Smoothness	105.19%
PF Composite	**108.46%**
Payadj (lot)	**$13,135.12**
Pay (lot)	**$168,454.72**

Table B-11. Southbound Lot 11 PRS Computation Results

LOT INFORMATION

Lot Number	11		Project No.	
Bid Price, $/sq yd	31.95		Begin Station	553+38
Lot Length, feet	1557	Check Stations	End Station	568+95
Lot Width, feet	24		Lane No's.	4 & 5
Resulting Lot Area, sq yds	4152.00		Paving Date(s)	

THICKNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Thickness Core 1, in	13.1	13	13	13.1					
Thickness IE 1 (avg of 3), in									
Sublot Thickness, in	13.1	13	13	13.1					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in	13.0
Lot Thickness Mean, in	13.1	Lot RQL, in	12.0
Lot Thickness Mean Acceptable?	Yes	Lot MQL, in	14.0
Notes on Lot Thickness Mean:	Lot mean thickness is between RQL and MQL.		
Notes on Sublot Thickness Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9213		
Lot Thickness Std. Dev., in	0.06267		
Resulting Pay Factor:	**100.58%**		

STRENGTH

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Strength cylinder 1, psi	4,850	4,860	4,520	4,740					
Strength cylinder 2, psi	4,840	4,820	4,860	4,600					
Sublot Strength, psi	4845	4840	4690	4670					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, psi	4500
Replicates per lot (m)	2.0	Lot RQL, psi	3000
Lot Strength Mean, psi	4761.3	Lot MQL, psi	5500
Lot Strength Mean Acceptable?	Yes		
Notes on Lot Strength Mean:	Lot mean strength is between RQL and MQL.		
Notes on Sublot Strength Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9213		
Lot Strength Std. Dev., psi	72.30		
Resulting Pay Factor:	**101.57%**		

SMOOTHNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
PI for Pass 1, in/mi	3.7	1.3	0.9	3.5					
PI for Pass 2, in/mi	6.3	2.8	3.4	4					
PI for Pass 3, in/mi	5.3	0.8	0.6	3					
PI for Pass 4, in/mi	5.5	2.7	1.8	3					
Sublot Mean PI, in/mi	5.20	1.90	1.68	3.38					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in/mi	7.0
Replicates per lot (m)	4.0	Lot RQL, in/mi	9.0
Lot PI Mean, psi	3.2	Lot MQL, in/mi	0.0
Lot PI Mean Acceptable?	Yes		
Notes on Lot Smoothness Mean:	Lot mean smoothness is between RQL and MQL.		
Notes on Sublot Smoothness Mean:	All sublots are at or below RQL.		
Std. Dev. Correction Factor	0.9213		
Lot Smoothness Std. Dev., in/mi	1.07		
Resulting Pay Factor:	**104.13%**		

RESULTS

All Pay Factors Determined?	Yes
Equal Number of Sublots?	Yes
PF Thickness	100.58%
PF Strength	101.57%
PF Smoothness	104.13%
PF Composite	**106.39%**
Payadj (lot)	**$8,470.70**
Pay (lot)	**$141,127.10**

Table B-12. Southbound Lot 12 PRS Computation Results

LOT INFORMATION

Lot Number	12		Project No.	
Bid Price, $/sq yd	31.95		Begin Station	568+95
Lot Length, feet	1693	Check Stations	End Station	585+88
Lot Width, feet	24		Lane No's.	4 & 5
Resulting Lot Area, sq yds	4514.67		Paving Date(s)	

THICKNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Thickness Core 1, in	13.1	12.8	13.1	12.5					
Thickness IE 1 (avg of 3), in									
Sublot Thickness, in	13.1	12.8	13.1	12.5					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in	13.0
Lot Thickness Mean, in	12.9	Lot RQL, in	12.0
Lot Thickness Mean Acceptable?	Yes	Lot MQL, in	14.0
Notes on Lot Thickness Mean:	Lot mean thickness is between RQL and MQL.		
Notes on Sublot Thickness Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9213		
Lot Thickness Std. Dev., in	0.31176		
Resulting Pay Factor:	**99.50%**		

STRENGTH

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Strength cylinder 1, psi	4,620	4,740	3,700	5,180					
Strength cylinder 2, psi	4,925	4,850	3,840	4,730					
Sublot Strength, psi	4772.5	4795	3770	4955					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, psi	4500
Replicates per lot (m)	2.0	Lot RQL, psi	3000
Lot Strength Mean, psi	4573.1	Lot MQL, psi	5500
Lot Strength Mean Acceptable?	Yes		
Notes on Lot Strength Mean:	Lot mean strength is between RQL and MQL.		
Notes on Sublot Strength Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9213		
Lot Strength Std. Dev., psi	415.64		
Resulting Pay Factor:	**100.41%**		

SMOOTHNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
PI for Pass 1, in/mi	3	4.5	4.1	1.2					
PI for Pass 2, in/mi	2.6	5.1	3.8	3.6					
PI for Pass 3, in/mi	2.3	2.6	3.7	3.2					
PI for Pass 4, in/mi	2.4	2.7	3.4	6.4					
Sublot Mean PI, in/mi	2.58	3.73	3.75	3.60					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in/mi	7.0
Replicates per lot (m)	4.0	Lot RQL, in/mi	9.0
Lot PI Mean, psi	3.5	Lot MQL, in/mi	0.0
Lot PI Mean Acceptable?	Yes		
Notes on Lot Smoothness Mean:	Lot mean smoothness is between RQL and MQL.		
Notes on Sublot Smoothness Mean:	All sublots are at or below RQL.		
Std. Dev. Correction Factor	0.9213		
Lot Smoothness Std. Dev., in/mi	0.36		
Resulting Pay Factor:	**103.92%**		

RESULTS

All Pay Factors Determined?	Yes
Equal Number of Sublots?	Yes
PF Thickness	99.50%
PF Strength	100.41%
PF Smoothness	103.92%
PF Composite	**103.83%**
Payadj (lot)	**$5,517.48**
Pay (lot)	**$149,761.08**

Table B-13. Southbound Lot 13 PRS Computation Results

LOT INFORMATION

Lot Number	13		Project No.	
Bid Price, $/sq yd	31.95		Begin Station	585+88
Lot Length, feet	1872	Check Stations	End Station	604+60
Lot Width, feet	24		Lane No's.	4 & 5
Resulting Lot Area, sq yds	4992.00		Paving Date(s)	

THICKNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Thickness Core 1, in	12.8	12.9	13	12.7					
Thickness IE 1 (avg of 3), in									
Sublot Thickness, in	12.8	12.9	13	12.7					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in	13.0
Lot Thickness Mean, in	12.9	Lot RQL, in	12.0
Lot Thickness Mean Acceptable?	Yes	Lot MQL, in	14.0
Notes on Lot Thickness Mean:	Lot mean thickness is between RQL and MQL.		
Notes on Sublot Thickness Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9213		
Lot Thickness Std. Dev., in	0.14013		
Resulting Pay Factor:	**99.60%**		

STRENGTH

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Strength cylinder 1, psi	4,610	4,460	4,960	4,530					
Strength cylinder 2, psi	4,960	4,710	4,330	4,490					
Sublot Strength, psi	4785	4585	4645	4510					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, psi	4500
Replicates per lot (m)	2.0	Lot RQL, psi	3000
Lot Strength Mean, psi	4631.3	Lot MQL, psi	5500
Lot Strength Mean Acceptable?	Yes		
Notes on Lot Strength Mean:	Lot mean strength is between RQL and MQL.		
Notes on Sublot Strength Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.9213		
Lot Strength Std. Dev., psi	89.36		
Resulting Pay Factor:	**100.95%**		

SMOOTHNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
PI for Pass 1, in/mi	1.2	1.3	0.68	1.15					
PI for Pass 2, in/mi	3.6	4.2	4.59	7.8					
PI for Pass 3, in/mi	3.2	4.8	4.55	7.67					
PI for Pass 4, in/mi	6.4	3.5	1.18	1.99					
Sublot Mean PI, in/mi	3.60	3.45	2.75	4.65					

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	4	Lot AQL, in/mi	7.0
Replicates per lot (m)	4.0	Lot RQL, in/mi	9.0
Lot PI Mean, psi	3.1	Lot MQL, in/mi	0.0
Lot PI Mean Acceptable?	Yes		
Notes on Lot Smoothness Mean:	Lot mean smoothness is between RQL and MQL.		
Notes on Sublot Smoothness Mean:	All sublots are at or below RQL.		
Std. Dev. Correction Factor	0.9213		
Lot Smoothness Std. Dev., in/mi	0.25		
Resulting Pay Factor:	**104.36%**		

RESULTS

All Pay Factors Determined?	Yes
Equal Number of Sublots?	Yes
PF Thickness	99.60%
PF Strength	100.95%
PF Smoothness	104.36%
PF Composite	**104.93%**
Payadj (lot)	**$7,869.53**
Pay (lot)	**$167,363.93**

Table B-14. Southbound Lot 14 PRS Computation Results

LOT INFORMATION

Lot Number	14		Project No.	
Bid Price, $/sq yd	31.95		Begin Station	626+21
Lot Length, feet	1850	Check Stations	End Station	644+71
Lot Width, feet	24		Lane No's.	4 & 5
Resulting Lot Area, sq yds	4933.33		Paving Date(s)	

THICKNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Thickness Core 1, in	12.5	13.1	13						
Thickness IE 1 (avg of 3), in									
Sublot Thickness, in	12.5	13.1	13						

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	3	Lot AQL, in	13.0
Lot Thickness Mean, in	12.9	Lot RQL, in	12.0
Lot Thickness Mean Acceptable?	Yes	Lot MQL, in	14.0
Notes on Lot Thickness Mean:	Lot mean thickness is between RQL and MQL.		
Notes on Sublot Thickness Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.8862		
Lot Thickness Std. Dev., in	0.36273		
Resulting Pay Factor:	**99.39%**		

STRENGTH

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
Strength cylinder 1, psi	5,340	4,750	5,435						
Strength cylinder 2, psi	5,530	4,780	4,765						
Sublot Strength, psi	5435	4765	5100						

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	3	Lot AQL, psi	4500
Replicates per lot (m)	2.0	Lot RQL, psi	3000
Lot Strength Mean, psi	5100.0	Lot MQL, psi	5500
Lot Strength Mean Acceptable?	Yes		
Notes on Lot Strength Mean:	Lot mean strength is between RQL and MQL.		
Notes on Sublot Strength Mean:	All sublots are at or above RQL		
Std. Dev. Correction Factor	0.8862		
Lot Strength Std. Dev., psi	267.30		
Resulting Pay Factor:	**102.94%**		

SMOOTHNESS

	Sublot 1	Sublot 2	Sublot 3	Sublot 4	Sublot 5	Sublot 6	Sublot 7	Sublot 8	Sublot 9
PI for Pass 1, in/mi	3.9	6.3	3.41						
PI for Pass 2, in/mi	1.8	4.8	2.62						
PI for Pass 3, in/mi	8.6	5.45	7.21						
PI for Pass 4, in/mi	6.5	4.18	5.48						
Sublot Mean PI, in/mi	5.20	5.18	4.68						

Information must be provided for at least 3 full sublots

Resulting Samples per lot (n)	3	Lot AQL, in/mi	7.0
Replicates per lot (m)	4.0	Lot RQL, in/mi	9.0
Lot PI Mean, psi	3.8	Lot MQL, in/mi	0.0
Lot PI Mean Acceptable?	Yes		
Notes on Lot Smoothness Mean:	Lot mean smoothness is between RQL and MQL.		
Notes on Sublot Smoothness Mean:	All sublots are at or below RQL.		
Std. Dev. Correction Factor	0.8862		
Lot Smoothness Std. Dev., in/mi	0.17		
Resulting Pay Factor:	**103.59%**		

RESULTS

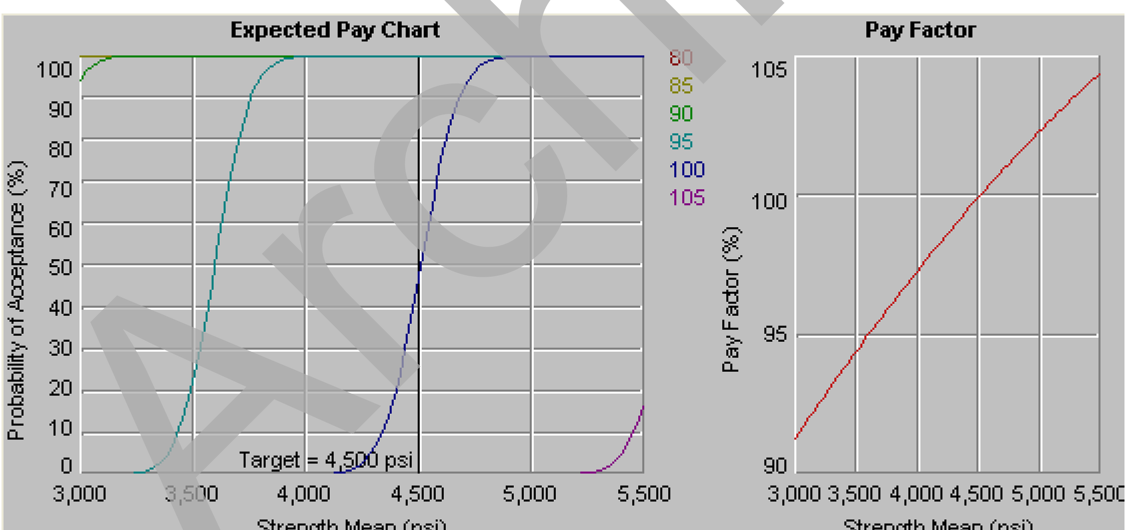
All Pay Factors Determined?	Yes
Equal Number of Sublots?	Yes
PF Thickness	99.39%
PF Strength	102.94%
PF Smoothness	103.59%
PF Composite	**105.98%**
Payadj (lot)	**$9,432.15**
Pay (lot)	**$167,052.15**

APPENDIX C—Expected Pay Information

EXPECTED PAY CHARTS

Information can be developed that shows the risks of using the plan to both the agency and the contractor. The PaveSpec software provides expected pay charts, which are graphical representations of an acceptance plan, that show the relation between the actual quality of a given lot and the pay the contractor can expect to receive (on average) for submitted lots of that quality. Figures C-1, C-2, C-3, and C-4 show the expected pay for strength (with two different standard deviations), thickness, and smoothness or profile index, respectively.

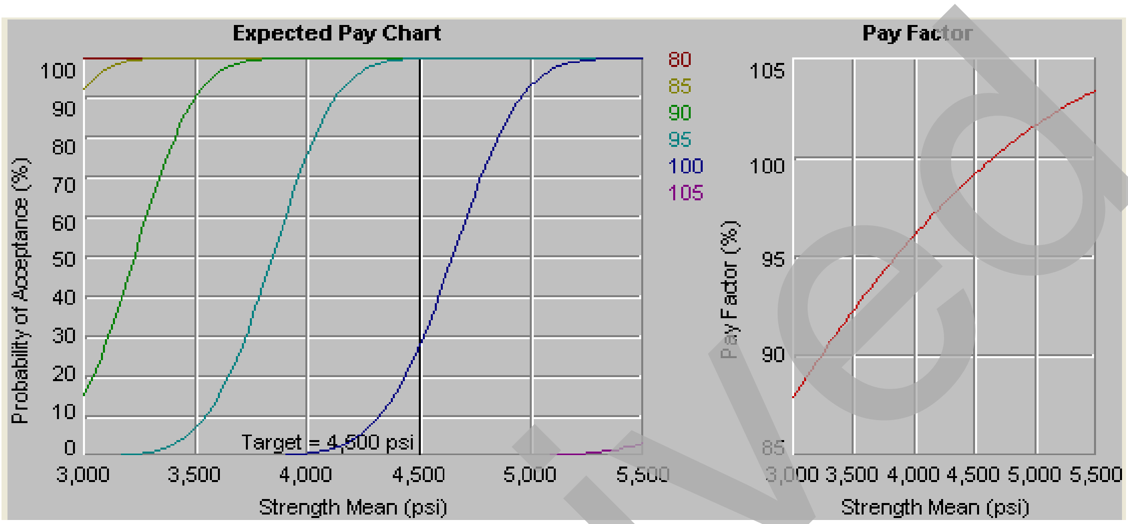
Focusing on strength as an example, if the contractor produces a lot with exactly the target mean strength of 4,500 lbf/in^2 (31.03 MPa) and standard deviation of 500 lbf/in^2 (3.45 MPa), figure C-1 (left side chart) shows that the probability of acceptance with, say, 100 percent pay or better is 50 percent (which of course is logical). If the contractor desires a higher probability to achieve an incentive, the mean strength of the lot could be increased to, say, 4,750 lbf/in^2 (32.75 MPa). The probability of acceptance with at least 100 percent is then 95 percent. For this true lot mean strength of 4,750 lbf/in^2 (32.75 MPa), the right hand chart of figure C-1 shows that the contractor would be expected to receive 102 percent 50 percent of the time. If the contractor wanted to greatly increase his pay factor, the mean lot strength would have to be increased to, say, 5,500 lbf/in^2 (37.92 MPa) where the expected pay factor would be about 104 percent. Obviously many other statements could be created to analyze the risks using the acceptance plan. Also, changing the number of samples per sublot would change the slope of these curves.



1 psi = 6.89 kPa

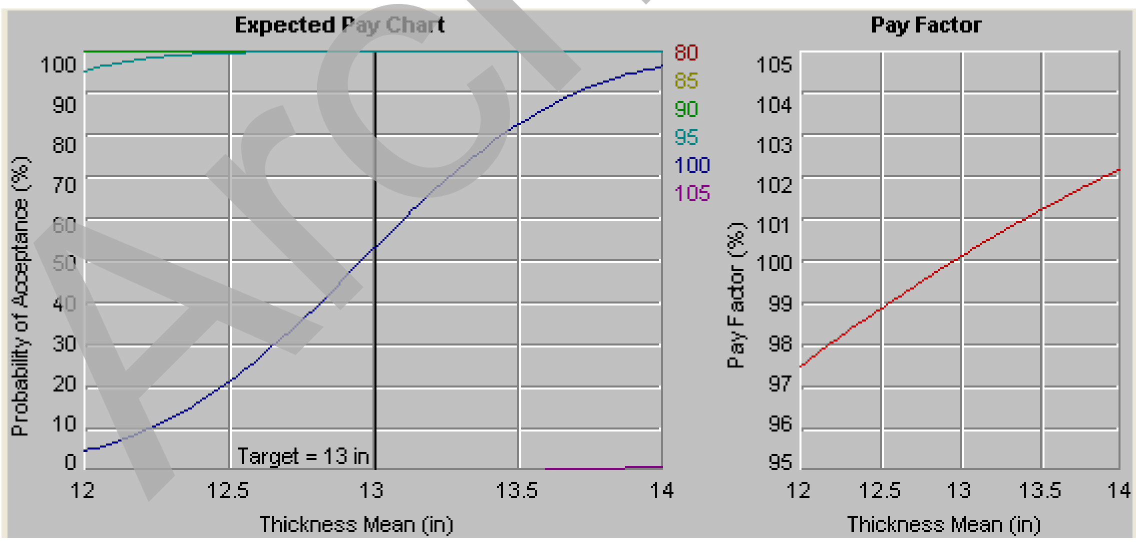
Figure C-1. Expected pay chart for compressive strength (standard deviation = 500 lbf/in^2).

Figure C-2 shows the impact of increased variation of strength on the risks involved to the agency and contractor. This expected pay chart is developed for a standard deviation of 1,000 lbf/in^2 (6.89 MPa) of strength or twice the variability of figure C-1. In this case, if the lot mean is truly at 4,500 lbf/in^2 (31.03 MPa), the probability of receiving 100 percent pay is reduced to 30 percent rather than 50 percent with a standard deviation of 500 lbf/in^2 (3.45 MPa). The mean expected pay factor is 99 percent.



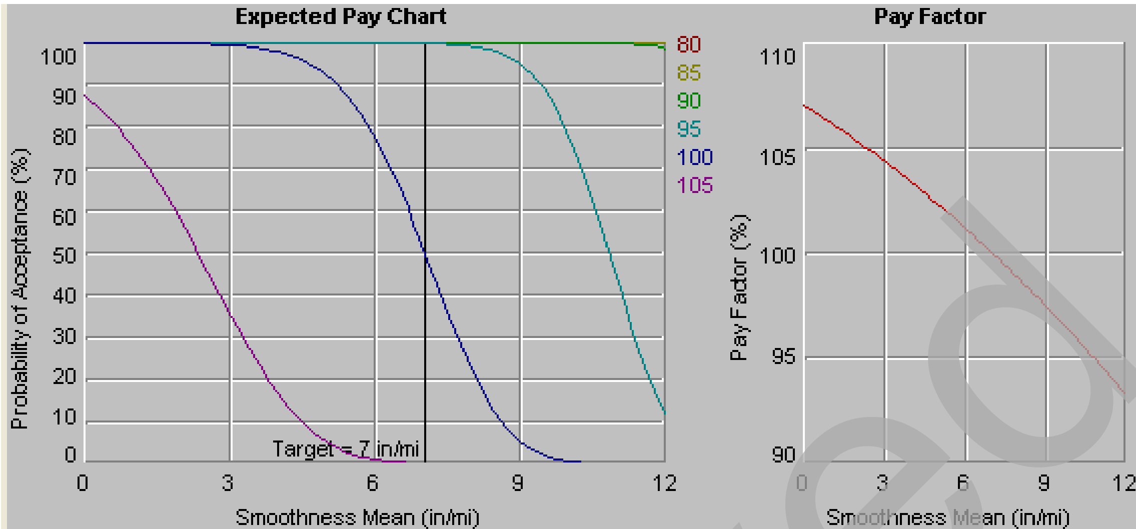
1 psi = 6.89 kPa

Figure C–2. Expected pay chart for compressive strength (standard deviation = 1,000 lbf/in^2).



1 in. = 25.4 mm

Figure C–3. Expected pay chart for slab thickness (standard deviation = 0.5 in.).



1 in./mi = 16 mm/km

Figure C-4. Expected pay chart for profile index (standard deviation = 1.0 in.).

The expected pay curves developed by PaveSpec provide very useful information for the contractor and the agency to assess the risks associated with the performance-related specification.

U.S. Department of Transportation
Federal Highway Administration

Office of Infrastructure
Office of Pavement Technology
Federal Highway Administration
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

Telephone: 202-366-0120
Fax: 202-493-2070
www.fhwa.dot.gov/infrastructure/pavement/concrete

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