Portland Cement Concrete Pavements Research

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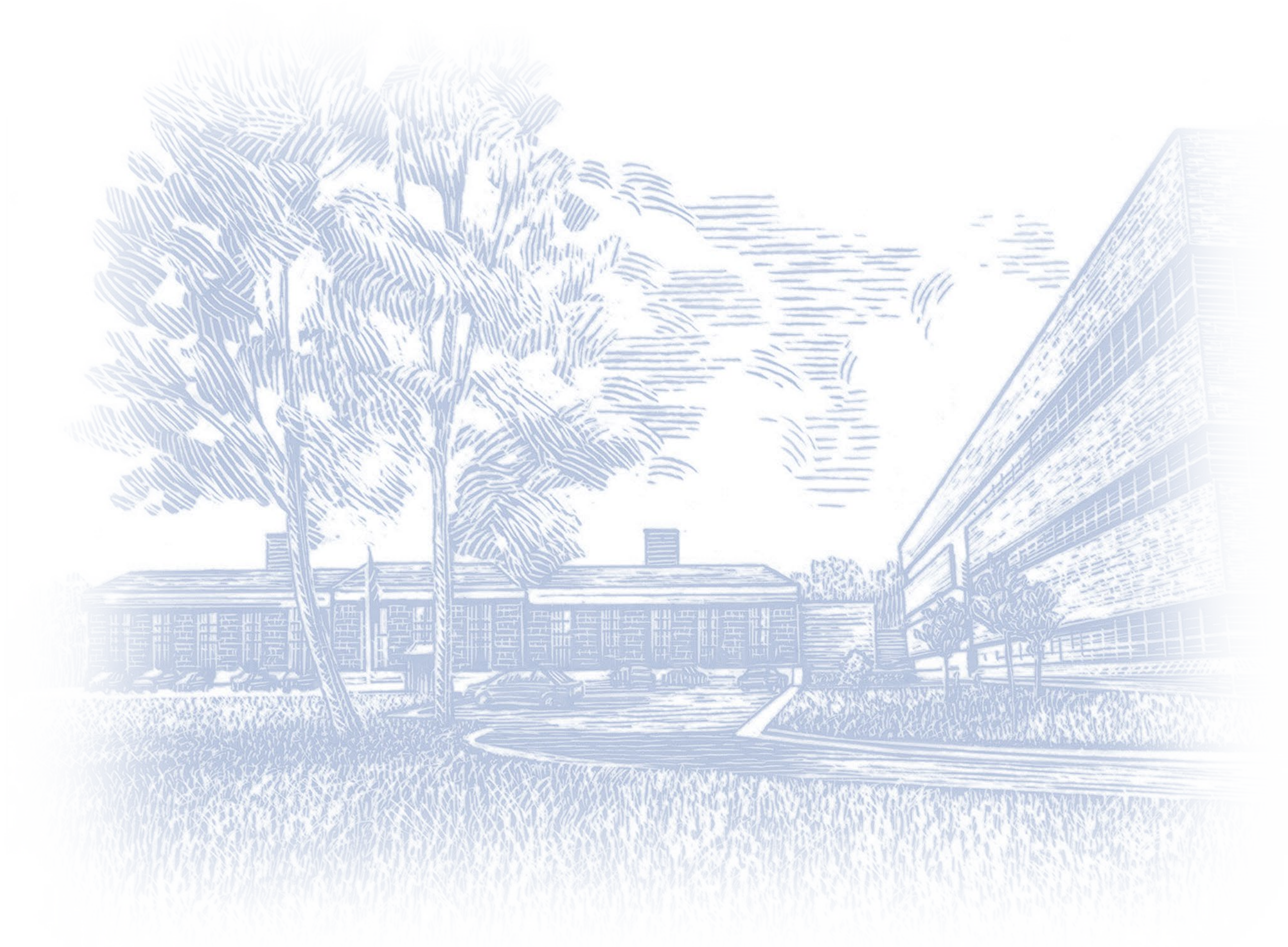

U.S. Department of Transportation
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Table of Contents

List of Figures

List of Tables

What Are Performance-Related Specifications?

Over the past 25 years, there has been a growing interest in the development of performance-related specifications (PRS) for highway pavement construction. PRS are similar to quality assurance specifications; however, the measured acceptance quality characteristics (or AQC's, which include concrete strength, slab thickness, initial smoothness and others) are directly related to pavement performance through mathematical relationships. Performance is defined by key distress types and smoothness and is directly related to the future maintenance, rehabilitation, and user costs of the highway. This link between measured AQC's and future life-cycle costs (LCC's) provides the ability to develop rational and fair contractor pay adjustments that depend on the as-constructed quality delivered for the project (figure 1 illustrates these concepts).

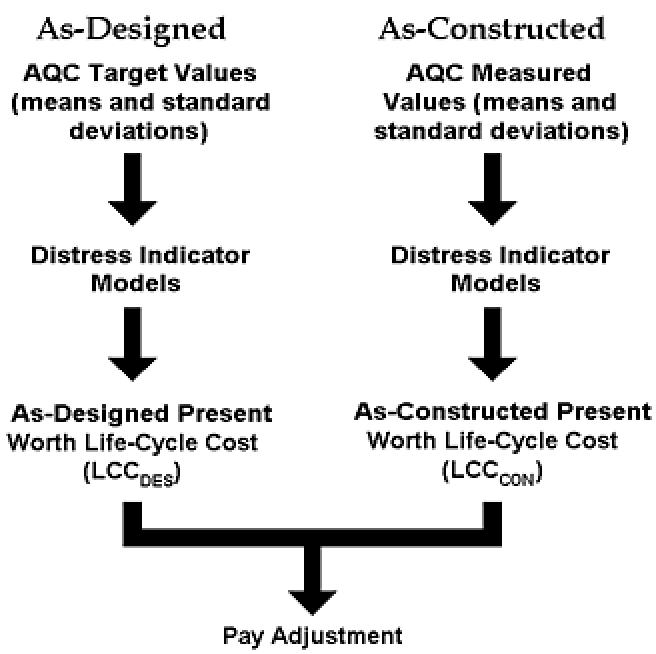

Figure 1. Basic concepts of the LCC-based PRS method used to establish contractor pay adjustments.

The State highway agency (SHA) must define the as-designed or target levels of quality for which it is willing to pay 100 percent of the bid price. Prior to bidding, the contractor is made fully aware of this desired level of quality and the price adjustments to be applied when this level is not obtained. Contractor pay for a lot is based on the difference between the as-designed target LCC and the as-constructed LCC, subjected to specified limitations by the SHA.

The clear and rational approach of PRS, with well-defined SHA 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. PRS also offer the opportunity to optimize the design and construction process to provide acceptable performance for lower LCC's.

A prototype PRS, using this methodology, was first developed under a previous Federal Highway Administration (FHWA) project conducted during the early 1990's.[1,2,3] Under the current FHWA project, the prototype PRS were revised and expanded to make them more practical. Three different implementation levels (Level 1, Level 2, and Level 3) were defined, with the first (Level 1) being a simplified PRS that should be reasonably compatible with current SHA sampling and testing procedures.

Key Products Of This Research

- Definition of the three levels of PRS development and implementation for jointed-plain concrete pavement (JPCP) highways and full development of a simplified Level 1 PRS approach for JPCP highways. This Level 1 PRS is implementable and does not normally require major changes to an SHA's current sampling and testing procedures.

- Complete stand-alone specifications for the Level 1 and Level 2 PRS (included as appendix A in volume I), along with user-friendly software (PaveSpec 2.0) to assist in PRS implementation and usage (see volume IV). SHA's and contractors can readily utilize PaveSpec 2.0 to demonstrate the PRS and to determine the risks and consequences of varying levels of quality.

- Practical guide to developing and implementing the revised Level 1 and Level 2 PRS. This practical guide (included as volume I) not only provides guidelines and recommendations for making the required PRS-related decisions, but also includes step-by-step procedures to using the PRS.

- Successful field investigations into the practicality and implementability of both the Level 1 and Level 2 PRS approaches (see volume II). The following three investigative methods were used: (1) shadow field demonstrations, (2) demonstration of the development of PRS for three functional classes of highways in a given SHA, and (3) comparing PRS-based vs. actual SHA price adjustments using historical project data.

The PaveSpec 2.0 Software And The Practical Guide

The PaveSpec 2.0 software was created to demonstrate and apply all aspects of the current PRS methodology (both Level 1 and Level 2). Some of the program's specific capabilities include:

- Simulation of pavement performance (key distresses, smoothness).

- Application of a user-defined maintenance and rehabilitation (M & R) plan; computation of lot LCC's; simulation of Level 1 AQC pay factor charts (an example of which is presented in figure 2).

- Computation of contractor lot pay factors (pay adjustments) based on actual measured AQC data. Simulation of the consequences and risks of achieving different levels of quality for a project.

- The ability to conduct sensitivity analyses on a given developed specification.

The PaveSpec 2.0 software is an invaluable tool for demonstrating and clarifying the revised PRS concepts to both the SHA and the contractor. It is also an excellent technology transfer tool for SHA's and contractors.

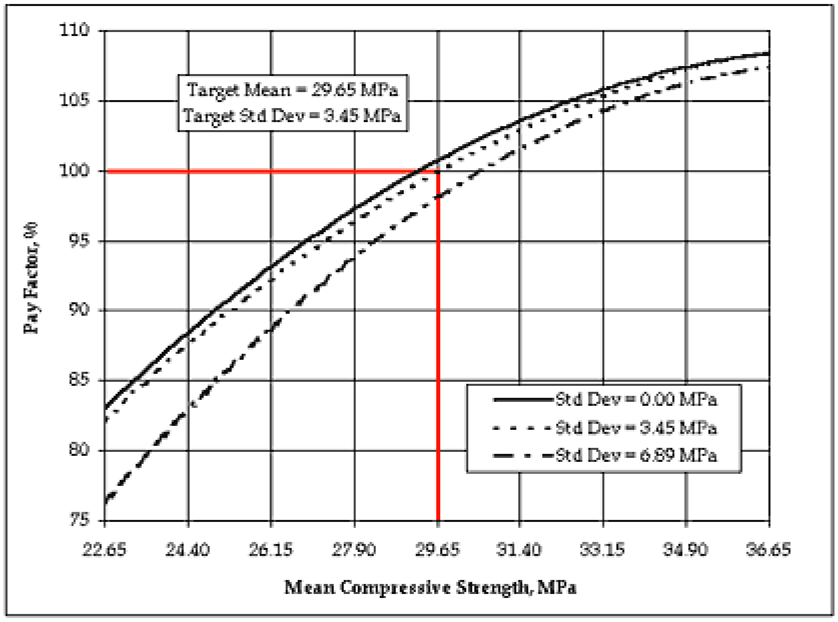

Figure 2. Example of a Level 1 pay factor chart for concrete strength. (Similar charts are developed for each AQC included in the PRS.)

Implementation Of The Level 1 PRS

It is recommended that an SHA interested in implementing a PRS for the acceptance of JPCP highway pavements begin with the implementation of the simplified Level 1 PRS. The Level 1 approach is explained in table 1.

Table 1. Summary of the basic steps used to develop Level 1 PRS.

1.	Define the general project information	This information includes items such as project location, lane configuration, starting and ending stations, and lane widths.
2.	Define pavement performance	Pavement performance is defined in terms of distress indicators. The following distress indicator models (shown with their associated AQC's) are available: • Transverse cracking (fatigue)—*function of concrete strength and slab thickness*. • Transverse joint faulting—*function of concrete strength, slab thickness, and percent consolidation around dowels (optional)*. • Transverse joint spalling—*function of air content and concrete strength (both are optional)*.

		• Pavement smoothness over time (Present Serviceability Rating [PSR] or International Roughness Index [IRI])—*function of initial smoothness and other predicted distress indicators*.
3.	Select the AQC's to include in the PRS	Include one or more of the following AQC's: concrete strength, slab thickness, entrained air content, initial smoothness, and percent consolidation around dowels.
4.	Define the required constant variables	A number of design-, climatic-, and traffic-related variables must be defined for the project. These required constant inputs correspond to the variables included in the distress indicator models.
5.	Define the AQC acceptance sampling and testing plan	The SHA must define the acceptance sampling and testing procedures used to measure the included AQC's in the field. This plan not only defines the actual required sampling and testing methods to be used, but it also defines the number of samples per sublot and the methods for determining random sampling locations.
6.	Determine the required AQC target values	The SHA must select as-designed target means and standard deviations for each of the included AQC's. (Note: The selected target values are dependent on the selected sampling and testing plan.) The target values identify the quality for which the SHA is willing to pay 100 percent.
7.	Define lots and sublots	Lots and sublots must be clearly defined for the project. A lot is typically chosen as one day's paving (or less). Each lot is divided into approximately equal area sublots. The target sublot length must be defined so that all included AQC's can be sampled from each sublot.
8.	Define the maintenance and rehabilitation plan	The selected M & R plan defines the type and frequency of application for maintenance and rehabilitation activities to be applied in response to predicted distress conditions.
9.	Define the included costs	The SHA must identify the particular costs to be included in the overall lot LCC. These decisions include identifying the M & R unit costs associated with the chosen M & R activities, defining an appropriate percentage of user costs to be included, and determining an appropriate discount rate.
10.	Define the simulation parameters	In order to conduct LCC simulations for the as-designed target or as-constructed pavement, the SHA must define the required simulation parameters (e.g., the number of simulation lots

		required to simulate a representative lot LCC and the number of sublots per lot).
11.	Develop individual AQC pay factor charts and corresponding equations	Individual AQC pay factor charts are developed specific to those AQC's included in the specification. Each chart is made up of a series of pay factor curves (each specific to a different AQC standard deviation) plotted over a chosen range of AQC mean (see figure 2). Pay factor regression equations are fit through simulated data points making up each pay factor curve. Individual AQC pay factors are determined using the developed regression equations by knowing the as-constructed AQC lot means and standard deviations.
12.	Define the composite pay factor equation	The overall lot pay factor is computed using a defined composite pay factor (CPF) equation. The CPF equation is a simple mathematical function of the individual AQC pay factors determined using the pay factor charts and equations developed in step 11.
13.	Define practical pay factor limits	The SHA must define practical pay factor limits to the computed individual AQC pay factors and the lot CPF.
14.	Develop and analyze expected payment curves	Expected payment (EP) curves should be developed and analyzed to make sure the expected payment at the target values is at or near 100 percent with the step 13 limits in effect.

Impacts Of This Study

Some of the recognized benefits of PRS to SHA's and contractors are the following:

- PRS require the establishment of clear AQC target values (means and standard deviations) that define the pavement quality for which the SHA is willing to pay 100 percent of the contractor bid price.

- PRS provide a straightforward method for determining rational (LCC-driven) pay adjustments (incentives and disincentives) that are applied when a higher or lower level of quality (as compared to the chosen AQC target values) is produced by the contractor. Potential contractors are made fully aware of the pay adjustments prior to bidding a project and can also utilize the PaveSpec 2.0 software to evaluate the consequences and risks of providing different levels of quality and the risks involved in sampling and testing.

- PRS relate the quality of pavement construction to the performance and subsequent LCC's of a given pavement lot. This ability provides the opportunity to identify optimum levels of AQC construction quality that would minimize LCC's while maintaining desired performance.

References

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