TECHBRIEF

Improved Prediction Models for PCC Pavement Performance-Related Specifications

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The FHWA Pavement Technology Program is a comprehensive and focused set of coordinated activities. These activities are grouped under five major areas—Asphalt; Portland Cement; Pavement Design and Management; Advanced Research; and Long Term Pavement Performance. The goal of the program is the development, delivery, and utilization of a broad spectrum of improved technologies that will lead to better-performing and more cost-effective pavements. The program is product and end-result oriented with the intent of significantly advancing and improving pavement technology and pavement performance.

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Performance-related specifications (PRS) for the acceptance of newly constructed jointed plain concrete pavements (JPCP) have been developed over the past decade. A PRS is a construction specification that describes the target levels of key materials and construction acceptance quality characteristics (AQC's) that have been found to correlate with key pavement performance indicators (distress and smoothness). These AQC's (e.g., initial smoothness, thickness, strength, air content, and percent consolidation around dowels) are amenable to acceptance testing at the time of construction. PRS also provide rational methods for contract price adjustment based on the difference between the as-designed and as-constructed life-cycle costs (LCC's) of the pavements. Thus, it is critical that PRS employ valid distress and smoothness prediction models to accurately relate the AQC's to future pavement performance and associated LCC.

Research Objectives and Approach

The main objectives of this study were to improve the distress and smoothness prediction models used in the current PRS approach for JPCP, and to provide guidelines for calibrating these models for local conditions. Both the improved prediction models and the calibration procedure were implemented in the PaveSpec 3.0 PRS software. The current PRS approach is fully discussed in the literature.[1-3]

To achieve the above objectives, the project team enhanced existing models for predicting:

- Transverse joint faulting.
- Transverse fatigue cracking.
- Transverse joint spalling.
- International Roughness Index (IRI).
- Initial IRI as a function of initial Profile Index (PI).

Field performance data were obtained from the Long Term Pavement Performance (LTPP) study, the Federal Highway Administration's Rigid Pavement Performance and Rehabilitation study, and the National Cooperative Highway Research Program (NCHRP) 1-19 study. These data included 447 JPCP sections located in 36 States and Canadian Provinces.

Improved Performance Models

The improved models are described in table 1 below in terms of AQC's that are included in the model and diagnostic statistics (coefficient of determination [R^2], standard error of estimate [SEE], and number of data points [N]). Since IRI is predicted as a function of faulting, cracking, and spalling, the AQC's shown in table 1 affect the IRI through their effect on these distresses.

These models are used for predicting performance over time for the as-designed pavement and the as-constructed pavement. The future LCC is computed based on the predicted performance and scheduled rehabilitation activities. Price adjustment is made using the following criteria:

Incentives: The AQC's of the as-constructed pavement are superior to those of the as-designed pavement; thus, the as-constructed pavement has improved performance and lower LCC.

Disincentives: The AQC's of the as-constructed pavement are inferior to those of the as-designed pavement; thus, the as-constructed pavement has reduced performance and higher LCC.

Example Application of the Improved Models

In this example, the improved models were used for predicting performance for the design shown in figure 1. The relative effects of PCC slab thickness, strength, and initial IRI on cracking and IRI were evaluated.

Figure 2 shows the effect of quality of construction on IRI using the model developed in this study for the following lots:

- As-designed lot (target quality levels).
- As-constructed Lot A (high quality): 10 percent lower initial PI and 10

Table 1. Description of the improved models for JPCP.

Model	AQC's of Portland Cement Concrete (PCC)	Diagnostic Statistics
Faulting	• Slab thickness • Consolidation of PCC around dowels	R^2 = 0.56 SEE = 0.029 in/joint(1) N = 511
Cracking	• Slab thickness • PCC strength	R^2 = 0.56 SEE = 9.3% of slabs N = 815
Spalling	• Slab thickness • Air content • PCC strength	R^2 = 0.78 SEE = 6.8% of joints N = 179
IRI	• Initial IRI • All the above factors	R^2 = 0.70 SEE = 0.35 m/km N = 183
PI to IRI	Direct correlation	R^2 = 0.76 to 0.8(2) N = 5000

(1) 1 in = 25.4 mm (2) Range for zero, 2.5-mm, and 5-mm blanking bands.

percent higher compressive strength than the as-designed lot.

- As-constructed Lot B (poor quality): 10 percent higher PI and 10 percent lower compressive strength than the as-designed lot.

This is a large difference in IRI over time from "good" to "poor" quality of construction.

Figure 3 (on the following page) shows the effect of the quality of construction on pay factor (PF). For example, if the as-constructed slab thickness were 10 percent higher than the as-designed slab thickness, the PF would be 115 percent of the bid price. On the other hand, if the as-constructed slab thickness were 10 percent lower than the as-designed slab thickness, the PF would be 85 percent of the bid price.

Calibration of Prediction Models

Practical guidelines were developed for calibrating existing national performance prediction models to reflect local conditions. For example, a State could utilize its LTPP sections or other test sections that have the required data to calibrate each of the performance models included in the PRS (faulting, spalling, cracking, and IRI).

PaveSpec Software

The PaveSpec PRS software was upgraded to version 3.0 under this project to implement the improved models and calibration procedure. The improved software demonstrates all aspects of the current PRS methodology and provides the following general capabilities:

Figure 1. Example JPCP target design, including AQC's.

Key Design Features	Key Site Conditions
Dowel Diameter = 1.5 in	Initial ESAL/year = 1 million
Joint Spacing = 15 ft	ESAL Growth Rate = 5% (simple)
Asphalt Shoulders	Dynamic k-Value = 200 psi/in
Dense-Graded Aggregate Base	Wet-Freeze Zone
(non-preformed joint sealant)	Freezing Index = 300°F-days

As-Designed AQC's (Target)

	Mean	Standard Deviation
Slab Thickness =	9 in	0.2 in
PCC 28-day Compressive Strength =	4000 psi	400 psi
Air Content =	7%	1%
Initial PI (0.2BB) =	7 in/mi	1.5 in/mi
Consolidation =	100%	1%

1 in = 25.4 mm, 1 ft = 0.305 m, 1 mi = 1.61 km, 1 psi = 6.89 kPa, °C = (F-32)/1.8

Figure 2. Illustration of effect of construction quality on performance.

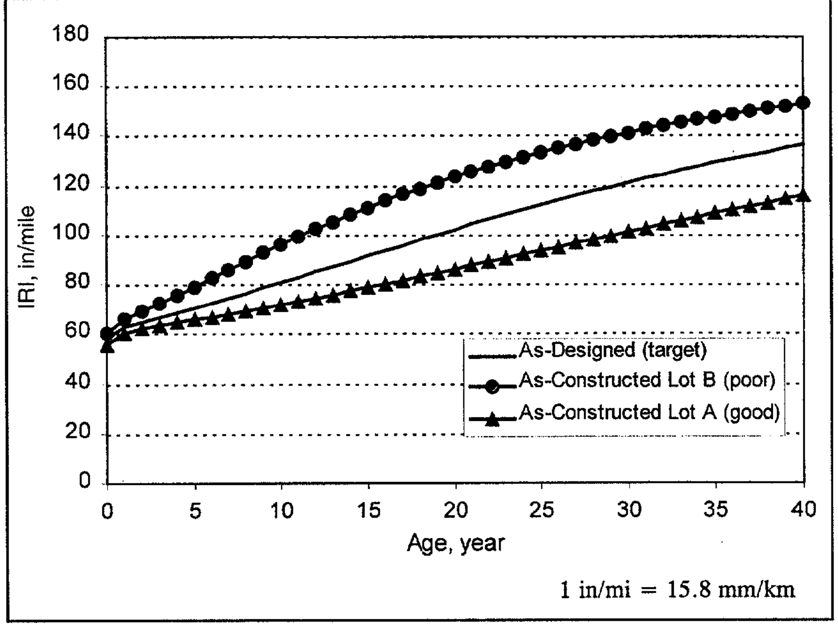
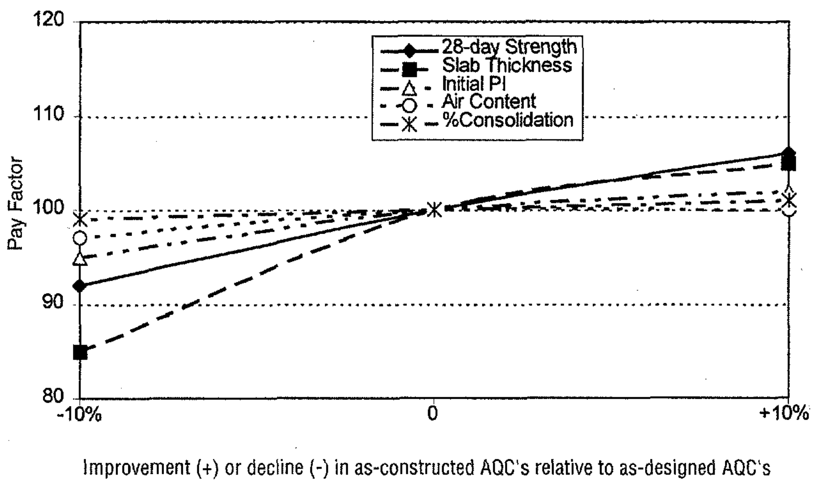


Figure 3. Illustration of effect of construction quality on contractor pay factor.



Development of a specification—The program helps the user to develop rational LCC-based pay factor curves associated with each AQC (concrete strength, slab thickness, concrete entrained air content, initial smoothness, and percent consolidation of concrete around dowels).

Evaluation of a developed specification—The user can perform sensitivity analysis to investigate the effects of AQC changes on pay factors. Also, the expected pay charts help analyze the risks for both the agency and the contractor.

Use of a developed specification—Performance-related lot pay factors (and pay adjustments) may be computed using actual AQC field data.

References

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Key Words—Jointed plain concrete pavement, pavement performance models, pavement construction, quality assurance, performance-related specifications, acceptance tests, life-cycle costs.