LARGE-SCALE DEPLOYMENT OF PERFORMANCE-RELATED SPECIFICATIONS FOR
JOINTED PLAIN CONCRETE PAVEMENT – RESULTS AND LESSONS LEARNED

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ABSTRACT
On May 18, 2015, jointed plain concrete (JPC) paving began on one of nine performance-related specification (PRS) contracts along the Jane Addams Tollway (I-90) west of Chicago. The nine contracts consisted of reconstruction and widening projects for the pavement and bridges that carry between 40,000 and 80,000 vehicles per day into and out of the City of Chicago. While the contracts included a host of activities and pay items, the JPC pavements that will make up the mainline lanes of I-90 were all built according to the Illinois Tollway PRS Special Provision. Overall, approximately 750,000 square yards of JPC were placed in 2015 using PRS pay factor adjustments based on how the contractors performed relative to the target values in five performance categories: plastic air content, thickness, dowel alignment, 28-day compressive strength, and pavement surface smoothness.

To manage all of the data collected for the PRS projects, a summary spreadsheet was established for each contract. All data are stored and reported by sublot, and the data are used to calculate the individual pay factors specific to each quality characteristic, as well as the overall pay factor for the contract.

Keywords: Performance-related specifications, Jointed Plain Concrete Pavement
INTRODUCTION
The Illinois Tollway is currently in the middle of a 15-year, $12 billion dollar capital program referred to as Move Illinois that includes the reconstruction and capacity expansion of the I-90 corridor between Chicago and Rockford. For the 2015 construction season, nine contracts were awarded that included pay items for “Jointed Plain Concrete Pavement – Performance Related.” Information on the background of the Tollway’s PRS effort was described in a previous paper (1). The focus of this paper is to present the results of one of the largest performance-related specification (PRS) implementations ever undertaken, where $50 million of JPC paving was placed and paid for using PRS pay factors.

BACKGROUND
The concept of PRS for concrete pavements has been around for over 30 years (2, 3). The Federal Highway Administration published its initial guide to developing PRS over 15 years ago (4). In the subsequent years, the PaveSpec program was created to assist agencies interested in implementing PRS for jointed plain concrete (JPC) pavement projects (5).

For the Illinois Tollway implementation of PRS, a Microsoft Excel-based workbook was developed to store all of the relevant testing data and calculate the quality pay factors for each of the quality characteristics (air content, 28-day compressive strength, thickness, dowel bar alignment, and rideability/smoothness of the pavement surface). The Tollway spreadsheet incorporates the PaveSpec 4.0 methodology in that the prediction of pavement performance is based on mechanistic-empirical pavement models and project-specific traffic and climatic inputs.

THE TOLLWAY PRS PROCESS
Since the Tollway had not previously implemented PRS on the scale of the 2015 contracts (which were part of the largest single year of capital expenditures in the history of the Tollway), a complete process needed to be established that would include the collection of all of the testing data, communication with the contractors when results were available, and a mechanism for resolving issues that were bound to arise between the Tollway and the paving contractors.

The first step in establishing the PRS process was the development of a summary spreadsheet for each contract. The spreadsheets would contain all of the data collected for each of the quality characteristics, as well as the up-to-date pay factors (both by quality characteristic and for the overall contract) and a record of the communication taking place between the Tollway, the independent assurance (IA) consultant, and the paving contractors.

The Tollway PRS spreadsheets are specific to each contract, and they contain raw data for each quality characteristic as well as the subplot level averages used to calculate the various pay factors. For the thickness, dowel alignment, and smoothness data, the raw data are entered into the spreadsheet after the appropriate values are calculated using the device-specific software. For the air content and compressive strength data, additional tabs are included in the summary spreadsheet that contain data as they are extracted from the Tollway’s materials database.

To date, approximately 500 versions of these spreadsheets have been created, as a new one is created each time new data are available for a contract. The spreadsheet archive is maintained in a ShareFile site that provides access to each member of the Tollway PRS team, allowing for data to be added by the various groups responsible for collecting the quality characteristic data.

One of the most critical components of the Tollway PRS implementation has been the communication of test results to the contractors on a regular basis. The Tollway has used E-Builder as means of transmitting the data so that a record of communication between the
Tollway, IA, and the contractors will be generated. To date, nearly 10,000 communication transactions have taken place in the E-BUILDER system.

RESULTS TO DATE
The following sections contain details regarding the various quality characteristics, including the results seen throughout 2015, the relevant pay factor impacts for each of the quality characteristics, and some of the lessons learned after having implemented PRS for JPC on this large a scale.

Air Content
The first piece of data collected for each sublot was the plastic air content recorded at the time of placement. The target value for air content was 6.5 percent for all contracts, which also represented the highest point on the pay factor chart, as shown in figure 1. Average air contents either above or below 6.5 percent resulted in lower pay factors.

![Figure 1. Pay factor for air content based on average and standard deviation.](image)

Overall, there were 2,084 air test results reported for the nine Tollway PRS contracts. The highest pay factor achieved among the nine contracts was 101.6 percent, corresponding to a mean air content of 6.5 percent and a standard deviation of 0.3 percent. The lowest pay factor achieved was 100.4 percent, corresponding to a mean and standard deviation of 6.8 percent and 0.7 percent, respectively.

Thickness
Generally speaking, the next data collected for PRS sublots were the thickness data. These data were collected using the MIT-T2 device to determine the pavement thickness in a highly accurate and non-destructive manner. The target thickness for all contracts was 13 inches, which when combined with a standard deviation of 0.25 inch, resulted in a pay factor of 100 percent. Higher average thickness values and smaller standard deviations resulted in higher pay factors, but the limit for thickness pay factor was 101.4 percent, as shown in figure 2.
Overall, there were 2,080 thickness measurements taken for all of the Tollway PRS contracts. The highest pay factor achieved among the nine contracts was 101.3 percent, corresponding to a mean thickness of 13.7 inches and a standard deviation of 0.28 inch. The lowest pay factor achieved was 100.1 percent, corresponding to a mean and standard deviation of 13.2 inches and 0.36 inch, respectively.

**Dowel Alignment**

Dowel alignment data were collected on a sample of joints in each sublot, often in conjunction with the thickness data collection. Dowel bar alignment was collected using the MIT-Scan device, which collects data on the position of each dowel relative to perfect alignment, which corresponds to no sideshift, no vertical rotation, and no horizontal rotation. MIT-Scan data were used to calculate the effective dowel diameter based on the alignment (6). If the alignment was found to be as expected, the effective dowel diameter would calculate as 1.5 inches. As the degree of misalignment increased, the effective dowel diameter would also decrease. Dowel alignment is the only quality characteristic for which a pay factor of 100 percent is the maximum that can be achieved, as is shown in figure 3. Dowel alignment is also the only pay factor for which the standard deviation does not impact the calculation of the pay factor.
There were 2,575 joints for which dowel alignment was measured for the Tollway PRS contracts. The highest pay factor achieved among the nine contracts was 100.0 percent, corresponding to an effective dowel diameter of 1.50 inches. The lowest pay factor achieved was 99.4, corresponding to an average effective dowel diameter of 1.45 inches.

**28-Day Compressive Strength**

Samples for the compressive strength testing were cast at the same time as material was tested for plastic air content, at the point where concrete was delivered to the paver. Compressive strength samples consisted of two pairs of 6-inch by 12-inch cylinders, noted as the “A” and “B” samples. The testing protocol required testing of the two A-cylinders after 28 days of curing, with the value for the sublot calculated as the average of the two cylinders, as long as the two individual values were within 900 psi of each other. In the event that the two A-cylinder strengths were more than 900 psi apart, the first of the B-cylinders would be tested, and that strength was compared to the two A-cylinder values. If the B-value was within 900 psi of one of the A-values, those two values would be used to calculate the sublot average value. If none of the values were within 900 psi of the others (e.g., 5,000 psi vs. 6,000 psi vs. 7,000 psi), then the second B-cylinder would be tested. After all four of the cylinders were tested, regardless of whether there were two values within 900 psi of each other, the two closest values were then used to calculate the sublot average value.

The target 28-day compressive strength for all PRS contracts was 5,500 psi. This value, in conjunction with a standard deviation of 500 psi, would result in a pay factor of 100 percent. Higher average strength and lower standard deviation could result in a pay factor of up to 102.7 percent, as shown in figure 4.
One of the issues that arose with the strength testing was the adjustment of higher strength values for use in the calculation of the strength pay factor. Several approaches were considered; the final adopted approach called for assigning a value of 6,500 psi for any strength values above 6,500 psi but below 7,000 psi. For strength values above 7,000 psi, the strength value used in the pay factor calculation was the twice the difference between the strength value and 7,000 psi, subtracted from 6,500 psi. For example, if the subplot strength value was 7,500 psi, the pay factor strength value was 5,500 psi—twice the difference (1,000 psi), subtracted from 6,500 psi.

One of the other major issues with respect to the compressive strength testing was the adjustment based on “cold-weather paving” activities that became necessary due to the length of the construction season. Ultimately, a second lot (Lot 2) was established for all of the contracts that had paving occur after November 6, 2015. This meant that the total paving quantity was divided into Lot 1 and Lot 2, with both lots having pay factors that only applied to the quantity of paving that occurred in each. As part of the establishment of a Lot 2 for a contract, the overall pay factor was calculated without using the compressive strength values.

For the Lot 1 paving, there were 502 compressive strength subplot results reported for all of the Tollway PRS contracts. The highest pay factor achieved among the nine contracts was 102.2 percent, corresponding to an average 28-day compressive strength of 6,319 psi and a standard deviation of 339 psi. The lowest pay factor achieved was 96.4 percent, corresponding to a mean and standard deviation of 4,967 psi and 1,008 psi, respectively. The strength pay factors that were below 100 percent were due to high strengths on a number of projects, not to low strengths. Several contractors feared that productivity would be reduced if the cement contents of Tollway optimized concrete mix designs were lowered, so they kept strengths higher than desired by the Tollway PRS. The Tollway therefore reduced minimum strengths for opening new pavements to construction traffic from 2,850 psi to 2,500 psi at 3 days age, which was easily obtained in 2015. The contractors also learned that lower-than-usual cement contents in optimized mix designs would not slow their pavers down. Almost all of the contractors reduced cement contents for the 2016 PRS contracts, and initial strength results collected to date indicate that the strength pay factors will be higher in 2016.
Pavement Smoothness

Pavement smoothness data were collected using a high-speed profiler which collected data in both the left and right wheelpaths. Data were intended to be collected over the entire length of a sublot, but there were instances where the literal end of the pavement or temporary barricades or parked construction equipment made it impossible to maintain the minimum required 25 mph, either due to lack of run-up or run-out length, or both.

The target smoothness for all PRS contracts was 60 inches/mile. This value, along with a standard deviation of 10 inches/mile for the lot, resulted in a pay factor of 100 percent, as shown in figure 5. As with the compressive strength pay factors, smoothness pay factors were not calculated for Lot 2 sublots, although data were still collected to ensure that the pavement surface met the minimum acceptable requirements for smoothness.

![Pay factor for pavement smoothness based on average and standard deviation.](image)

In a few instances, paving of the outermost lanes was directly adjacent to moment slabs that were placed as part of the barrier system. Where this occurred, data from the wheelpath nearest to the moment slab were not used in calculating the smoothness pay factor. This phenomenon will be an issue during the 2016 paving: the inside lanes are being paved next to the outside lanes paved in 2015 and require one of the two wheelpaths to be excluded from the pay factor calculation.

For the Lot 1 paving, there were 483 sublots for which smoothness testing was performed and used to calculate pay factors. The highest pay factor achieved among the nine contracts was 100.3 percent, corresponding to an average smoothness of 59 inches/mile and a standard deviation of 10 inches/mile. The lowest pay factor achieved was 94.5 percent, corresponding to a mean and standard deviation of 85 inches/mile and 15 inches/mile, respectively.

SUMMARY AND CONCLUSIONS

Currently, the JPC paving component of the 2015 Tollway PRS contracts is expected to have an overall, weighted-average pay factor that is very nearly 100 percent, with the highest overall pay factor for a contract being 102.4 percent and the lowest being 95.4 percent, for Lot 1 paving. For Lot 2 paving, the high and low overall pay factors are 102.5 percent and 101.5 percent,
respectively. With the elimination of strength and smoothness from the overall pay factor calculation in Lot 2, all of the contracts with Lot 2 paving had overall pay factors above 101.5 percent, while only two of the nine contracts had overall quality pay factors above 100 percent for Lot 1 paving.

While these numbers might indicate a lack of significant financial impact for either the Tollway or the contractors, the presence of the PRS effort has provided a maintained focus on the subject of paving quality for everyone involved. When a contractor has had issues with one or more of the quality characteristic pay factors being below 100 percent, the Tollway and the contractors have held focused conversations on how to improve the results for those specific parameters.

While contractors initially tended to be resistant to the PRS implementation, a year later, everyone involved appears to have a greater comfort level with the process. Initial paving has begun on seven additional PRS contracts for 2016, and the kick-off and establishment of data and communication flow is off to a smoother start than in 2015.

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REFERENCES


