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Illinois' Experience Using Quality Control for Performance and Pay for Performance to Determine Pay for Hot-mix Asphalt

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Evaluation of Data Trends and Variability in Quality for Performance and Pay for Performance Programs

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ILLINOIS' EXPERIENCE USING QUALITY CONTROL FOR PERFORMANCE AND PAY FOR PERFORMANCE TO DETERMINE PAY FOR HOT-MIX ASPHALT

The implementation of QCP and PFP for HMA acceptance and pay (featuring the use of both percent within limits and step system specifications) has allowed for the monitoring of HMA quality in Illinois DOT projects.

What Was the Motivation?

In 2014, the Illinois Department of Transportation (IDOT) transitioned to two specifications—quality control for performance (QCP) and pay for performance (PFP)—for acceptance of most hot-mix asphalt (HMA) to determine a contractor's pay incentives and/or disincentives for HMA. On both QCP and PFP, pay is computed based on HMA properties (volumetric) that have been found to be related to performance. IDOT uses air voids (AV), voids in mineral aggregate (VMA), and field density parameters to compute pay. Most projects smaller than 8,000 tons of HMA are paid using QCP. For projects that are more than 8,000 tons of HMA, districts select either the PFP or QCP specification depending on the roadway classification or other factors.

The main difference between QCP and PFP relies on the method used to compute the pay factor for each quality property (AV, VMA, and field density). Each project is divided into sublots of approximately 1,000 tons of HMA. One random jobsite sample of the HMA is collected per sublot to compute the AV and VMA pay factors. In the case of density samples, PFP uses a random core every 0.2 miles as a "sample," while a density "sample" for QCP is the average of five cores taken within a mile (1 core every 0.2 miles). Once all the sublot's samples have been collected and tests conducted, a pay factor (PF), which defines pay incentives/disincentives, for AV, VMA, and field density is computed. In PFP, the average and standard deviation of the test results from all sublots are used to compute the three pay factors. For QCP volumetrics (AV and VMA), the district randomly tests one of the four sublots to compute each PF. If the pay results in 100% pay and the tests are within the precision limits, the pay is based on that single value. If not, the district tests the remaining sublots and uses all four sublots to determine PF for AV and VMA. The three pay factors are then combined into one composite pay factor (CPF) per sublot using the following equation: CPF = 0.30*(PF AV) + 0.30*(PF VMA) + 0.40*(PF Density). (The same equation is used for QCP and PFP.) The CPF, price per ton, and total tonnage are multiplied to determine the pay for each pay item.

In QCP, the PF for AV, VMA, and field density for each sublot depends on the IDOT pay ranges ("steps"). Figure 1-A shows an AV PF computation for a hypothetical project of 4,000 tons (four sublots). For example, sublot 2 has 2.6% AV, which corresponds to a PF of 95% (IDOT, 2018). Once all the sublots are assigned a PF, the average is the final AV PF for the contract. The same procedure is used to compute a PF for VMA and field density.

In PFP, all sublots' results are used to fit a t-distribution that is used to compute the AV, VMA, and field density pay factor. Figure 1-B shows an air void's PF computation for the same sublots used in the QCP example. First, the average and standard deviation of all the sublot results were computed. Then, a t-distribution is fit using the average and standard deviation. A t-distribution is a statistical representation of data that allows the percent of the whole population to be determined (the 4,000 tons of HMA, in this case) that is within certain limits (the required AV limits, for example). This percent within limits (PWL) is used to determine the pay factor as PF=55+0.5*(PWL). The same procedure is used to compute a pay factor for VMA and field density. Other details and restrictions for both specifications can be found in IDOT's *Manual of Test Procedures for Materials* (IDOT, 2018c).

QCP and PFP disincentives are a major concern for contractors, who need to control production using quality control samples taken at the plant but receive payment based on quality assurance samples taken from the jobsite. During 2015 and 2016 approximately 55% and 44% of QCP and PFP HMA production, respectively, was paid with a disincentive. These disincentives averaged approximately $20,000 per project, which does not include any credits provided for unacceptable material. On large PFP projects, these disincentives were as high as approximately $100,000. In addition, approximately 196 mix and density sublots were disputed. It is important to determine if PFP and QCP disincentives reflect actual issues with mix production and construction. To assess this, an evaluation of the QCP and PFP data from more than 700 mix contracts constructed from 2015 to 2017 was conducted to understand the reasons driving pay disincentives and disputes.

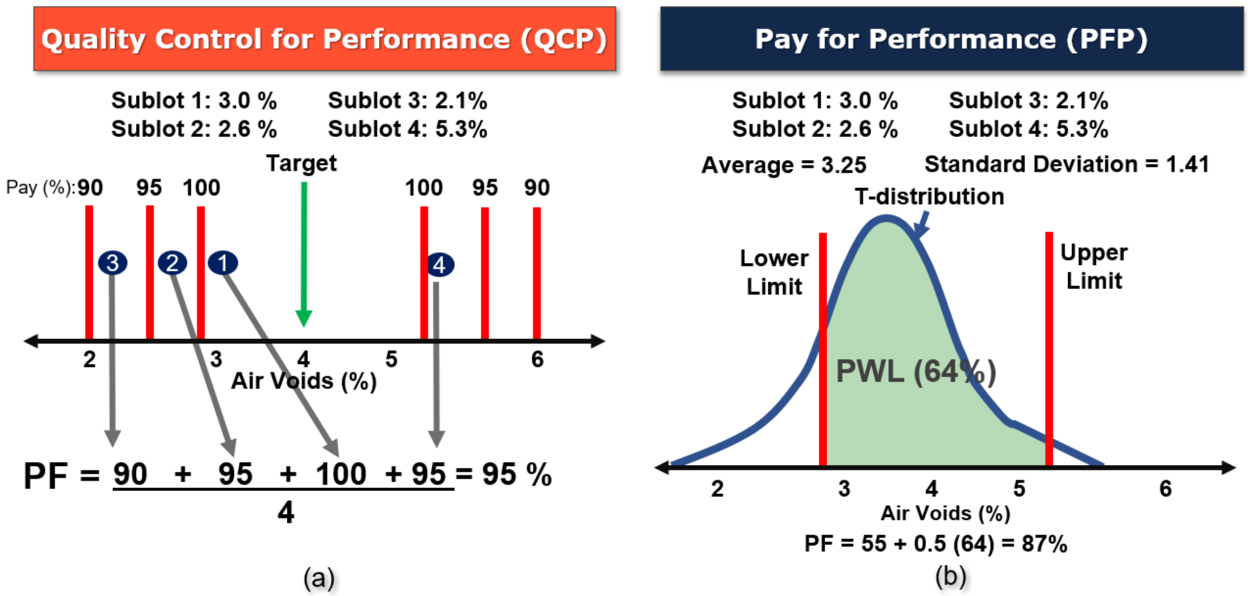

Figure 1. Example air voids pay factor computation for a hypothetical project of 4,000 tons (four sublots) using the (a) QCP and (b) PFP specification.

What Was Done?

IDOT sponsored a research project to assess the QCP and PFP specifications to understand the distribution and variability of quality control and quality assurance test results as well as to determine the potential causes of variability and disincentives. The statistical part of the project consisted of analyzing the data used to determine pay in both programs for the years 2015–2017. Data was collected from four main sources: pay factor results, sublot test results, PFP dispute data, and volumetric round robin results. The pay factor results are the pay factors reported by the department. The sublot test results are the volumetric test results (theoretical maximum specific gravity [G_{mm}], bulk specific gravity [G_{mb}], asphalt content, AV, VMA, aggregate gradation, and field density from cores) used to compute the pay factors. The PFP dispute data consist of laboratory results by IDOT's Central Bureau of Materials laboratory used to decide the final pay of sublots that were disputed by the contractor. Round robin results are the annual tests conducted by different labs (contractor and department) with a production mixture that the Central Bureau of Materials samples and uniformly splits. Ideally, all labs should report the same results. However, variability related to sampling, testing procedure, operators, and/or equipment used will result in different test values. Therefore, labs receive a rating based on how their test results compare to the total population.

The first part of the analysis was to observe pay trends. First, the pay factors were grouped per program, district, and year to check uniformity between districts and changes over time. In addition, each pay factor parameter's (AV, VMA, and field density) trend was analyzed individually to evaluate the effect of each parameter on payment per mix type. Hypothesis testing was conducted to determine if district and contactor results were significantly different in terms of averages and standard deviations. Additionally, sensitivity analysis was carried out to quantify the impact of variability (standard deviation) on the pay in the PFP program.

What Was Learned?

PFP is stricter than QCP but more rewarding

A total of 595 mixes were recorded between 2015 and 2017 in the QCP specification, while 115 mixes were recorded for the PFP specification. These cases correspond to 3,255,000 tons and 2,690,000 tons of HMA, respectively.

Figure 2 presents the composite pay factor for both QCP and PFP specifications from 2015 to 2017. For QCP, only 9% of the total tonnage received 97.5% pay or lower compared to 20% of PFP. At the same time, 45% of QCP production received full pay, while 54% of PFP production received an incentive and 2% received full pay.

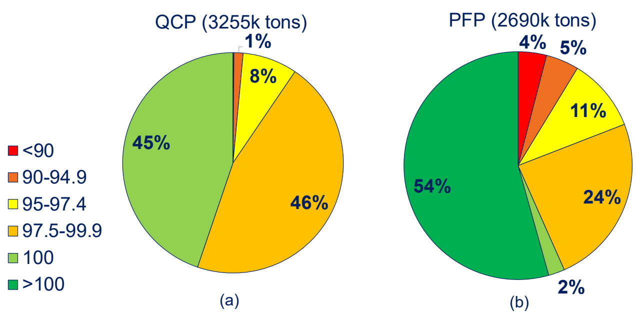

Figure 2. CPF for (a) QCP and (b) PFP projects built between 2015–2017.

Pay factors per parameter showed that PFP disincentives were most frequently caused by field density, followed by AV and VMA (Figure 3). For QCP, the influence of AV, VMA, and field density was similar. Pay factors indicate that the highest disincentives (lowest pay factors) are most frequently computed for VMA. This could be explained by the fact that contractors frequently design HMA at a VMA close to the lower minimum requirement; hence, variability would be manifested when the PWL approach is used. In general, PFP is a stricter specification than QCP because PFP considers variability in the pay computation. For example, if sublot results are within the upper and lower limits for 100% pay in QCP, they achieve 100% pay. However, in PFP, even if the test results are within the lower and upper limits, pay factor can be low if variability is high. Test results show that field density is the parameter that had the most variability and was the most frequently disputed parameter.

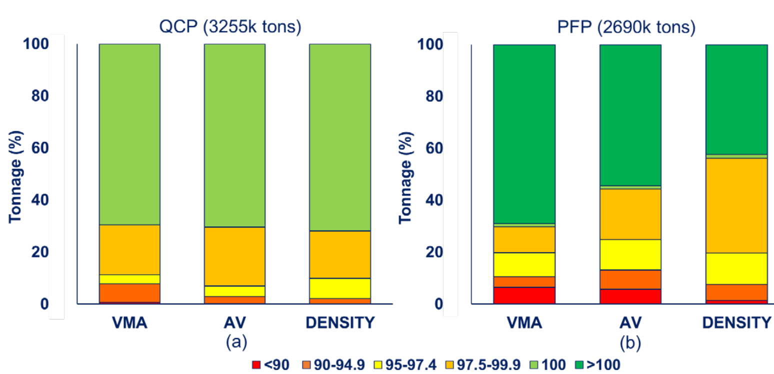

Figure 3. Pay factors per pay parameter for (a) QCP and (b) PFP specifications from 2015–2017.

Possible Causes of Variability

Sources of variability in HMA test results were grouped into four categories: production, sampling, construction, and testing. Sources of variability were not consistent between contractors and districts.

Cases that have a pay disincentive because of either AV or VMA also tended to have corresponding issues with the aggregate gradation. Aggregate gradation issues may be a result of aggregate variability from the supplier, production control (plant segregation, aggregate stockpile management, cold bin loading, etc.), improper sampling and/or not blending job site samples, and improper splitting for test samples.

Mix sampling procedures were not uniform, as shown in Figure 4. Most of the mix sampling was observed to be done behind the paver. This method consists of placing steel plates over the surface of the roadway. Then, the paver places the mix and the plates are pulled out with the collected sample. A variation of the same method (plates 2) consists of using nails to fix the plates into the ground and a square "mat cutter" to prevent segregation and losing samples from the edges of the plate. This method seems to be most appropriate. However, other methods were seen such as shoveling. In this case, a specially designed metal box shovel is used to take the sample from the mat after the mix is placed. In addition, other methods used include the following: sampling from the auger, pulling the sample directly from the material transfer device by dropping the mix into a "quarter master," and collecting samples by dropping mix from the material transfer device directly to the ground and shoveling. The last method presents may lead to severe segregation of the collected sample.

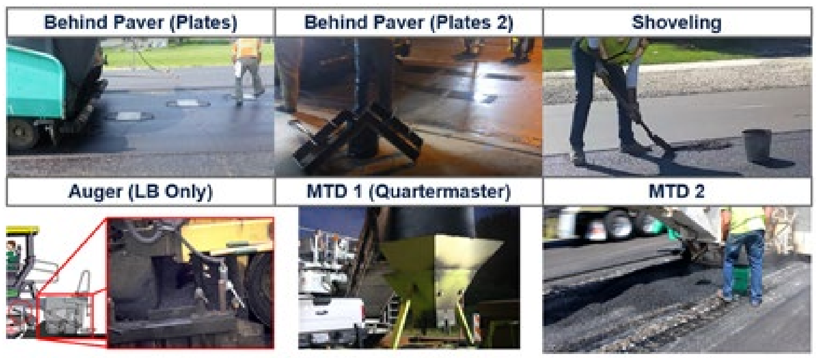

Figure 4. Mix Sampling Methods.

Testing variability could be caused by equipment, reheating, and testing procedures. Statistical analyses were performed to identify the differences between agency and contractor test results. At a statewide level, the agency and contractor results were not significantly different for 91% of AV, 88% of VMA, and 82% of density results. During jobsite visits of QCP and PFP projects, differences in the methods used for reheating the sample in the laboratory as well as the gyratory compactor used in the G_{mb} pill preparation were identified to be potential causes of these differences. These differences were most noticeable in AV because of the inherent testing variability in both G_{mb}.

During the placement and field compaction of HMA, several factors impact in-place density, including: base condition, lift thickness, air temperature and wind speed, type and amount of compaction, mix type and/or properties, and mix temperature. Field density was typically the most variable parameter likely because of these factors. Higher variability was also noted for leveling binder mixes placed to correct the irregularities before the surface layer is placed.

What Were the Key Outcomes and Lessons Learned?

The study addressed practical concerns and questions regarding QCP and PFP specifications, which reveal the following key outcomes:

- Contractors have more experience working with QCP projects. Training of contractors on PWL computations used in the PFP specification is warranted.
- Although pay incentives (PF>100%) are only possible in the PFP specification, PFP has reported consistently higher CPF pay disincentives than QCP. PFP does not have a maximum disincentive before being deemed as unacceptable material. For QCP, the maximum disincentive is 10% before being deemed as unacceptable material.
- Pay disincentives in QCP and PFP specifications are caused by several factors that require collaborative efforts to address them by agency and contractors.
- In the QCP specification, the performance of the contractors for individual pay factors (field density, AV, and VMA) is similar. The QCP specification is more lenient than that of PFP, especially for the density pay factors. When the PFP specification is used, the factor driving the pay disincentive is frequently related to the construction stage (field density), because of variability.
- Approximately, 82%, 88%, and 91% of field density, VMA, and AV, respectively, are statistically similar when comparing contractor and agency test results. Hence, production is highly impacting the pay.
- Both mix production and construction issues cause contractors' pay loss. Production and construction control are important to increase pay and improve HMA constructed quality. IDOT's Quality Management Program for HMA is appropriate for identifying mix production and/or construction issues and assigning pay correspondingly.
- Consistency in sampling and testing are required to limit variability between contractors and agencies.

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