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Asphalt Concrete Specs

QA SPECIFICATION PRACTICES

DRAFT

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This report provides an initial examination of current quality assurance (QA) and quality control (QC) programs at state highway agencies (SHAs). Of specific interest is the states' use of statistically based specifications.

The report overviews questionnaire results from the responding SHAs, recently obtained information from the Texas Department of Transportation on mix segregation, and sample results from the Washington State Department of Transportation (WSDOT) QA database.

This report is the first of two that examine the current WSDOT QA hot mix specification.

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INTRODUCTION

In the last two decades, the trend in the highway construction industry has been away from traditional, method-based specifications that had been used in the industry for nearly a century and toward the use of statistically based specifications. The focus of this report is on Quality Assurance (QA) specifications for hot-mix asphalt concrete.

Responses to surveys and reports from the mid-1990s indicate that the nation's various state highway agencies (SHAs) have approached the development of statistically based specifications at differing paces, degrees of implementation, and development processes. Estimates from these reports indicate that by the mid-'90s anywhere from one-fifth to three-quarters of the states were actively using statistically based specifications in new highway construction or were conducting tests on prototype projects (Chamberlin 1995, Weed 1996). Weed has called for a national policy on the matter (Weed 1996).

The Washington State Department of Transportation (WSDOT) first tested the use of statistically based specifications during the 1989 paving season. Favorable initial evaluations of the specification have led to their continued use (Markey et al 1994). However, issues remain. For example, in recent years the issue of nonrandom pavement defects due to non-uniform compaction and/or aggregate segregation has been identified (e.g., Mahoney et al 2000). Furthermore, numerous paving projects are experiencing construction-related defects. Though the documentation of these defects is limited, a recent WSDOT research report on pavements with superior and inferior performance suggests that construction variability has a major impact on WSDOT asphalt concrete pavements (Baker et al 2000).

PURPOSE OF THE REPORT

This report provides an initial examination of the current status of quality assurance (QA) and quality control (QC) programs at U.S. state highway agencies (SHAs). Of specific interest is the various states' use of statistically based specifications and policies concerning ranges of tolerance in their QA specifications. WSDOT will use the information to review its asphalt concrete QA specification.

SCOPE

The scope of this report is limited to quality assurance (QA) and quality control (QC) programs. This report overlaps somewhat with the recently published NCHRP Synthesis 263 *State Management Techniques for Material and Construction Acceptance* (Smith 1998). However, while that synthesis focused primarily on management techniques, testing, certification, and training issues related to materials and construction acceptance, this report is more narrowly focused on specifications, quality control requirements, and their overall effect on asphalt concrete pavement construction.

ORGANIZATION OF THE REPORT

The following topics are provided in this initial study report:

- a brief history and review of QA specifications
- a summary of the WSDOT survey of the U.S. SHAs
- the results of a recent survey on mix segregation by the Texas DOT
- examples of data from the WSDOT QA database
- a summary of comments received from WSDOT and contractor personnel concerning the QA specification.
- conclusions, including those relevant to the revised QA specification proposal.

A BRIEF HISTORY AND REVIEW OF QA SPECIFICATIONS

The history and evolution of highway construction specifications is well documented. It is perhaps best summarized by Chamberlin in the National Cooperative Highway Research Program (NCHRP) Synthesis 212 (1995). Chamberlin traces the history of contracting for construction of public roads back to the mid-19th century when William M. Gillespie authored *A Manual of the Principles and Practice of Roadmaking: Comprising the Location, Construction, and Improvements of Roads and Railroads* (1849). Gillespie described the specification as "...containing an exact and minute description of the manner of executing the work in all its details." As Chamberlin noted, Gillespie's account is "strikingly familiar" despite being a century and a half old, and "concisely and unequivocally states what has come to be known as a methods specification" (Chamberlin 1995). The method specification was the basis for most highway construction throughout the twentieth century.

Chamberlin pointed out several weaknesses of method specifications that eventually led to other alternatives. For example, the instructions or methods for performing the work in each case had to be precisely written and often relied on the integrity of the contractor and the judgment of inspectors overseeing the work. Even when properly executed, the method specification did not always produce the desired result because of changed conditions or other factors that impacted the quality of the finished product (Miller-Warden Associates 1966). Additionally, as technology advanced and contractors became larger and more specialized, the contractor was increasingly responsible for devising innovative ways to provide a better product and/or reduce cost. The methods specifications had no provision for this and often "retarded advances in construction technology" because they were "codified in written documents and often supported by attitudes not easily changed" (Chamberlin 1995).

Two events in the 1950s/1960s caused a change in pavement-oriented specifications. The first of these was the American Association of State Highway Officials (AASHO) Road Test, a large experiment consisting of accelerated loading on various combinations of pavement structures and materials. Significant in the findings of the AASHO experiment were the "variability of materials, construction methods, and sampling and testing procedures" (Weed 1993) and that "sampling plans [then] being used were not adequate for estimating the true characteristics of materials or construction items for which the specifications [were] written, and certainly [could not] guarantee 100 percent compliance to the specification limits" (Carey/Shook 1966).

The second event during that period was actually a conglomeration of related circumstances on the national level. These included unprecedented demand for and funding of new highway construction after World War II and an increase in the pace of highway construction because of more sophisticated paving technology and equipment. The consequence was a shortage of properly trained personnel to provide engineering expertise and quality assurance inspections. In turn, Congress established the House Committee on Oversights and Investigations in 1961-62 to curb the "many instances of accepted highway construction in which the prevailing acceptance practices had resulted in less than 100 percent compliance with materials and construction specifications" (Chamberlin 1995). The outcome of these events was increased use of statistical concepts in quality assurance and development of specifications that focused on the quality and performance of the delivered product rather than the procedures used to build it.

Since the late 1960s, the evolution of statistically based quality assurance has been fluid and continual in principal, but slow in practice. Chamberlin noted that "applicable statistical sampling and decision theory had been fully developed for highway construction by the early 1970s...[but] even now [in 1995], implementation status is more of an ideal toward which to strive than an accomplished fact" (Chamberlin 1995). During recent decades, several reviews and research reports have been undertaken to promote or evaluate the various aspects of specifications and quality assurance. In 1980, the Federal Highway Administration (FHWA) initiated research on performance-related specifications for highway construction with the following objective:

> to "...identify those existing specifications for construction of flexible and rigid pavement structures that relate directly to performance and to develop additional specifications, as needed, to provide complete systems of performance-related specifications for such construction" (Mitchell 1981).

Still, in 1996, NCHRP Synthesis 232 *Variability in Highway Pavement Construction* noted that "Many specification limits used today...consider neither the process capability nor the performance measures necessary to achieve an adequate product" (Hughes 1996). That same year, the New Jersey Department of Transportation's Richard Weed suggested properly establishing statistically based specifications on a national level in *Managing Quality: Time for a National Policy*. These works and other research results are summarized in the literature review below.

WSDOT first implemented statistically based specifications during the 1989 paving season. Positive responses to the initial projects from both contractors and state employees led WSDOT to continue their use on subsequent projects. In 1994, Markey, Mahoney, and Gietz published *An Initial Evaluation of the WSDOT Quality Assurance Specification for Asphalt Concrete*. Among their conclusions were that statistically based specifications were applicable and that the quality of pavement had improved in comparison to projects completed with non-statistically based specifications (Markey et al 1994).

Chamberlin, Markey et al, and Weed have all discussed various aspects of the theory of statistically based QA specifications. Chamberlin particularly focused on the various forms of performance specifications and established common definitions for them. He emphasized the performance-related specification, and that will be briefly reviewed here.

Performance-related specifications as described by Chamberlin (1995) include the following components:

- *End-result focus*—Based on the measurable attributes of the finished product, rather than on the processes used to produce the product.
- *Statistical base*—Acknowledges inherent variability in each process associated with the production and placement of AC pavement because of variations in material, equipment, and procedures.
- *Performance-models*—Based on attributes that are related to the performance of the finished product through models that have been validated for specific materials and climatic conditions.
- *Cost/performance optimization*—Balance between the criticality of the pavement structure and the costs and frequency of sampling and testing.
- *Adjustable payment*—Pay adjustments, both positive and negative, that reflect changes in the worth of the product resulting from departures in the level of acceptable quality.

Both Chamberlin and Markey noted that it is not possible to produce AC pavement that conforms 100 percent to all specification parameters because of the inherent variability in processes and products. Chamberlin made the distinction that "the goal of a performance-related specification is not to improve the quality of construction per se. The goal is to identify the level of quality providing the best balance between quality and performance…" (Chamberlin 1995). Markey discussed this balance in terms of risk. "Seller's risk" occurs when the buyer decides to reject a material lot produced by the seller when the product in fact meets acceptance criteria.

"Buyer's risk" is just the opposite: the buyer accepts a material lot that is actually defective. Increasing the number of samples (tests) reduces both types of risk by providing a more accurate indication of the true quality of the material lot. Markey noted, however, that this relationship between risk and sample size becomes a tradeoff between economics and quality since additional sampling and testing increase the cost (Markey et al 1996).

An operating characteristic (OC) curve graphically portrays the risks for both the buyer/agency and seller/contractor, as discussed by Markey. Figure 1 is Weed's example of a conventional OC curve showing Acceptable Quality Level (AQL) and Rejectable Quality Level (RQL) limits. Chamberlin covered the topic by providing data and analysis from a survey of the 50 states and various transportation authorities. In addition to the previously cited coverage of quality assurance history and statistical theory, the synthesis provided a [then] current state of the practice with regard to performance-related specifications for both portland cement concrete (PCC) and asphalt concrete (AC) pavements. Chamberlin's findings revealed widespread confusion between end-result and performance-related specifications. Of the 77 agencies surveyed by Chamberlin, only 13 cited one or more performance models for various attributes (see Table 1).

Weed's article also cited a survey (unpublished by that author and only a year after the Chamberlin report) which estimates that as many as half of the states were using statistically based QA specifications and another quarter had statistical specifications in various stages of development (Weed 1996). The article acknowledged that there was "significant disparity from state to state in the manner in which applied," and that "current practices and published standards are far from optimal" (Weed 1996).

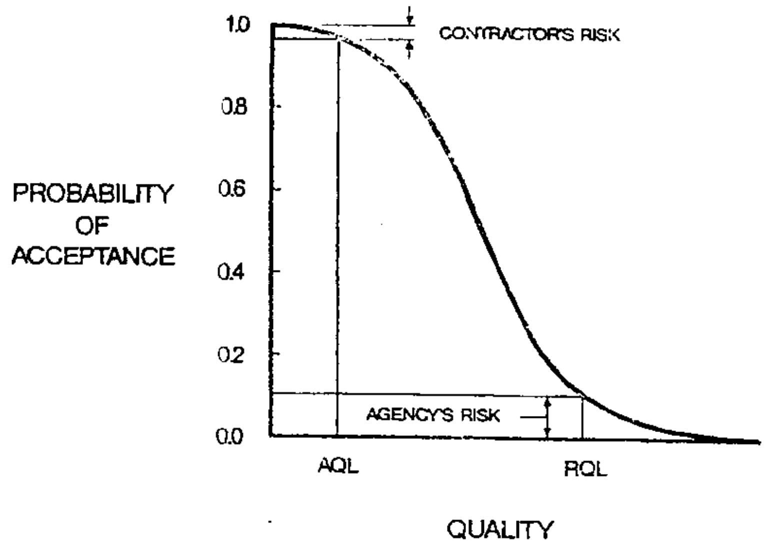

Figure 1. Example of an Operating Characteristic Curve (Weed 1996)

It is important to note that Weed's survey used the term "Statistical Quality Assurance (SQA)," and his discussion focused on statistics, which constitutes only one of Chamberlin's criteria for "Performance-Related Specifications (PRS)." The terms are not interchangeable. According to Chamberlin, SQA is an end-result specification that measures characteristics of the product immediately during or after construction. Payment adjustments are tied to tolerance levels in various attributes such as aggregate gradation, binder content, and mat density. While PRS includes similar measurements, it is different in that payments to the contractor are calculated by the expected performance of the product as defined by a performance model.

Both Chamberlin and Weed provided extensive bibliographies on materials and construction acceptance processes.

Chamberlin's synthesis is one of several on the topic of materials and construction acceptance sponsored by NCHRP. Others are shown in Table 2. Of specific note is NCHRP Synthesis 232 *Variability in Highway Pavement Construction*, which presented typical variabilities for asphalt concrete and other paving materials (Hughes 1996). It also documented DOT practices for setting specification limits (discussed later in this report) and provided an instructional section on proper uses of variability to establish these limits.

Markey's report, as its title indicates, was specific to the state of Washington. Its purpose was to evaluate statistical QA specifications used on several paving projects. Markey reviewed the WSDOT specification including step-by-step explanations for analyzing typical test data and calculating pay factors. The report's conclusion was that the pavement produced under the WSDOT QA Specification was "of higher consistency and better quality" (Markey et al 1994) than that produced under the former specification. Markey's work was more detailed than were the more broadly focused national level works by Chamberlin and Weed.

A year after the Markey report was published, Phillips authored *A Risk and Pay Factor Analysis of Washington State's Department of Transportation 1994 Standard Specification.* Phillips' report provided insight into statistical sampling methods and their uses in a properly designed acceptance plan. He provided in-depth discussion on the development of operating characteristic (OC) curves, buyer and seller risk, and comparison to previously used non-statistically based specifications. Recommendations specific to Washington were minimal and centered on further study, but the report provided a good technical explanation of statistical models and risk quantification.

RESULTS OF SHA SURVEY—1999

Because of the differences in, and therefore the opportunity to learn from, QA and QC programs in the U.S., a survey of the SHAs was conducted. Appendix A is a copy of the questionnaire that was sent by electronic mail during April 1999 to each of the 50 states. Responses were received from 12 of the SHAs (including WSDOT). The questionnaire was organized into three parts: general questions about asphalt concrete, contractor quality control programs, and QA specifications (including pay factors). The results are summarized in several tables.

GENERAL

As shown in Table 3, the annual SHA volume of asphalt concrete placed by the responding SHAs varied from 0.6 to 8 million tons, with a mean of 3.2 million. Nearly all of the responding states estimated that the majority of their AC paving efforts were in the form of overlays versus new construction. A ratio of 70 percent overlay to 30 percent new construction was the average. Oregon, Florida, and Washington reported the most extensive use of overlays, with ratios of 95 percent overlay to 5 percent new (Oregon) and 90 percent overlay to 10 percent new (Florida, Washington). Arkansas and Kentucky responded that they use more asphalt concrete in new construction. The expected life of AC pavements ranged from 8 to 20 years for new construction and 6 to 20 years for AC overlays. Several SHAs responded that the expected life was related to the volume of truck traffic and associated equivalent single axle loads (ESALs). The average lives for AC overlays placed on existing PCC were about the same as AC on AC.

Principal construction-related problems (Table 4) included mix segregation, less than desirable compaction, smoothness problems, poor longitudinal joints, and deviations from the job mix formula. No respondents indicated problems with variable binder content. A majority of respondents observed problems due to differential cooling of the AC mix and/or cyclic segregation (see Table 5).

CONTRACTOR QUALITY CONTROL PROGRAMS

Responses to questions about quality control programs were similar among the SHAs. Tabulated results are shown in Tables 6 and 7. Over 80 percent of the respondents required contractors to perform quality control on various attributes of the hot mix and in-place pavement. Nine of the ten states reported that their QC program either increased or greatly increased asphalt concrete quality. Florida and Ohio reported that their QC programs specifically increased contractor knowledge of materials and specifications and/or increased consistency. Several of the SHAs responded that the level of increase in quality varied from contractor to contractor, depending on the level of commitment. Table 6 shows the QC tests that contractors are expected to perform in the respondent states. Table 7 provides state comments on the impact of QC programs.

QUALITY ASSURANCE SPECIFICATIONS

All of the responding states have quality assurance specifications in place. South Carolina is currently experimenting with pilot projects and is planning for full implementation in the summer of 2000. Survey responses from the states are summarized in Tables 8 through 16.

Most SHAs reported that their QA specifications were developed within their states through a combination of test projects, past experience, or engineering judgment (see Table 8).

Federal Highway Administration (FHWA) specification guidelines and information from other states were cited as well.

The years in which the QA specifications were implemented ranged from 1976 (Florida) to 2000 (South Carolina). On average, the "typical" QA specification had been in use nine years. Responses to this question varied greatly, but most states reported annual updates and/or multiple revisions within the last ten years.

Table 9 indicates that most of the responding states required tests on aggregate gradation, binder content, in-place density, and air voids to assess QA compliance. Five states also had a VMA requirement. Tests required by quality assurance specifications were very similar to those required by contractor quality control programs. South Carolina plans for the aggregate gradation test to be a QC test only. Wyoming is developing a smoothness QA specification.

Lot sizes tested for quality assurance ranged from 750 tons (Kansas and Wisconsin) to 5,000 tons (Wyoming, for the aggregate gradation test). See Table 10. Several states had varying lot sizes for the different attribute tests and/or used a day's production in lieu of a specific quantity. For example, Wyoming's specification calls for aggregate gradation to be tested every 5,000 tons, in-place density every 1,500 tons, and asphalt content once per day. Indiana differentiates lot sizes based on purpose of the mix: QA tests every 4,164 tons for mixes to be used for base or intermediate courses and every 2,500 tons for surface course mixes.

All twelve respondents reported that their QA specifications required the use of random sampling, with about 75 percent reporting provisions that enable suspension of random sampling, if a systemic field problem is observed. Most states that did have such a provision gave the project engineer or other designated agency representative the authority to stop work if there were apparent defects (e.g., the mat was not uniform). Oregon allows for separation and retesting of defective material contingent on an assignable cause being identified.

Two questions concerned statistical risk to the seller (α) and buyer (β), as discussed earlier. Only Indiana responded, with a α risk of 2-3 percent and a β risk of 4-5 percent.

Most of the states (75 percent) reported the use of incentives in their pay factors. (See Table 11) Typically, the maximum incentive was a 1.05 pay factor. The average pay factor reported ranged between 1.02 and 1.03. Most states reported that a large percentage of jobs earned a bonus, and lots were seldom rejected. Table 12 summarizes the mix-related factors on which bonuses were paid. Most were paid for in-place density and smoothness, followed by binder content (an additional summary is shown in Table 18).

Most states reported that rejection of work was minimal (Table 11). Seven of the twelve respondents reported that work was rejected on virtually no paving jobs, though several commented that individual lots were occasionally rejected or that work was accepted at reduced price. Wyoming required test strips before full production and reported that most of its rejected lots were on the test strips, thus enabling it to "catch" defective lots before full production.

In Table 13, one-half of the respondents reported that the overall effect of their QA specification slightly increased the cost of AC production (added 5 percent to the total cost). Wyoming experienced an increase in the cost of its projects initially, but reported that costs decreased as the contractors gained familiarity with specification requirements. The majority of the respondents indicated that the effect of their QA specification was somewhat effective (noticeable improvement to pavement quality and performance) to very effective (significant improvement).

As shown in Table 14, Arkansas, Florida, and Kentucky were the only states to report changes to their QA specification to accommodate the SUPERPAVE® mix design system, with Indiana in the planning stages to convert. Changes from previous systems included the addition of air void testing and increased density requirements. Kentucky adjusted its VMA requirements to conform to AASHTO MP2.

Additional comments from the states on how their QA specifications could be improved and "concluding" comments are shown in tables 15 and 16.

A 1996 survey published in NCHRP Synthesis 232 (Table 17) showed that roughly half of the nation's SHAs used some form of incentive/disincentive program tying material and construction attributes to contractor pay. Furthermore, the study indicated that disincentives outweighed incentives almost threefold.

The questionnaire for this report did not directly cover disincentives, but the responses concerning the use of bonuses (Table 18) seemed to indicate a similar percentage of states using them. The maximum bonus was 112 percent of full price, reported by Kansas, with 105 percent the most common. Of the states that offered incentives, the range of projects on which contractors earned bonuses was between 20 and 100 percent of all jobs.

COMPARISON OF SPECIFICATIONS

An interesting aspect of asphalt paving is the broad array of quality requirements and specifications in use by the different states for an end product that serves essentially the same purpose. This chapter examines some of the differences between state QA requirements, especially focusing on the established specification limits and level of variability allowed in certain quality acceptance/assurance tests.

Data in the following tables were obtained from SHA specifications. In many cases, states had ranges of values for attributes, depending on the quality level desired or projected highway usage (e.g., estimated ESALs). For comparison purposes, the highest quality pavement was selected.

Common QA/QC measures are the aggregate gradation and binder content tests. Table 19 shows seven responding states' gradation sieve requirements for their highest quality mixes, and associated tolerance for deviation from the Job Mix Formula. Tolerance values for the larger sieves ranged from 4 to 7 percent, with 2 percent the most common tolerance value for the No. 200 sieve. Some states, such as Minnesota, established warning limits within the broad band JMF ranges. Asphalt binder content tolerances (Table 20) ranged from +/-0.25 to +/-0.7 percent.

Table 21 shows QA sampling requirements for respondent states. Most of the states established lot sizes as either the amount produced from a specific Job Mix Formula or as a day's production. All had methods to divide defined lots into sublots for testing, either by establishing a specific sublot size (Florida, Indiana) or by using a formula based on the volume of production (Minnesota, Ohio). In spite of the differing methods for lot and sublot determination and the variety of their sizes, the sampling frequency was somewhat similar.

Tables 22 and 23 compare the density and compaction sampling requirements of the various states. As with the aggregate gradation and binder content tests, the disparity among lot sizes and number of tests per lot was fairly large. Density requirements, however, were fairly consistent.

As tables 19 through 23 indicate, Washington's specification for asphalt concrete is not remarkably different from those of the survey respondent states. Values for aggregate gradation, binder content, and density tests fall within the ranges used by the other states, and compaction, density, and sampling requirements are also similar.

TEXAS HOT-MIX SEGREGATION STUDY

As previously indicated in Table 4, the most frequent pavement construction problem noted by the respondents was segregation of materials. Though not a questionnaire respondent, the Texas DOT provided results of a survey it conducted to find possible solutions to this issue.

States responding to the Texas survey indicated two primary approaches to solve the segregation problem: use or alteration of mechanical devices, and innovative management techniques. States such as Louisiana, Kentucky, and Pennsylvania have specifications that require use of material transfer vehicles (MTVs) for placement of the final lifts of asphalt concrete on the roadway to prevent segregation. Kansas and Georgia give favorable reviews to a specific model called the " Shuttle Buggy" manufactured by Roadtec.

In addition to the MTVs, contractors from some states have attempted to control segregation by altering paving machines, production plants, and other equipment. Some contractors in Georgia have modified silo discharge gates with what has become known as the "Georgia gate" so that mix is discharged the full width of the truck bed. Clark's Welding and Machine Works of Sacramento, Californi, manufactures the Lincoln Hopper Insert, which, as its name implies, fits into the paver hopper and remixes material waiting to be placed. The drawback of the Lincoln device is that it requires the use of a loader because it raises the height of the paver so that trucks can not discharge directly into the hopper. Another Lincoln product, the Lincoln Pugmill, mounts in the paver hopper above the feeder tunnel and mixes the hot mix just before it is fed through the feeder tunnels on the paver.

Several states are approaching the segregation problem with management techniques and further study. For example, Illinois uses a "partnering" approach, which requires the DOT engineer and the construction superintendent to survey the previous day's paving for segregation problems. If problems are found, then the contractor proposes changes to improve the product. Feedback from both engineers and contractors on this method has been negative, however, as engineers are dissatisfied with what they perceive as the specification's "lack of teeth," while contractors think the requirements are too stiff. Further study and specification development in cooperative efforts between SHAs and the hot mix asphalt industry is ongoing in Texas and Kansas, among others.

WSDOT QA DATABASE

WSDOT maintains a database for all QA paving projects that contains test results and calculated pay factors for all sublots for each project. The edition of the database used contained project summaries dating from 1991 to 1998. To evaluate whether the database would be of use for this study, an initial attempt was made to examine selected project data. Figures 2 and 3 illustrate typical results that can be summarized.

Figure 2 is a plot of compaction versus the difference in binder content and the JMF percentage. Each data point plotted represents all sublot results averaged for one mix design. The data scatter is large; however, few projects exceed a ±0.4 percent range. Additionally, there is no specific trend associated with binder content differences and the percentage of Rice density (essentially a "flat" line) with an R^2 approaching zero.

Figure 3 is a plot of compaction versus the difference in percentage passing the No. 200 sieve and the JMF percentage. The data scatter is also large; however, few projects exceed a ±1.5 percent range. For both binder content and percentage passing the No. 200 sieve, few of these projects (on average) exceed the WSDOT tolerance bands of ±0.5 percent for binder content and ±2.0 percent for passing the No. 200.

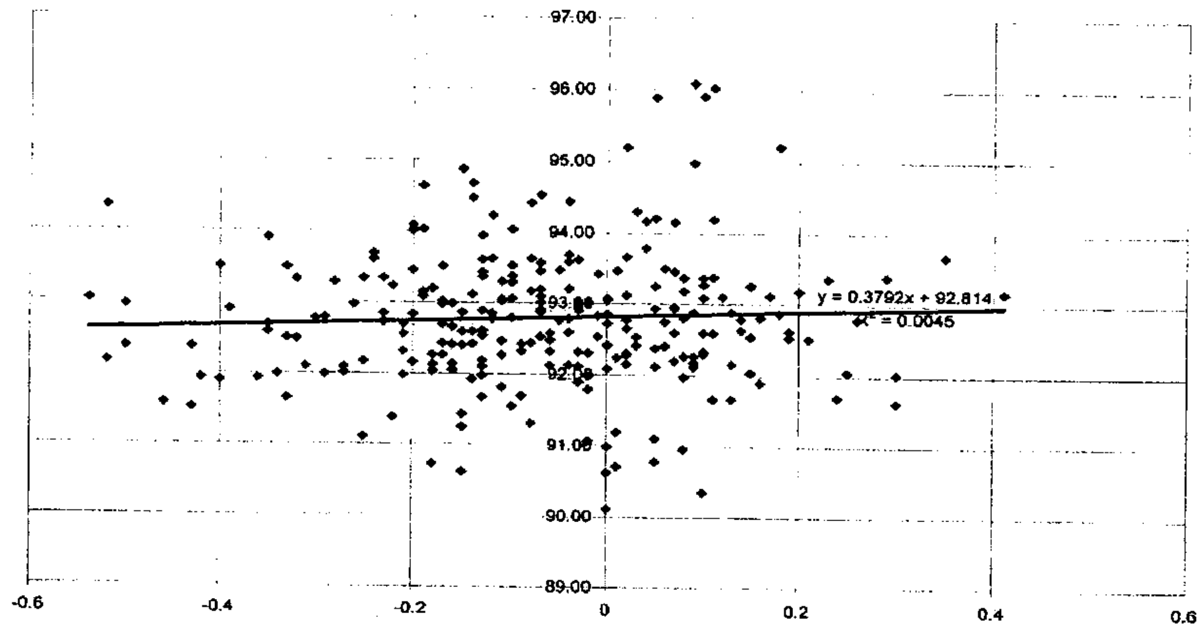

Figure 2. Plot of Percentage of Rice Density vs Deviations of Binder Content from the Job Mix Formula

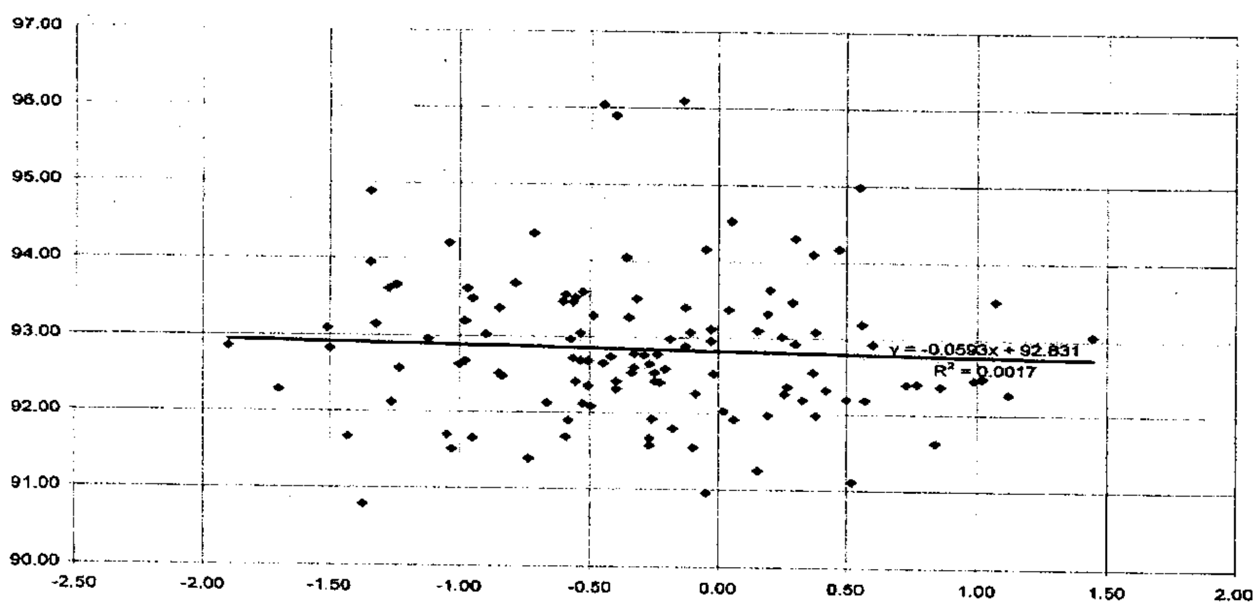

Figure 3. Plot of Percentage of Rice Density vs Deviations of the Percentage of Passing the No. 200 Sieve from the Job Mix Formula (each data point represents the average for one mix design)

WASHINGTON STATE INTERVIEWS

To better define important issues (either positive or negative) concerning the current WSDOT hot-mix QA specification, informal interviews were held with a limited number of WSDOT and contractor personnel. Additionally, Jon Epps of the University of Nevada at Reno was interviewed (subsequently he has retired from UNR and now is employed by a paving contractor). The results of these interviews (held in late 1998 and early 1999) are summarized in Table 24.

WSDOT personnel were generally concerned about the following:

- Shoulder compaction is viewed as inadequate.
- Mix tolerances are too high.
- Bonuses are too high for the quality of mix obtained.
- In general, the compaction of main lanes is inadequate.
- Determination of density needs examination (Rice, time of coring, etc.).
- QA specification generates too much paper work.

Contractor personnel noted the following:

- Generally satisfied with WSDOT QA specification.
- If a QC program is required, ensure that there is a level playing field for contractors (i.e., that minimum QC requirements the same for all). This was supported by Jon Epps (UNR) as well.
- No obvious support for a contractor QC program.

CONCLUSIONS

The purpose of this report was to summarize findings to date for the QA specification study. This included the following:

- an initial assessment of SHA QA specification practices (12 of 50 states responded)
- in-state interviews on the WSDOT QA specification
- a brief summary of the Texas DOT hot-mix segregation survey
- initial results from the WSDOT QA specification database.

Most QA/QC programs are very similar in purpose and effect, but varied in the details. Implementation of a national policy, as Weed suggested in 1996, would seem beneficial. Standardization of this sort would allow for a clearer, more common understanding of requirements and more effective training of industry personnel (contractors and state employees). It could also optimize the benefits of statistical quality assurance, thus providing a more effective overall standard.

The QA/QC programs currently used are cost effective in increasing quality; respondents typically reported noticeable improvements in pavement quality at only a slight increase in cost. Initial increases in overall cost due to new acceptance procedures eventually subside as contractors gain familiarity with them.

Aggregate gradation, compaction, smoothness, and binder content are the primary tests of quality in pavement construction. The new SUPERPAVE® mixes are designed and analyzed volumetrically. As the performance of SUPERPAVE® mixes becomes more broadly documented, more states may implement volumetric quality measures.

There seems to be a lack of understanding of statistical risk among SHAs. Of the respondents, only Indiana provided probability percentages for the risks associated with the contractor and the agency.

Mix segregation/mat uniformity is the principal construction-related quality problem. The Texas hot-mix survey is indicative of the industry's attempts to combat this problem.

Interviews with selected WSDOT personnel revealed that the current QA specification is not rigorous enough with respect to compaction requirements. Furthermore, the bonuses are earned too easily for less than desirable hot-mix and mix tolerances. In general, contractor personnel are comfortable with the current QA specification, and there is little interest in WSDOT requiring a contractor QC program.

Finally, an initial examination of WSDOT's QA specification database reveals promising results that should aid further examinations of mix tolerance and compaction levels (more possibilities exist).

Table 1. Performance Models Cited for PRS (NCHRP Synthesis 212 (1995))

Construction Element	Attribute	Model Cited	Citing Agencies*
AC Pavement	Abrasion resistance	"CA Model	CA
AC Pavement	Aggregate gradation	AASHTO	KS
AC Pavement	Density	"Oregon Model"	CA
		TRR 1217	NY
		AASHTO	IA
AC Pavement	Roughness	AASHTO Des Eq	IA, KS
AC Pavement	Voids	Asph Inst MS-2	MN
PCC	Air Content	PCA Research	MN
		R-73-1	PA
PCC	Strength	ACI 212/214	MDTA*
PCC	Aggregate (pavement vulnerability factor)	Wallace	KS
PCC Pavement	Roughness	AASHTO Des Eq	KS, NJ
		NY RR 16	NY
PCC Pavement	Strength	AASHTO Des Eq	NJ
PCC Pavement	Thickness	AASHTO Des Eq	DE,KS,MN,NE,NJ OR
		"Pay form"	ISTHA*
Polymer Overlays		Local Experience	VA

*MDTA = Maryland Transportation Authority; ISTHA= Illinois State Toll Highway Authority

Table 2. Related NCHRP Synthesis Reports (Smith 1998)

Synthesis Number	Title (Publication Year)
263	State DOT Management Techniques for Materials and Construction Acceptance (1998)
232	Variability in Highway Pavement Construction (1996)
195	Use of Warranties in Road Construction (1994)
146	Use of Consultants for Construction Engineering and Inspection (1989)
102	Material Certification and Material-Certification Effectiveness (1983)
65	Quality Assurance (1979)
38	Statistically Oriented End-Result Specifications (1976)

Table 3. General Asphalt Concrete Information

State	Annual Tonnage (millions)	New Construction		Overlays		
		Percent of Total Tonnage Placed	**Avg Life[1] (years)**	**Percent of Total Tonnage Placed**	**Avg. Life[1] over HMA (years)**	**Avg. Life[1] over PCC (years)**
Arkansas	2.4	67	20	33	15	15
Florida	4.0	10	15-20	90	15-20	-
Indiana	8.0	25	Varies	75	10-12 (Interstate) 12-18+ (Secondary)	8-12
Kansas	3.0	50	10	50	6	6
Kentucky	4.5	60	20	40	12	12-15
Ohio	3.8	-	8-10	-	8	8
Oregon	1.5	5	15	95	15	15
Rhode Island	0.6	30	12	70	6	8
South Carolina	3.0	15	15	85	12	12
Washington	2.3	10	15	90	12	10
Wisconsin	3.0	40	15-20	60	15-20	18
Wyoming	1.6	30	Varies[2]	70	Varies[2]	15 (Crack and Seat PCC) 7 (Overlay Only)

Notes

1. Average life defined as the time from construction to replacement or resurfacing for wearing courses.
2. For Wyoming "New Construction"

- Traffic > 25 million ESALs: 12 years
- Traffic 5-25 million ESALs: 15 years
- Traffic < 5 million ESALs: 20+ years

For Wyoming overlays on HMA

- Same as for New Construction if final section designed for a 20-year life.
- 5-10 years if overlay used for long-term maintenance.

Table 4. Principal Construction-Related Problems

Problem	Percent Reporting (Total of 12 States)
Mix Segregation	73%
Less than Desirable Compaction	55%
Smoothness	55%
Poor Longitudinal Joints	45%
Deviations from Mix Design	27%
Variable Binder Content	0%

Note: Multiple problems could be listed in the questionnaire

Table 5. Have Problems Due to Differential Cooling and/or Cyclic Segregation Been Observed within the First Year or So Following Paving?

State	Yes, No, Do Not Know	Comments
Arkansas	No	
Florida	Yes	
Indiana	Yes	"Thermal segregation—intend to investigate this further during the 1999 construction season."
Kansas	Do not know	
Kentucky	Yes	"In particular on base mixtures or coarse-grained mixtures when a material transfer vehicle is not utilized."
Ohio	Yes	"At times, but not as a rule."
Oregon	Yes	
Rhode Island	Do not know	
South Carolina	Yes	
Washington	Yes	"Have experienced both large temperature differentials resulting in low mat densities and aggregate segregation."
Wisconsin	No	
Wyoming	Do not know	"Segregation problems, especially in the fall may be due to differential cooling."

Table 7. Impact of Contractor QC Programs

State	Impact on Quality of Work	Comments
Arkansas	Increase	
Florida	Increase	"Increased contractor knowledge of product/specs."
Indiana	Increase/Great Increase	"Depends on contractors level of commitment."
Kansas	Great Increase	
Kentucky	Increase	
Ohio	Other	"Consistency has increased."
Oregon	Increase	
Rhode Island	No Program Required	
South Carolina	Unknown	
Washington	No Program Required	
Wisconsin	Great Increase	
Wyoming	Increase	"Requiring QC testing is new. The first projects requiring QC testing were constructed in 1996, with 1999 being the first year it will be required on all projects."

Table 8. QA Specification Implementation and Revisions

State	QA Program?	Date QA Spec Implemented	QA Spec Revisions	How Was QA Spec Developed?
Arkansas	Yes	1996	-	State developed, not statistically-based.
Florida	Yes	1976	-	Multiple sources
Indiana	Yes	1985	Annually (Major re-write 97-98)	State projects, FHWA
Kansas	Yes	1996	0	State data
Kentucky	Yes	1994	2 to 3 revisions over 5 year period	State projects, data—"not a true statistical specification (i.e., PWL approach)
Ohio	Yes	1979	5 to 6 over 10 year period	State projects, data
Oregon	Yes	1996	Annually	FHWA guidelines
Rhode Island	Yes	-	-	Not statistically-based
South Carolina	Yes (Implementation Underway)	2000	0	State data, other SHA specs
Washington	Yes	1991	Minimal changes	State data, Oregon DOT, FHWA
Wisconsin	Yes	1990	Annually	State projects, data
Wyoming	Yes	1985	Several	FHWA guidelines

Table 10. Quality Assurance Sampling

State	Random Sampling Required?	Sampling Suspension Provision?	Comments on Sampling Suspension Provision	Lot Sizes (Sublot Size)
Arkansas	Yes	Yes	"Yes, if obvious problems are observed."	3,000 tons (Sublots 750 tons)
Florida	Yes	Yes		4,000 tons
Indiana	Yes	No	"Project Engineer can stop work if the mat is not uniform."	4,164 tons (base mixes) and 2,500 tons (surface mixes)
Kansas	Yes	No		750 tons (volumetric properties) and 5 lots per day's production for density
Kentucky	Yes	-		4,000 tons (1,000 ton sublots) and 5,000 LF for density
Ohio	Yes	Yes		3,000 tons (one day's production for density)
Oregon	Yes	Yes	"A portion of the material may be separated out and statistically analyzed separately."	One mix design (1000 Mg sublots)
Rhode Island	Yes	Yes	"Poor mix quality on the job would initiate increased sampling frequency at the plant."	500 tons
South Carolina	Yes	No		One day's production
Washington	Yes	Yes	"The Project Engineer can designate separate areas of the mat for special attention if defects noted."	– JMF (800 tonnes max sublot size for binder and grad) – One day's production or 400 tonnes for compaction
Wisconsin	Yes	Yes	"We can random sample anytime."	750 tons
Wyoming	Yes	Yes	"Obviously defective material is isolated and handled separately at the DOT's direction. The contractor does not have the option to separate low quality material (identified by QA testing) out of a lot.	5,000 tons (Aggregate gradation) 1,500 tons (In-place density)

Table 12. Mixture-Related Factors on Which Bonuses Are Paid

State	Aggregate Gradation	Binder Content	In-place Density	Smoothness	Others
Arkansas		Yes	Yes	Yes	Air Voids, VMA, No Segregation
Florida			Yes	Yes	-
Indiana					-
Kansas			Yes	Yes	Voids on Plant Produced Material
Kentucky			Yes		Air Voids
Ohio				Yes	
Oregon	Yes	Yes	Yes	Yes	Mix Moisture
Rhode Island					
South Carolina		Yes	Yes	Yes (But not in QA Spec)	Air Voids, VMA
Washington	Yes	Yes	Yes		
Wisconsin					
Wyoming	Yes	Yes	Yes		

Table 13. Impact of QA Specifications

State	Impact on Cost (and How Much)	Impact on Mix Quality
Arkansas	Slight Increase	Somewhat Effective
Florida	Slight Increase	Somewhat Effective
Indiana	None to Slight Increase	Very Effective
Kansas	Slight Increase (<5%)	Very Effective
Kentucky	Slight Increase	Somewhat Effective
Ohio	Slight Increase	Somewhat Effective
Oregon	None	Somewhat Effective
Rhode Island	-	-
South Carolina	Unknown	Unknown
Washington	None	Somewhat Effective
Wisconsin	Slight Increase (5-10%)	Very Effective
Wyoming	None	Somewhat Effective

Table 14. Changes to QA Specification to Accommodate Superpave

State	Have Pay Factors Changed to Accommodate Superpave?	Has QA Specification Changed to Accommodate Superpave?
Arkansas	Yes	Dropped acceptance requirements for stability.
Florida	Yes	Added air voids test and tightened density requirements.
Indiana	No	Planning to change to Superpave volumetric parameters.
Kansas	No	-
Kentucky	Yes	Air voids and density requirements adjusted from Marshall acceptance versus Superpave mix acceptance. VMA adjusted to conform to AASHTO MP2.
Ohio	No	
Oregon	No	
Rhode Island	-	
South Carolina	No	
Washington	No	No
Wisconsin	No	
Wyoming	No	"Will do our first Superpave projects in 1999. There will be more QC requirements placed on the contractor but the QA will be unchanged."

Table 15. Comments on How QA Specification Could Be Improved

State	Comments
Arkansas	No Comments
Florida	"Always looking to improve."
Indiana	"We usually make minor updates/changes to improve the specs on September of each year."
Kansas	"Need to move to more statistical basis (PWL) and raise the AQL limit."
Kentucky	"It appears once the Industry got experience with the QC/QA approach, they were consistently able to achieve bonus pay. Possible revisions may be needed to raise the criteria (i.e., tighten the ranges for bonus pay on air voids, density, VMA, and binder content."
Ohio	No Comments
Oregon	– "Need to include better indicators at performance in statistical process, i.e., air voids, VMA, VFA, shear tests, rut tests, etc. – "Change statistical program—focus on hitting targets as well as producing consistency."
Rhode Island	No Comments
South Carolina	No Comments
Washington	"Study underway examining current QA specification."
Wisconsin	No Comments
Wyoming	"Not dissatisfied, but the specification could be strengthened by adding a smoothness requirement and a voids acceptance specification."

Table 16. Concluding Comments on QC Program and/or QA Specification

State	Comments
Arkansas	No Comments
Florida	"Now working on a statistically valid spec incorporating use of contractors data for acceptance and combined pay factor focusing on consistency, air voids, and agency verification and independency assurance to comply with FHWA CFR."
Indiana	"QC only works if you randomly audit the Contractor's operation to verify the 'Plan'."
Kansas	"We phased in the program over a 5-year period. Currently in the last year prior to making all bituminous QA based."
Kentucky	"Kentucky's program is not a true PWL (statistical) approach. The program is set to use test results based on acceptance tests by the Contractor with verification testing by the Department. A pay value is applied for each test result within a sublot. The sublot pay values are then averaged for the average lot (4,000 tons) pay values for binder content, air voids, VMA, and density."
Ohio	No Comments
Oregon	"ODOT's QA program has significantly increased Contractor awareness and knowledge of their product. It is paying dividends in terms of Contractors improving heir process to affect quality. I firmly believe our bonus/penalty system (bonus especially) encourages Contractors to strive to do better. The carrot is mightier than the stick!"
Rhode Island	"The HMA is sampled at the plant at random intervals every 500 tons. If it is slightly out of specification, it will conform substantially. If it is severely out of specification it will be rejected."
South Carolina	No Comments
Washington	No Comments
Wisconsin	"We place 100% of our asphalt using QC/QA specification. We have increased the quality and decreased staff requirements."
Wyoming	No Comments

Table 17. SHAs' Use of Incentive and Disincentive Pay Schedules in 1996 (Hughes 1996)
(46 Total Respondents)

Material Property	Incentive	Disincentive
Aggregate Gradation	6	21
Asphalt Content	8	25
Volumetric Properties	3	10
AC Compaction	14	31
AC Thickness	1	4
Ride Quality	14	16

Table 18. SHAs' Use of Incentives in 1999
(9 Total Respondents)

Material Property	Incentive
Aggregate Gradation	3
Binder Content	5
In-place Mat Density	8
Smoothness	8
Air Voids	4

Table 19. Gradation Tolerances

State [spec para]	% Passing sieves --highest quality mix (numbers in parenthesis indicate percentage of tolerance for each sieve)							
	37.5 (1.5")	**25.0 (1")**	**19.0 (_)"**	**12.5 (_")**	**9.5 (3/8")**	**4.75 (#4)**	**2.36 (#8)**	**.075 (#200)**
Florida [331-1]			100 (7.0)	88 (7.0)	75 (7.0)	47 (7.0)	31 (5.5)	2.0 (2.0)
Indiana [401.05]	90	<90				<=34.7	15 (4.0)	6.0 (0.5)
Minnesota [Table 2350-1]	100	90-100 (7.0)	55-90 (7.0)			15-70 (7.0)	10-55 (6.0)	2.0-7.0 (2.0)
Ohio [448.05]			100 (6.0)	95-100 (6.0)	70-85	38-50 (5.0)	20-37 (4.0)	2.0-6.0
Oregon [745.14]	99 (5.0)	90 (5.0)	45-90 (5.0)				19 (4.0)	1.0 (2.0)
Washington [9-03.8(6)]			100	90-100 (0)	75-90 (5.0)			3.0-7.0 (2.0)
Wyoming [5.01]		100 (7.0)	90-100 (7.0)	55-95 (7.0)	45-85 (7.0)	30-65 (7.0)	20-50 (5.0)	2.0-7.0 (2.0)

Table 20. Asphalt Binder Content Tolerances

State [spec para]	Tolerance
Florida [330-10.3]	+/- 0.55%
Indiana [401.09]	+/- 0.30% to +/- 0.70%[1]
Kentucky [402.03.03]	+/- 0.50%
Minnesota [Table 2350-4]	+/- 0.4%
Ohio [448.05]	+/- 0.6%
Oregon [00745.14]	+/- 0.5%
Washington [5-04.3(21)]	+/- 0.5%
Wyoming [7.0109]	+/- 0.25%

Note 1: Depending on number of samples taken

Table 21. QA Sampling Requirements for Selected States

State [spec para]	Lot Size	Gradation *(# tests)*	Binder Content *(# tests)*	VMA/VFA *(# tests)*
Florida [330-10.3.3]	3600 metric tons	4/lot	4/lot	1/lot
Indiana [401.07]	2800 tons	4/lot	4/lot	4/lot
Minnesota [2350.5 (C3)]	2200 tons	days prod/1000	days prod/1000	days prod/1000
Ohio [448.05]	day's prod)	day's prod/1000	1/million liters	days prod/1000
Oregon [165.3]	each JMF	3/lot	3/lot	3/lot
Washington [5-04.3(8)A]	each JMF	5/lot (min.)	5/lot (min)	
Wyoming [8.02]	each JMF	1/1000 Mg min 3/lot	1/day's prod	1/1000 Mg min 3/lot

Table 22. Density Requirements

State	Percent Density*
Florida	96**
Indiana	91.5
Kentucky	96**
Minnesota	91.5
Ohio	92
Oregon	92
Washington	91
Wyoming	92

* % of Maximum Specific Gravity (MSG) unless otherwise noted
** % of valid control strip density

Table 23. Compaction Sampling Requirements

State (spec para)	Lot Size	No. Tests/Lot	Type Test
Florida 330-10.3	1500 m paving pass	10	nuke
Indiana 401.16	2400 Mg	5	core/nuke
Kentucky 402.03.02	3600 metric tons	8	core
Minnesota 2350.6	day's prod (~545 metric tons)	3	core
Ohio 446.05	day's prod (~400 metric tons)	3	core
Oregon 745.49 (QC)	prod/JMF	3/1000 Mg	nuke
Washington 5-04.3	day's prod (~400 metric tons)	5	nuke
Wyoming 8.0302	1500 tons	7	core

Table 24. QA/QC Specification Interviews

Interviewed Group/Person	Comments
Project engineer and inspectors—NW Region	Pros • Random sampling • Use of infrared camera • Need for well-trained street inspectors Cons • Shoulder compaction • No density spec • No calendar restrictions • Bonus: Too high—contractors should earn it • Not enough attention paid to breakdown rolling • QA/QC has not improved mix quality • Not in favor of going to warranties • Binder tolerance of +/- 0.3% probably OK • Variability between WSDOT street inspectors is a problem • QA/QC spec results in too much paperwork
Materials Office—NW Region	Cons • Compaction of shoulders a major issue. Why? • Construction detours • Widening projects • Adding HOV lanes This is of special importance due to advent of full-depth shoulders. Earlier WSDOT spec (1963) stated that shoulders to be compacted along with mainlanes. • Questions whether high enough density being achieved • Nighttime paving. Noise restrictions result in no vibe rollers, and, along with cool temperatures, not getting enough compaction. • Concerned that not enough samples being taken and tests done. • Contractor with low compaction will try to let traffic aid densities by delaying the time to coring • Clarification needed on Rice densities. NW Region will use a running average (3 days).
Epps—University Of Nevada	• Joints vs mat: USCOE and FAA have separate requirements for joints and mat. Joints typically have 2% higher air voids. • Contractors should be <u>required</u> to have a <u>minimum</u> QC program—creates a "level playing field." Implies at least a minimum specified number of tests. • QA/QC specs must continue to have elements of "method" specs. This is particularly true for issues such as differential compaction.
Contractor-Central Washington	• Generally satisfied with current QA specification. • Not in favor of contractor QC program.
Contractor-Western Washington	• If contractor QC program required, a minimum specified program must be set by WSDOT.

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APPENDIX A
STATE HIGHWAY AGENCY QUESTIONNAIRE

April 16, 1999

Questionnaire on State Highway Agency Quality Control/Quality Assurance Programs for Asphalt Concrete

Introduction

This questionnaire is being used to examine the quality assurance (QA) and quality control (QC) programs for U.S. State Highway Agencies (SHAs). The information will be summarized and used by the Washington State Department of Transportation in reviewing and possibly revising its asphalt concrete QA specification. The questionnaire is split into three parts: general questions about asphalt concrete, contractor quality control programs, and SHA quality assurance specifications (including pay factors). We recognize that a number of questions may require an opinion since firm data may not be readily available.

This questionnaire has only a minor overlap with the recently published NCHRP Synthesis 263 "State Management Techniques for Material and Construction Acceptance." That synthesis primarily focused on management techniques, testing, certification, and training issues related to materials and construction acceptance.

To recognize the time and effort to complete this questionnaire, the study team will email (or mail if you prefer) you a summary shortly after we receive the responses from the States.

Please fill in the blank or mark "X's" by the appropriate answer. This will work for email responses as well as fax or mail. We would prefer transmittal by email if possible.

We will appreciate receiving your response by April 30, 1999.

<u>General Questions About Asphalt Concrete</u>

1. What is the annual tonnage of asphalt concrete that your SHA places? ______________ (tons).

2. What percentage of the total tonnage is placed as an overlay?_____%. As new construction? _____%

3. What are the principal construction-related problems that occur with your asphalt concrete paving? (Note the principal ones which apply)
   a. Less than desirable compaction
   b. Poor longitudinal joints
   c. Variable binder content
   d. Mix segregation
   e. Smoothness
   f. Deviations from mix design or the job mix formula
   g. Other____

4. Have you observed during within the first year or so after paving construction-related problems due to differential cooling of the mix and/or cyclic segregation?
   a. Yes
   b. No
   c. Do not know

5. What is the average life (time from construction to replacement or resurfacing) for asphalt concrete wearing courses for:
   - New flexible pavements? ____ years
   - Overlays on existing HMA? ____ years
   - Overlays on PCC? ____ years

Contractor Quality Control

6. Does your SHA require a contractor quality control program?
   a. Yes
   b. No

1. If the answer to Question 6 is No, do some of the contractors in your State voluntarily conduct QC programs?
   a. Yes
   b. No

2. If the answer to Question 6 is Yes, please indicate the QC tests the contractor is expected to perform.

• Aggregate gradation	Yes	No
• Binder content	Yes	No
• In-place mat density	Yes	No

- Others (please list) ____

3. In your judgment, what is the net effect due to the contractor QC program on asphalt concrete quality:
   a. Greatly increased
   b. Increased
   c. No noticeable increase
   d. Do not know
   e. Other____

SHA Quality Assurance

10. Does your SHA use an asphalt concrete quality assurance specification?
    a. Yes
    b. No

    If the answer is No, please skip to the end of the questionnaire and complete the address information.

11. How was the **statistical basis** for your QA specification developed?
    a. Adopted from another SHA
    b. Adopted from the FHWA
    c. Developed solely within your state
    d. Military Standard 414/105
    e. Do not know
    f. Other________________________________

12. What **lot** sizes are tested? ________ (tons) or other measure of lot size
    ____.

13. If known, what is the statistical risk of the contractor having a **lot** of material rejected when in fact it is acceptable? _____%

14. If known, what is the statistical risk of your SHA accepting a **lot** of material when in fact it should be rejected? _____%

15. Does your QA specification require the use of random sampling?
   a. Yes
   b. No

16. If the answer to Question 15 is Yes, are there conditions whereby random sampling can be suspended if a systematic field problem is observed (an example of a field problem could be cyclic segregation)?
   ____

17. How long has your QA specification been in use? ______(years) or year adopted_______(e.g. 1990). If the QA specification was revised, did the changes "tighten" or "loosen" the specification? _______

18. During the last ten years, how often has your QA specification been revised, if at all?
   ____

19. What tests are required by your QA specification?
   - Aggregate gradation Yes No
   - Binder content Yes No
   - In-place mat density Yes No
   - Smoothness Yes No
   - Others (please list) ____________________
   ____

20. What lot sizes are tested? _________(tons) or other measure of lot size____________________________

21. Are bonuses provided for in your QA specification?
   a. Yes
   b. No
   If the answer is Yes, the maximum bonus is ________% of full price?
   If the answer is No, what is the maximum penalty? ________ % of full price?

22. If bonuses are used by your SHA, they are applied to
   - Aggregate gradation Yes No
   - Binder content Yes No
   - In-place mat density Yes No
   - Smoothness Yes No
   - Others____________________
   ____
   ____

23. If bonuses are used, have they increased asphalt concrete quality?
   a. Yes
   b. No
   c. Do not know

24. On what percentage of asphalt concrete paving jobs do contractors earn a bonus? ______%
   What is the **average** bonus? _______ % of full price

25. How often is lots of asphalt concrete rejected?
   a. Almost every pavement job
   b. Over half of the paving jobs
   c. Some paving jobs (≥10% but < 50%)
   d. Virtually no paving jobs

26. In your opinion, what effect does the QA specification have on cost per ton of in-place asphalt concrete pavement as compared to the specification previously used?
    a. Significantly increased cost
    b. Slightly increased cost
    c. Did not affect cost
    d. Reduced cost
    e. Do not know

    If the cost per ton increased due to the QA specification, how much was the increase? ______ %

27. Has your SHA changed your QA specification and its pay factors to accommodate the Superpave® mix design system?
    a. Yes
    b. No

28. If you answered Yes to the previous question, what changes were made to accommodate Superpave®?

    ____
    ____
    ____
    ____

29. What effect does your QA specification have on the overall quality and consistency of in-place asphalt concrete (as compared to jobs done with specifications other than QA)?
    a. Very effective (significant improvement in pavement quality and performance)
    b. Somewhat effective (noticeable improvement in pavement quality and performance)
    c. No effect (no difference in pavement quality and performance)
    d. Negative effect (reduced pavement quality and performance)
    e. Do not know

30. If you are dissatisfied with your QA specification, how could it be improved?

    ____
    ____
    ____

31. Any additional comments on any aspect of your SHA's asphalt concrete pavement QA specification or contractor QC program?

    ____
    ____
    ____
    ____
    ____
    ____

We will appreciate receiving your response by April 30, 1999.

Thank you for completing this questionnaire. A summary of the results will be sent to you shortly after we have received the responses by email or fax. To send you a summary, we need the following information:

Name of person completing questionnaire________________________
Title/Position________________________
Organization________________________
Address________________________
____
Telephone________________ Fax ________________
Email Address________________________

We would appreciate receiving a copy of your current QA specification and, if applicable, a description of your contractor QC program. These can be mailed to:

Dennis C. Jackson
State Materials Engineer
Washington State Department of Transportation
Materials Laboratory
P.O. Box 47365
Olympia, Washington 98504-7365

Your QA specification will assist us with information on mix tolerances and specific test methods (for measures such as air voids, asphalt concrete, mat thickness, aggregate gradation, VMA, smoothness, etc.).

This questionnaire can be emailed to curtist@wsdot.gov.wa or faxed to Teresa Curtis at 360-709-5588.

This document was prepared using Microsoft Word 97.