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Quality Assurance

Past, Present, and Future

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Quality Assurance

Past, Present, and Future

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Summary

Workshop 1605 on Quality Assurance: Past, Present and Future, was held at the 99th Annual Meeting of the Transportation Research Board (TRB) in January 2020. This workshop was broken up into three sections. The first section provided an overview of the TRB Centennial Paper developed by the Standing Committee on Quality Assurance Management (AKC30) for the 100th anniversary of TRB in November 2020. The second section provided highlights of select state departments of transportation (DOT) programs regarding quality assurance (QA) practices in the materials, construction, and design areas. The third section discussed the future of QA. The workshop attendees shared their thoughts on several different questions that posed to the audience at different times during the workshop. Comments documented from the interactive activities are recorded in the sections noted "Workshop Discussion Questions."

Following a brief introduction by the session moderator, Georgene Geary, the first speakers, Chuck Hughes and Kevin McGhee presented an overview of the Centennial Paper by covering Quality Assurance: Past, Present and Future. This was followed by presentations by Rick Bradbury of the Maine DOT and Dave Huft of the South Dakota DOT discussing different aspects of their materials QA program. Carol Luschen and Weng On Tam shared aspects of the Texas DOT construction and design QA programs as related to alternative project delivery. The final presentation of the session was by Robert Conway of the Federal Highway Administration (FHWA). He shared FHWA's perspective on implementing new technologies and QA.

This E-Circular provides a synopsis of the workshop by including key slides along with a synthesis of the points delivered by each of the six presenters. As mentioned above, comments and questions from attendees were collected and included. The material included in this E-Circular provides a valuable reference and a reminder that there is value in understanding where QA came from to understand where it needs to go in the future.

Contents

Quality Assurance

Past, Present, and Future

KEVIN MCGHEE
CHARLES HUGHES
ASHLEY BUSS
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INTRODUCTION

As the 100th Anniversary of the Transportation Research Board's (TRB's) Annual Meeting was approaching, the Standing Committees of TRB were asked to consider developing Centennial Papers to commemorate the event. This presentation, Construction Quality Assurance Accomplishments and Outlook for the Next Century, shares an overview of that effort by the Quality Assurance Management Committee. The full document can be found on the TRB website at http://onlinepubs.trb.org /onlinepubs/centennial/papers/AFH20-Final.pdf.

YESTERDAY

Genesis

This committee is 52 years old and was first named Quality Assurance and Acceptance Committee. Its primary purpose was to "Address the need for a more scientific approach to developing construction and material specifications". This need to improve agencies' construction and materials specs came about as the result of the findings of the AASHO Road Test, shown in Figure 1. Note that is not a typo, AASHTO was once AASHO, but not many know that it almost was AASTO. In the mid-1960s AASHO wanted to broaden its scope and name to use Transportation in place of Highway. They wanted to drop the H and add a T. Doug Fugate, the Chief Engineer of Virginia Department of Highways, was Chairman of AASHO at that time. Being quite persuasive, he got AASHO to retain the H and add the T.

Committee Evolution

The committee's name was "Quality Assurance and Acceptance" for many years. In the early 1990s the committee's name was changed to "Management of Quality Assurance" and most recently, in 2017, it was changed again to "Quality Assurance Management." As can be seen, the name evolved and became broader and more inclusive and the designation evolved as TRB did as well. Over time the leadership of the committee has changed the past and present chairs are noted in Figure 2.

FIGURE 1 Origin of the committee.

FIGURE 2 Committee leadership, 1960s to present.

Major Accomplishments

Although there have been many accomplishments of this committee during its existence, one that stands out is the development of the *Glossary of Highway Quality Assurance Terms*. Recently the sixth update, or seventh edition, of *Transportation Research Circular E-C235: Glossary of Transportation Construction Quality Assurance Terms: Seventh Edition* (August 2018) was published. It originated with *Transportation Research Circular Number 457: Glossary of Highway Quality Assurance Terms* (1996). Just like Quality Assurance (QA) terms are still being misused, this committee has brought variability to the forefront, but increasing the understanding of variability as part of specification writing is still an ongoing effort, as shown in Figure 3.

TODAY

The processes for delivering big public works projects have evolved considerably in the last 50 years, and these new delivery methods are changing the way the community approaches QA. They have a profound effect on many of the traditional elements of construction QA, impacting details as fundamental as who does the testing and how those test results are used. QA must also accommodate advancing construction and management technologies, as well as the role for quality management of the life of facilities. Consequently, among the committee's present-day priorities are

FIGURE 3 Terminology and varibility.

- Alternative project delivery;
- Validating contractor test results;
- Automated and digital construction; and
- Facility life cycle.

Alternative Project Delivery

As evidence of the committee's commitment to QA in the alternative delivery context, it recently established a joint subcommittee devoted to alternative delivery methods. The subcommittee, a collaboration with AKC20 (Project Delivery Methods), concerns itself with all aspects of quality management as related to the planning, procurement, design, construction, operations and maintenance of transportation facilities delivered by some alternative method [public–private partnership, design–build (DB), CMG at Risk, etc.]. In the short time of its existence, the subcommittee has developed 27 research needs and synthesis ideas relating to quality management for nontraditional project delivery.

Validating Contractor Test Results

The use of contractor-performed tests for acceptance and payment, which was enabled by 23 CFR 637B, remains a necessity for many owner–agencies. In practice, agencies sometimes struggle to achieve the required data for adequate validation, which often causes one or both parties to face situations where risks are unfairly applied.

NCHRP Project 10-100, Procedures and Guidelines for Validating Contractor Tests Results, which is inspired by a statement developed within the committee, seeks to

- Identify the procedures currently available for validating contractor test data for construction materials and other applications;
- Develop procedures for use in validating contractor test data for construction materials;
- Prepare guidelines for the application of these procedures; and
- Reduce the risk of incorrect acceptance decisions and pay adjustments.

The principal investigator for this study is an active member of the committee. Past, ongoing, and future work by the committee have contributed and will continue to contribute to this latest effort.

Automated and Digital Construction

Digital models can incorporate data from preliminary engineering, design, ongoing and post-construction, and even in-service surveys. Effective combination and use should accommodate the accuracy and reliability of the contributing sources, especially when used to manage quality. Construction automation processes that can take advantage of digital elevation models include thickness compensation and real-time smoothness tools. Other technologies to address include intelligent compaction, thermal profiling, and ground penetrating radar (for thickness and compaction determination) like shown in Figure 4.

Facility Life Cycle

As the concepts of sustainable development continue to grow, there is an increased emphasis on the interconnectedness of the various elements of a transportation facility's life cycle as shown in Figure 5. Researchers continue to pursue applications that combine design, construction, and performance data to optimize facility management. For example, many mechanistic–empirical design models require as-built construction data and subsequent performance data for proper calibration and validation.

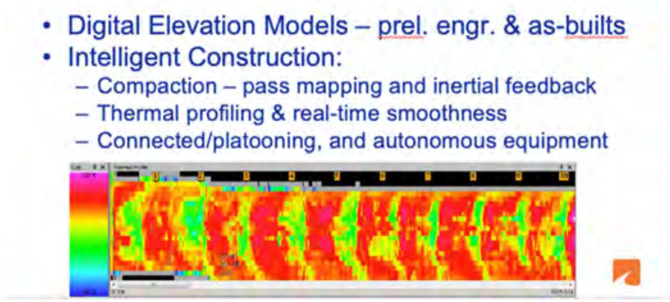

FIGURE 4 New technologies.

FIGURE 5 Life-cycle components.

TOMORROW

As with nearly every imaginable discipline of study, QA of the future will be immersed in Big Data. Applications for real-time validation, vulnerability checks, and backup will be essential. With individual data so numerous, tools of the future will likely need to monitor system-level behavior and be able to do that while the system runs. Example systems may even be those to support design and construction, especially tools to support construction automation.
Finally, as traditional resources of public agencies continue to shrink, QA plans that include strategies for partnering and risk-based inspection will be more important. Some of these emerging issues are depicted in Figure 6.

FIGURE 6 Tomorrow's trends and emerging issues.

WORKSHOP DISCUSSION QUESTION 1

What are the changes that you have seen in QA over your career that you feel have had the most positive (or negative) impact?

One attendee noted that states need more educational opportunities related to QA. Another shared that the National Highway Institute (NHI) has a new course coming out this year (NHI 131411, Quality Assurance for Highway Construction Projects) covering the fundamentals of QA as well as the mathematical terms and principles used in QA sampling, testing, and decision-making QA.

Another attendee noted that they have seen the evolution of departments of transportation (DOTs) from being process minded to results minded. When the DOT had more control of the quality control (QC) they were focused too much on the process and not the results, this sometimes caused problems to continue. Now that DOTs are more results minded they can focus on resolving problems with the contractor, instead of focusing on maintaining a process that really needed to be adjusted.

A contractor noted that he has seen more of a focus on QC by the contractor. In the past the contractor would run one QC test in the morning and if it was within specifications that was all they did. But now they are testing 10 samples throughout the day and reviewing the trends in the results. The QC personnel are not necessarily engineers but they are now more educated and specifically trained to react to any issues identified because of trends in the test results, and not just file the results.

A state DOT noted that they have seen an improvement in test methods including improved consistency in results due to trained technicians and improved test methods (e.g., AASHTO T 58 Chloride Permeability).

An attendee noted that one concern with new technology is keeping up with the rate of construction; contractors can now build faster than the work can be inspected. There is a need to speed up QA.

Maine Department of Transportation's Quality Assurance Program

RICK BRADBURY

MAINE DEPARTMENT OF TRANSPORTATION'S QUALITY ASSURANCE JOURNEY

Maine DOT has a long history of QA (Figure 7) that has focused on the six core elements. Specific attention was paid to those program elements designed to increase confidence in QC and acceptance test results:

- Partnered with industry to reduce test variance:
  - Policies and procedures manual;
- Developed good systems for dispute resolution; and
- Placed value on QC plans:
  - Invested in inspector and technician certification through the NorthEast Transportation Training and Certification Program.

System-Based Independent Assurance Program

One of the core elements of a QA program is independent assurance (IA). Maine DOT uses a system-based IA program that allows them to cover the entire state with three IA technicians (Figure 8). Each year is divided into two equal periods. The goal of the program is to perform IA inspections on at least 90% of all field technicians who conduct acceptance sampling and testing during that period. The department's testing information management system tracks all acceptance sampling and testing activities by technician for each period to allow the IA team to schedule their inspections.

FIGURE 7 Maine DOT's QA journey.

2019 IA INSPECTION OF FIELD TESTERS BOTH PERIODS

Grand Total										
Possible Inspections (>3 samples taken)	17		42		7		146		60	
Obtained Inspections		16		42		6		145		58
Possible Inspections (>3 samples taken), %	94.1%		100.0%		85.7%		99.3%		96.7%	
Total Inspections		16		43		7		150		61
All Possible Inspections (>3 samples taken)	272		Obtained IA Inspections	267			All Percent Obtained (>3 samples taken)	98.2%		

FIGURE 8 Maine DOT IA program.

Quality Control Plans

Maine DOT specifies two different QC plan requirements:

- Standard QC plan: company-wide QC practices and
- Project-specific QC plan: detailed for single project.

The standard QC plans require approval from a team of statewide QA personnel and the Federal Highway Administration (FHWA). This approach provides consistency of review and prevents changes from being missed. The project-specific QC plans are approved based on a combination of statewide personnel and the project team.

Once approved, the QC plan becomes equivalent to a contract document and financial penalties are enforced for nonconformance as shown in Figure 9. These penalties are not related to material quality; they are focused solely on encouraging compliance with the submitted QC plan.

Dispute Resolution

Maine also has a well-defined and vetted dispute resolution program that includes specific requirements for submitting a request for dispute retesting. The dispute resolution works as follows:

Quality Control Plan Value		Pay Reduction		
From More Than	To and Including	1st	2nd	3rd & Subsequent
$0	$500,000	$1,000	$2,000	$4,000
$500,000	$1,000,000	$2,000	$4,000	$8,000
$1,000,000	$3,000,000	$5,000	$10,000	$20,000
$3,000,000	and more	$10,000	$20,000	$40,000

FIGURE 9 Specification penalties for noncompliance.

- To have the ability to dispute a DOT test, contractor must obtain a split of the DOT acceptance sample.
- Results of split sample are submitted to DOT prior to release of DOT test results.
- Contractors compare their results to DOT results; if the results on pay-related properties exceed a specified tolerance, the results may be disputed. Tolerances are based on d2s (two standard deviation) limit values.
- DOT's QA engineer determines validity of dispute. If valid, a retained split of the original DOT sample is sent to an alternate DOT lab.
- When completed, the result of the DOT dispute test is compared to the initial DOT test result and the contractors result.
- If the dispute result is closer to the initial DOT result, the initial DOT result stands; if the dispute result is closer to the contractor's result, the DOT dispute result replaces the initial DOT result in the acceptance decision.

Using this process, disputes are resolved relatively quickly. The dispute process is based on the expected difference between two labs—arbitrary retests are not allowed. All parties understand the clearly defined business process. The DOT has also worked proactively with industry to reduce disputes through improved consistency of testing practices, resulting in reduced rates of disputed test results over time.

Sample Security

FHWA requires agencies to control the acceptance sampling process to reduce opportunities for fraud and abuse. Traditionally, this has required that the DOT technician take immediate possession of all acceptance samples and either deliver them to the appropriate DOT laboratory, or have them delivered by another DOT employee, to avoid possible tampering with the sample. However, Maine is a rural state and often has projects in remote locations, leading to situations where acceptance samples were not delivered to the DOT lab for several days. Contractors and material suppliers desired quicker turnaround of acceptance test results, so Maine DOT worked with FHWA and industry, and developed a system using tamper-evident seals that would provide visual evidence that asphalt mix and core sample containers had not been opened prior to delivery to the DOT laboratory.

NEW TECHNOLOGIES

Maine DOT is investigating several new technologies to assist with its QA program (Figure 10). In 2014, the surface resistivity (SR) test replaced the rapid chloride permeability (RCP) test to determine the permeability of structural concrete. SR is much simpler and quicker to run, does not require extensive sample preparation or hazardous chemicals, and correlates extremely well with RCP. The relative simplicity and cost of the SR test will also allow producers to evaluate mixes as part of a performance engineered-design process.

Several technologies are being investigated for asphalt QA. Two of these are continuous thermal profiling, which monitors the surface temperature of the newly placed pavement, as well as recording paver speed and number and duration of paver stops. All of these characteristics must be controlled in order to produce a smooth, properly densified pavement. Another tool, the

Surface Resistivity

PaveScan Rolling Density Meter

FIGURE 10 New technologies.

rolling density meter (RDM), uses radar technology to map the surface dielectric values of the compacted asphalt, which correlates to pavement density. Maine DOT's current sampling rate of one 6-in. diameter core specimen for every 250 tons of asphalt provides density data for much less than 1% of the pavement area. Use of the RDM greatly increases the amount of available data for assessing quality. Maine DOT is continuing to evaluate the accuracy and precision of these tools, as well as how to best implement them as part of the QA program, including their applicability for QC and/or acceptance testing. Even if a tool such as the RDM does not provide equivalent pavement density when compared to an individual core sample, the large amount of real-time data it can measure holds great promise as a measure of relative density and uniformity of the compaction process.

RETHINKING QUALITY ASSURANCE

Maine DOT recognizes that improvements have occurred since implementation of QA specifications. Development of contractor–supplier QC programs and the increased focus and investment on technicians, labs and equipment led to many early quality improvements. However, in recent years, they have noticed some disturbing trends:

- Lack of continuous improvement—quality levels static or decreasing;
- Reactive approach to acceptance testing; and
- Increased rate of cease production and reject quality level (often triggered by acceptance results, not QC).

There is some discussion in Maine DOT that there has been too much focus on the acceptance process, especially specification limits and pay adjustment provisions, and not enough focus on process control. There is even a concern that the specifications are hindering progress by focusing the QC effort on testing the output of the asphalt or concrete being used for specification compliance, rather than on reducing variability of the constituent materials and production processes. Current minimum QC sampling rates on the produced material may be shifting limited resources away from process control. Some of the discussions have focused on the QC misnomers as noted in Figure 11. There also is a concern that too much focus on meeting specifications, instead of controlling overall quality, could hinder continuous improvement.

A lesson was shared from a case study of Ford and Mazda transmissions. Ford noted that when building automobiles in one of their assembly plants using transmissions, some of which were supplied by a Ford manufacturing facility and others by Mazda that cars built with the Ford transmissions had a much higher rate of warranty repairs. They compared the conformance of critical dimensions of parts built in both facilities, and while both facilities were producing parts within tolerance, the Mazda parts showed almost no variability. Ford realized "We worried about specifications; *they* worried about uniformity."

Based on this case study a new way to define quality is proposed. Quality is inversely proportional to variability. W. Edwards Deming (Figure 12) encouraged a focus on process improvement to reduce variability as the way to achieve quality. While statistical acceptance procedures such as percent within limits (PWL) are far superior to the past method of basing acceptance on pass–fail of individual samples, their use alone cannot improve the quality of the product delivered to Maine DOT's customers. Improved process control procedures using new technology with real-time quality measures and increased coverage will provide important tools in the quest for continuous improvement.

As Maine DOT moves to implement new performance engineered mix design procedures for asphalt and concrete, it will be more important than ever to have excellent process control in place at production facilities. While sophisticated test procedures that measure fundamental

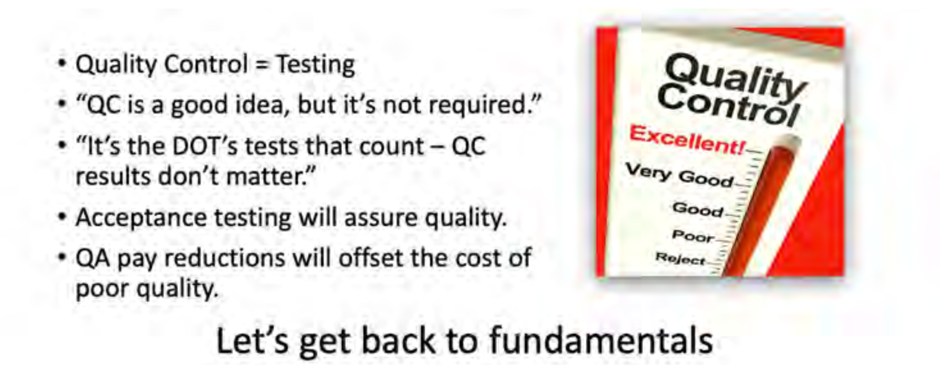

FIGURE 11 Mistaken ideas about QC.

FIGURE 12 W. Edwards Deming's philosophy.

properties are needed to improve long-term performance of materials, these tools are often too complex and time-consuming to be effective for process monitoring or project acceptance. A better approach may be to use them to design an improved product up front and rely on continuous process improvement to minimize variability during construction, resulting in a better product for the traveling public.

South Dakota's Asphalt Concrete Quality Assurance Procedures

DAVE HUFT

IMPROVEMENT GOALS

In the late 1990s, South Dakota set out to improve the quality of the asphalt concrete pavements. The intent was to reduce rutting, achieve a more consistent product by using field tests that predict performance. This also included a focus on contractor QC processes that could improve the final product. South Dakota DOT initiated pay incentives and disincentives to encourage consistent quality. Over time, additional improvement actions were taken as noted in Figure 13.

QUALITY ASSURANCE PROJECTS

South Dakota has a Class Q asphalt concrete that is used for projects with plant production greater than 10,000 tons per project, which includes approximately 70% of the tons of asphalt used by South Dakota per year. For these projects the contractor's testing may be used for acceptance when they are verified by the state's testing as shown in Table 1.

The contractor must test and maintain control charts for non-pay attributes which include: aggregate gradation, binder content, lime content, moisture content, sand equivalence, lightweight particles, crushed particle, fine aggregate angularity, voids in the mineral aggregate), dust to binder ratio and recycled asphalt pavement (RAP) content. These attributes must be maintained within South Dakota DOT specification requirements. Incentives and disincentives are identified by PWL statistical procedures based on a composite pay factor that addresses percent air voids and in-place density (Figure 14).

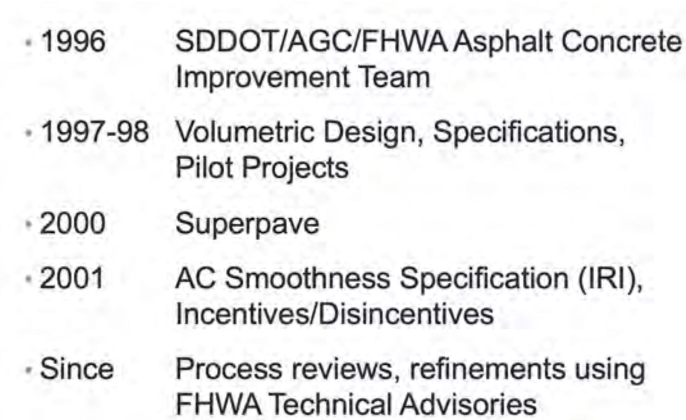

FIGURE 13 Timeline of improvements.

TABLE 1 South Dakota DOT Use of Contractor's QC Tests

Project Type	Contractor	Area	Region Materials
Other	Production Quality Control	QA Testing Acceptance	IA
QA/QC Asphalt Concrete	Production Quality Control QC Testing (1,000 tons) Acceptance	QA Testing (5,000 tons)	IA (10,000 tons)

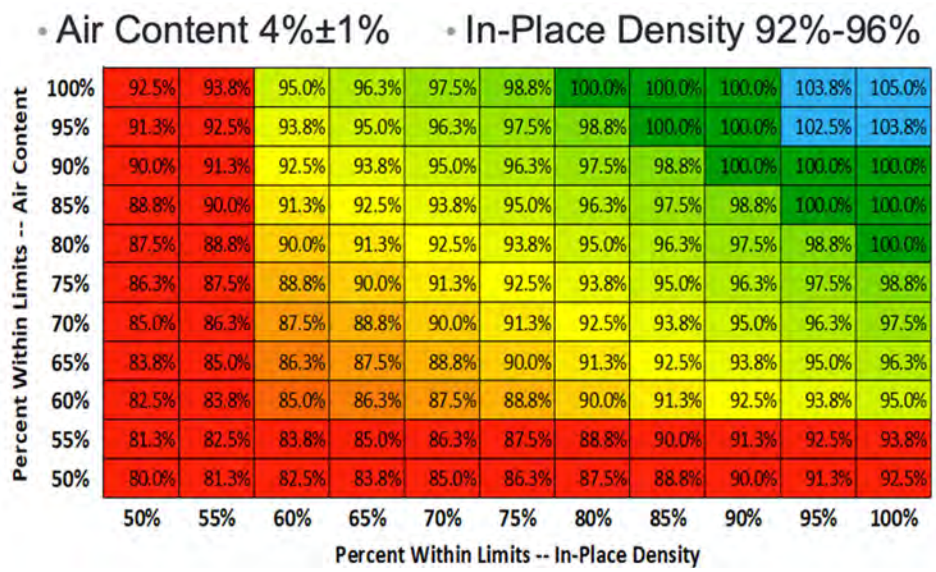

FIGURE 14 South Dakota DOT AC mix composite pay factor table.

South Dakota uses joint DOT/contractor/consultant courses for training and certification of technicians. The Dakota Asphalt Paving Association provides five courses that cover everything from the design, control and installation of asphalt paving:

- Introduction to AC;
- Aggregate;
- Hot Mix;
- Road Inspection; and
- Mix Design and QC.

South Dakota DOT requires certification and AASHTO round robin (proficiency) sample testing for acceptance testing.

QUALITY ASSURANCE BENEFITS

South Dakota documented the benefits of the QA program in 2016. It was estimated that the new program extended the life of South Dakota DOT pavements by 4.5 years. Prior to the improvements the surface condition index (SCI) averaged 3.3 (fair) at year 13, compared to a SCI of 4.2 (very good) at year 13. Figure 15 shows that the difference varied little in the first 6 years, but then the QA (QA/QC) projects maintained a higher index after 7 years. Besides improving the longevity, it also reduced the frequency of resurfacing required from 32% of projects resurfaced to only 7% by year 14.

With change some contractors were apprehensive about what they considered increased responsibly, and PWL was a new concept at the time. A few contractors even quit paving for the state, but over the 20 years South Dakota has now been using PWL, acceptance in the contracting industry has grown. Ken Swedeen from the Dakota Asphalt Paving Association recently noted, “I think it is the greatest, least mentioned, and least celebrated breakthrough in asphalt pavement quality since the invention of the drum hot mix plant. I think most contractors, after the initial learning curve, agree completely. The data stands for itself.”

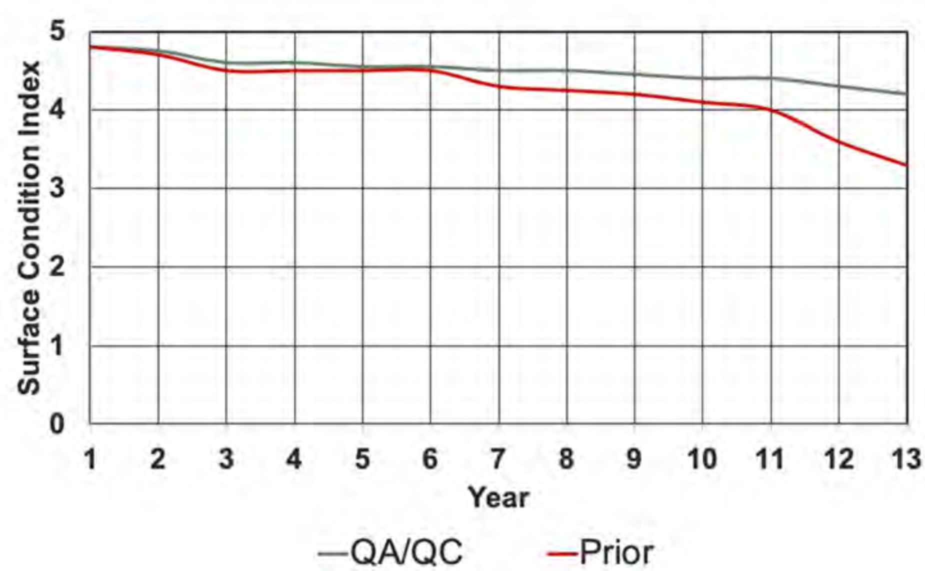

FIGURE 15 QA/QC performance comparison, 2016; measured benefit of QA.

WORKSHOP DISCUSSION QUESTION 2

Can you share with us any innovative QA procedures used in your state for materials, or do you have any suggested procedures?

The moderator requested the audience to discuss the Workshop Discussion Question 2 related to innovative QA procedures over the break and the audience was provided flip charts and markers to note their thoughts. Although there was not time to discuss the contributions, they are noted here with links for the reader to explore as appropriate.

- MIT T2 Scan for Pavement Thickness:
  - https://www.fhwa.dot.gov/pavement/concrete/scant2.cfm.
- Risk-Based Inspection at Ohio DOT:
  - http://www.dot.state.oh.us/engineering/OTEC/2018_OTEC_Presentation/Kahlig_Session15_2018%20Presentation%20%20-%20Risk%20Based%20Inspection%20%20electronic%20documentation.pdf and
  - http://www.dot.state.oh.us/Divisions/ConstructionMgt/Admin/Manuals/2017 MOP_Final_11162016%20for%20print.pdf.

A Connecticut DOT staff member noted they had success in improving communications with industry and even improved the quality of their pavements when they started sharing an annual report to industry regarding their performance. It is presented at the annual group meeting with the producers–contractors when all the data from the previous paving season has been analyzed. It summarizes the statewide industry performance as a whole with regard to plant testing of the mix and density testing of in-place material. They are able to analyze the same data on an individual Producer/Contractor basis, but review that in separate meeting with each one at a later time.

What type of innovative technologies are you using or looking at using?

An attendee noted they are increasing use of 3D construction and other innovative processes, but QA was a bottleneck, too much focus on legacy methods.

Time was limited for further discussion. Another lesson learned!

Evolution and Lessons Learned on Texas Department of Transportation's Design–Build Quality Program

CAROL LUSCHEN
WENG ON TAM

OVERVIEW OF PROGRAM

Texas DOT has a long history of design–build (DB) projects and public–private partnership enabling legislation. As early as 1991 Texas House Bill 749 authorized public–private partnership agreements. Texas DOT's first DB (SH 130 Segments 1–4) started in 2002. Texas DOT calls their public–private partnerships Comprehensive Development Agreements (CDAs). CDA projects were created by state law in 2004 and can be DB or concession projects. SH-130 Segments 5 and 6 were Texas DOT's first concession project in 2007. After a short moratorium on the CDA process in the 2008–2011 timeframe, legislation after 2011 set limits on the number of CDA projects that can be that could be performed through a CDA. From 2001 to 2020 Texas has advanced 12 DB projects, six DB CDA projects, and five concession CDA projects. In that period, CDA contract values increased from \$1 to \$20 billion total contract amount. Figure 16 shows Texas DOT projects from the first project (SH-130 Segments 1 through 4) through current procurements.

Starting in 2002, Texas DOT started developing programmatic documents for quality management of CDAs. Figure 17 shows the progression of programmatic documents.

Texas DOT realized that programmatic contract documents could provide Texas DOT and the DB contractors consistency in expectations associated with their alternative delivery program and streamline the procurement process. The contract documents have evolved over

FIGURE 16 Texas DOT's DB and concession projects.

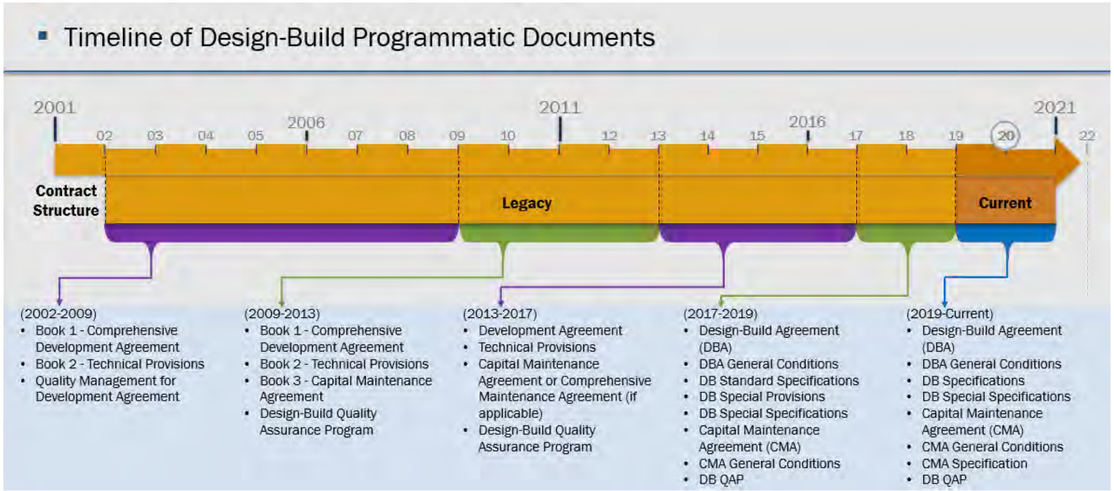

FIGURE 17 Progression of Texas DOT programmatic documents.

time to the current ones listed below:

- DB Agreement (DBA),
- DBA General Conditions,
- DB Specifications,
- DB Special Specifications,
- Capital Maintenance Agreement (CMA),
- CMA General Conditions,
- CMA Specification, and
- DB Quality Assurance Program (QAP).

LESSONS LEARNED FROM DESIGN–BUILD QUALITY ASSURANCE PROGRAM

Texas DOT's DB QAP was developed to address 23 CFR 637 Part B (Quality Assurance Procedures for Construction, 1995). It is also compliant with guidance related to using contractor test results (FHWA Technical Advisory T 6120.3, 2004, and the nonregulatory supplement to 23 CFR 637B, 2006) and specific guidance on DB projects issued by FHWA in 2012 (FHWA HRT-12-039, Construction Quality Assurance for Design–Build Highway Projects). Figure 18 shows the difference phases of the program.

Lessons learned in each of the phases of project procurement, implementation, operations and closeout are provided next.

For the procurement phase, Texas DOT has learned the importance of standardizing contract requirements and uniform implementation of the DB QAP. Texas DOT's Materials and Testing Division (MTD) is currently responsible for the standardization, training, FHWA quarterly report review, software support, and continuous improvement of the DB QAP. This

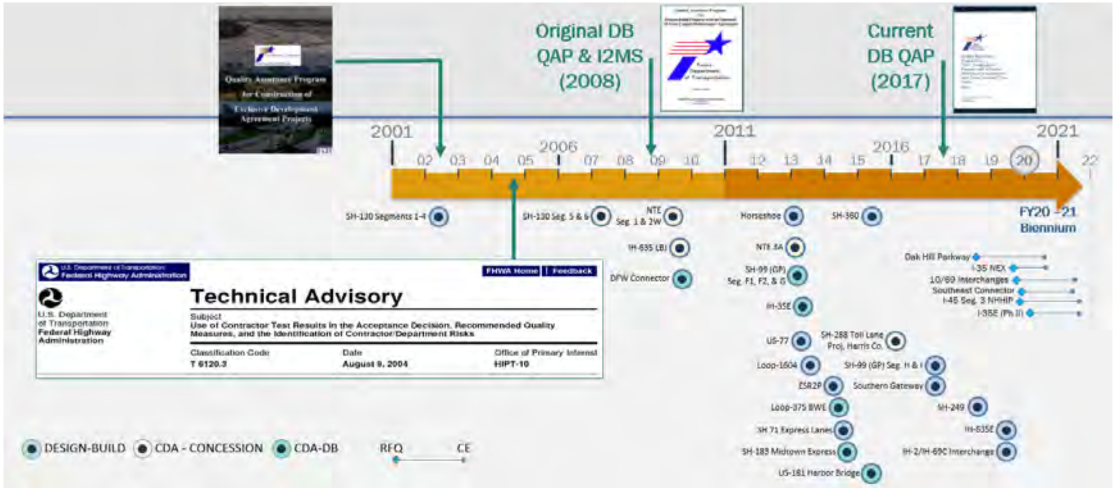

FIGURE 18 Evolution of DB QAP program.

allows Texas DOT to develop and provide uniform training to each project team (Texas DOT staff and consultants) for consistent implementation of the program. It also allows DB contractors and their independent quality firms (IQFs) to better budget and prepare to deliver quality construction and construction acceptance. Over time, the owner verification and testing consultants and IQFs engaged on these projects have also gained the necessary experience to successfully deliver these DB projects.

Another lesson learned is to have specific and detailed requirements for each quality role as well as specific procedures for addressing nonconforming work and non-validating analysis categories (Figure 19). These details are important to minimize or eliminate ambiguities in the quality functions and ensure that each role comprehensively understands and fulfills their obligations under the contract.

FIGURE 19 Lessons learned during project procurement phase.

For the implementation phase (Figure 20), Texas DOT has learned that it is critical to review the DB contractor's construction quality management plan (CQMP) thoroughly. The CQMP should contain detailed procedures that can be followed to successfully deliver QC and quality acceptance work. These procedures need to be written in a manner that can be objectively verified by Texas DOT. This minimizes conflict over whether a subjective procedure has been met.

Texas DOT developed the I2MS software system to automate the data entry, review, and approval of data. I2MS also has the ability to run the Level 1 continuous *F*- and *t*- test analyses, Level 2 independent verification, and the Level 3 observation verification. It also includes search, data analysis, technician qualification verification functions and generates the necessary analyses required satisfy FHWA's verification requirements. This tool has been instrumental in the daily analysis of records and allows for "real-time" monitoring of materials validation.

Texas DOT typically has its district laboratories perform the IA role on projects though it is sometimes outsourced to a qualified consultant laboratory. The Texas DOT laboratories check that technicians have received the proper training and certifications for the tests performed and also provide certification for some of the test methods.

Alignment of the Texas DOT owner verification lab and the IQF lab is key first step in materials verification. At the beginning of each project, both these labs participate in lab alignment to ensure that test results are within acceptance tolerances on split-samples. This helps eliminate potential nonvalidation between Texas DOT and the IQF due to systematic biases in test results. Lab alignment should be continued during project operations as new technicians join the project or when there are any concerns with the alignment of the two labs.

For the operations phase (Figure 21), Texas DOT uses a risk-based approach to inspection oversight. Unlike testing oversight which has specific risk levels identified (Levels 1, 2 and 3), risk-based inspection does not have defined levels of verification though it allocates more inspection oversight resources to elements of the project that have greater risk. For example, bridges and pavements are considered elements with higher long-term risks while sidewalks are an item with lower long-term risk. Texas DOT also assigns more oversight resources to IQF inspectors who are new to the project or have less experience until confidence in their inspection abilities has been established.

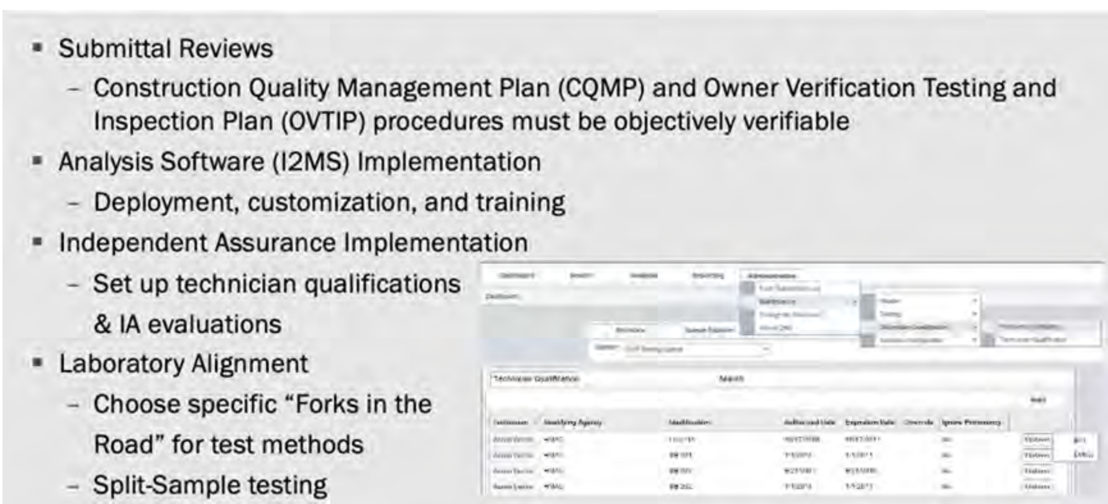

FIGURE 20 Lessons learned during project implementation.

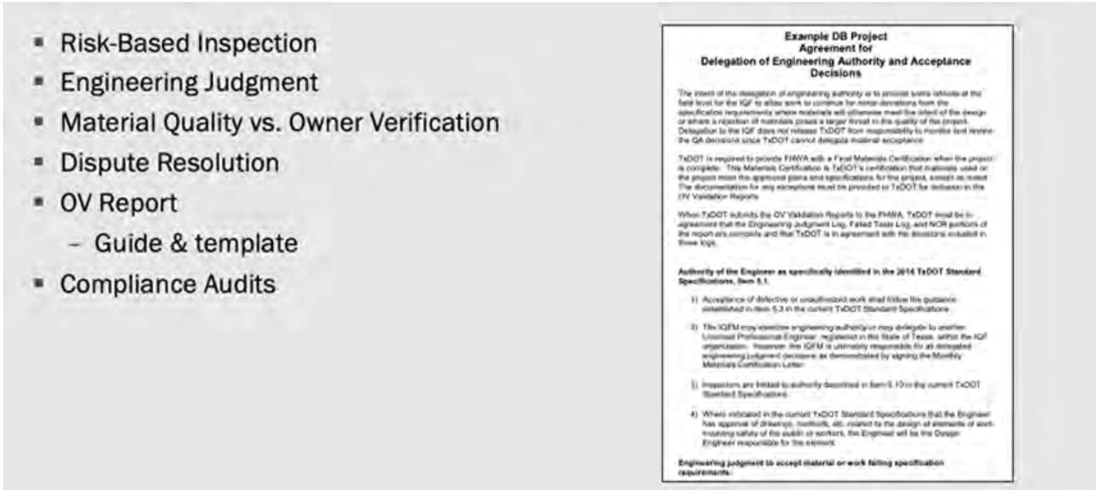

FIGURE 21 Lessons learned from project operations.

Engineering judgment is used to accept work that has only minor deviations from the plans and specifications and will perform its function no impact to life-cycle costs. Detailed requirements have been established for the use of engineering judgment and the IQF's engineering judgment privileges may be suspended or removed if they do not exercise engineering judgment in accordance with these requirements.

Owner verification is Texas DOT's verification of the IQF's acceptance inspection and testing. It is separate from material quality, which is a measure of whether the materials and workmanship meets the drawings and specifications. An element of work can have good material quality while the Texas DOT test results do not verify the DB contractor's results at a given point in time. As an example, both Texas DOT and the IQF may have test results showing that the concrete compressive strength exceeding the specifications comfortably. However, Texas DOT's compressive strength results may be statistically higher than the IQF's results, which could lead to a nonvalidation for that specific mix design. The concrete is acceptable and can be incorporated into the project. However, an investigation into the nonvalidation should be conducted to determine the root cause of the nonvalidation and the mix design should be brought back into validation. There should be clear dispute resolution procedures to address non-validating materials and materials not meeting specification requirements.

Texas DOT has also developed an OV report guide and template to provide further standardization of the DB QAP. This allows Texas DOT's MTD division to easily review the OV reports before they are submitted to FHWA. For project closeout (Figure 22), the process is made much easier with OV reports being submitted and approved by FHWA quarterly. The final OV report is the last quarterly OV report. All the quarterly OV reports are compiled as attachments to the final materials certification letter for MTD and FHWA approval. One lesson learned is to establish which Texas DOT position is responsible to sign the final materials certification letter since more than one person may have been providing oversight of the project through the project's life.

FIGURE 22 Lessons learned from project closeout.

FUTURE

While Texas DOT has made great strides in the last 20 years of the DB QAP program, it is continually reviewing projects and looking for opportunities to improve its program. In October 2020, an updated DB QAP was released that incorporated the lessons learned over the last 3 years.

Incorporating New Technologies into the Quality Assurance Environment

ROBERT CONWAY

FHWA AND QUALITY: HISTORY

FHWA has always pursued, supported and continues to encourage innovations in its Stewardship role. FHWA also has an oversight responsibility to ensure there is accountability for the public's tax dollars.

The Highway Program was in a crisis in the early days. There were a lot of people that didn't share the vision of an Interstate Highway System where people could drive across the county without stop signs and traffic lights. The tremendous cost to construct the interstate system was under attack by many who felt it was too expansive and unnecessary. At the same time, negative news investigations and the infamous Blatnick Hearings that highlighted fraud and corruption throughout the program occurred. At one point it was even proposed to transfer the oversight of the interstate program from the Bureau of Public Roads (then the name of the FHWA) to the U.S. Army Corps of Engineers. In response, FHWA developed accountability, transparency, and documentation standards that define how to document and defend the expenditure of the public's money.

EMERGING TECHNOLOGIES

Some of the current emerging technologies are noted in Figure 23. Federal funds can be used to pay the contractor for using this equipment and providing the data, but federal funds should not be used (without agency verification) to pay incentive/disincentive based on the material quality shown by the data.

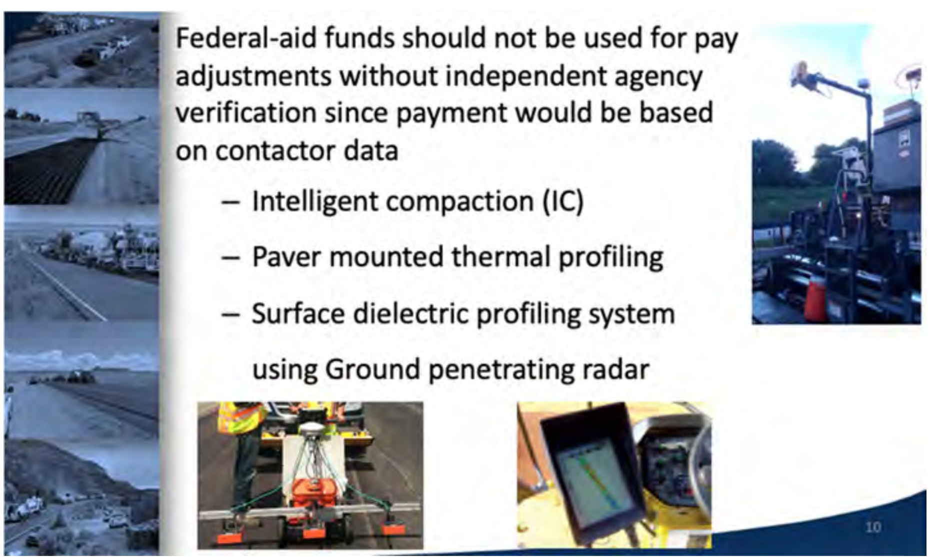

FIGURE 23 Some emerging technologies. (Photos courtesy of Steve Cooper, FHWA).

When considering an emerging technology, these are some of the questions that should be considered:

- Is the emerging technology a contractor process control tool?
- Is the Innovation an enhancement to the contractor's equipment?
- Does the Innovation provide the contractor real-time QC of a quality characteristic that the Owner can independently verify in the final product?
- Is the emerging technology a quality measurement tool that can be operated independent of the contractor production or QC?
- Will the Innovation be required by contract?
- Will the use of the emerging technology be compensated with a pay item or will it be incidental?
- How will the emerging technology's use be documented, what QC deliverables will be available?
- How does the Owner Agency intend to monitor the contractor's QC?
- Will the technology be used for Basis of Acceptance?

How will Independent Verification of Quality by the Owner Agency be accomplished?

To move to implement an emerging technology the fundamental elements that should be considered are:

- Recognition of Agency Acceptance and Accountability Fundamentals;
- QC and Agency Acceptance Roles and Responsibilities;
- Process Control or Quality Measure Tool;
- Encourage and Promote Adoption of the Quality Improvement Innovation; and
- Agency Verification of any QC data used for pay adjustment.

The current status of QA reviews are shown in Figure 24.

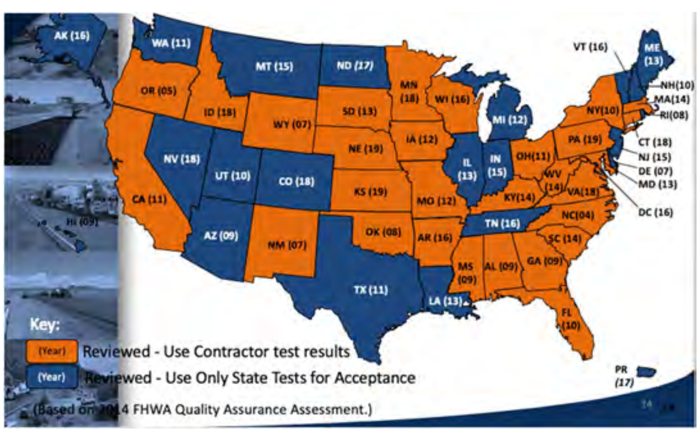

FIGURE 24 Current status of FHWA QA reviews.

Concluding Thoughts

Quality Assurance management for transportation infrastructure has evolved over time. Even the definitions and terms have been transformed (e.g., QA/QC is now just QA!). This E-Circular provided some of the history and shared examples from several states of how QA practices are continuing to advance. New technologies are driving some of the advancements in QA, along with new alternative methods of contracting (e.g., DB and public–private partnerships). Throughout this E-Circular the importance of keeping an eye on the fundamentals of QA was shared. QA fundamentals involve an essential focus on reducing variability, measuring the appropriate performance outcomes, like smoother longer-lasting roads, and providing proper oversight, no matter the method of construction. By considering the fundamentals, when either addressing QA for new technologies or in using new technologies to perform QA, the result will be that overall performance will be improved.

About the Presenters

Tim Aschenbrener is a Senior Asphalt Engineer in FHWA's Headquarters Office of Infrastructure.Tim joined FHWA in 2012 after working with the Colorado DOT for 22 years. His work and expertise focus on asphalt materials, recycled materials, and quality assurance. Tim is Chair of TRB Committee on Quality Assurance Management (AKC30).

Rick Bradbury is the Director of Materials Testing and Exploration for Maine DOT. Prior to this, Rick served as QA Engineer, and spent 12 years as a field testing technician and plant inspector. He is currently serving on several regional and national technical panels overseeing QA research, and he is member of AFH20.

Ashley Buss is the Bituminous Materials Engineer for the Iowa Department of Transportation and a registered professional engineer. Ashley received her education at Iowa State University earing Masters and Doctoral degrees in civil engineering. She is a member of TRB Committees on Design and Rehabilitation of Asphalt Pavements (AKP30), Asphalt Mixture Evaluation and Performance (AKM40) and recently finished a term of service on the Committee on Quality Assurance Management (AKC30).

Robert Conway is a Senior Pavement and Materials Engineer with the FHWA Resource Center. Prior to joining the Resource Center he served as the Division Project Oversight Manager and Pavement & Materials Program Engineer in the Michigan Division of the FHWA. In addition, prior to joining FHWA in 2006, he spent 13 years of his career working for local agencies in the Chicago area. He is a registered professional engineer, certified construction manager and a graduate of Purdue University and first time attendee to TRB.

Dave Huft is the Research Program Manager for South Dakota DOT. He has degrees from Michigan State University and the South Dakota School of Mines. He has long been an innovator- developing the original South Dakota Profiler and starting RPUG in 1989.

Charles Hughes has worked in the QA area since the early 1960s, first with the Virginia Dept. of Highways (now Virginia DOT) and retired from that organization in 1991. He then became a consultant. He has attended every Highway Research Board and TRB meeting since 1959. Chuck is an Emeritus member of AFH20.

Carol Luschen is a graduate of Texas A&M University, College Station with a BS in Civil Engineering and an MBA from Our Lady of the Lake University in San Antonio. With over 33 years of experience, Ms. Luschen currently serves as the Strategic Contract Management Section Director for the Project Finance, Debt and Strategic Contracts Division of Texas DOT overseeing and assisting the department on all phases of the state's multi-billion-dollar Alternative Delivery Program.

Kevin McGhee is the Associate Director for Pavements at the Virginia Transportation Research Council. He has degrees from Virginia Tech and University of Virginia. He has varied research experience in pavement surface characteristics and performance related specifications. Kevin is a member of AFH20.

Weng On Tam has more than 15 years' experience with innovative project delivery. His alternate delivery projects range from $30 million to $2.7 billion, from Texas to Alaska. On these projects, he has served as the Owner's representative, Independent Engineer, and DB Team. Weng On is a member of AFH20 and its subcommittee, Quality Management for Alternative Project Delivery.

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