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**TxDOT Design-Build QAP: Lessons Learned and Development of an FHWA-Approved Statewide Program**

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ABSTRACT

The SH 130 (Segments 1 through 4) and 183A design-build projects with contractor quality control acceptance testing were completed recently. In light of the lessons learned from these two projects and continuing use of contractor acceptance on design-build projects, TxDOT developed a new design-build quality assurance program (DB QAP). This program has been reviewed and approved by the Federal Highway Administration for statewide use. By including the approved DB QAP in design-build procurement documents, proposers will have a clear understanding of quality assurance expectations during the proposal phase of the project which will minimize the challenges of negotiating unspecified requirements during construction.

The DB QAP includes requirements for contractor process control, contractor-performed testing for acceptance, owner verification, independent assurance and dispute resolution. It clarifies the roles and responsibilities of the contractor quality control and the owner verification with specific details on how verification will be performed and each group’s role in addressing non-validation and material quality. It also contains specific requirements for process control, clear direction on the independent assurance program and avenues for dispute resolution. The DB QAP includes a new three-tiered approach to owner verification that allows for proactive monitoring and more timely action to minimize non-validation. Due to space limitations, this approach is not described in this paper.

With the DB QAP, TxDOT has provided statewide consistency and a programmatic approach to quality assurance for design-build projects in Texas. The methodology described herein may provide guidance to other agencies in their development of a similar program.
INTRODUCTION

The role of transportation infrastructure development is rapidly changing at the Texas Department of Transportation (TxDOT). TxDOT’s Strategic Plan for 2009 through 2013 (1) prescribes new strategies for innovative financing methods and decentralization of project prioritization to the regional level to better meet transportation needs and concerns. To manage these new challenges, updates were made to TxDOT internal procedures and TxDOT’s Local Government Project Procedures to address a number of new transportation tools, including toll equity, pass-through tolls, and local government reliance on Comprehensive Development Agreements (CDA) or design-build methodologies. With a shift to the design-build approach for certain projects, TxDOT also realized the need to update their traditional quality assurance program to address verification procedures when the contractor’s test results are used in the acceptance decision.

There are multiple considerations that must be addressed before considering the design-build delivery approach. For those agencies contemplating the use of design-build, an implementation plan is presented by Scott et al. that includes a step-by-process to guide an agency in selecting the appropriate parameters (2). Hanna et al. provides effective strategies and the lists common barriers to implementation for the design-build delivery approach (3). Their research indicates that lack of resources, writing good procurement documents, and managing quality and risk are barriers to implementation that need to be overcome before the design-build approach is to be used successfully.

To manage quality and risk on design-build projects, an agency must evaluate whether to allow the use of contractor’s test results in the acceptance decision since a significant verification program is required for project success. Mitigating risks associated with the project schedule was a key factor in utilizing the contractor’s test results for acceptance on State Highway (SH) 130, the first design-build project of its kind in Texas. Given the size and fast track nature of the project, TxDOT wanted the risk for scheduling and staffing technicians for acceptance testing to be with the Design-Builder. With a different risk profile, however, a design-build project could utilize state highway agency sampling and testing for acceptance. While the SH 130 project was underway, the 183A design-build project in Austin, Texas, ran concurrently and also provided additional insight into the owner verification testing process.

To incorporate and build upon lessons learned from the SH 130 (Segments 1 through 4) and 183A projects, TxDOT contracted HDR Engineering, Inc. to work collaboratively with TxDOT and the FHWA to develop a new Design-Build Quality Assurance Program (DB QAP) for Texas. TxDOT’s traditional quality assurance program has been implemented for many years and terms have been embedded within the agency. Terminology that has been used includes Quality Control (QC) for contractor performed process control testing and Quality Acceptance (QA) for acceptance testing traditionally performed by TxDOT personnel.

The synthesis of state quality assurance programs (4) indicates that vocabulary within various quality assurance programs has been problematic due to different interpretations of terms. Additionally, the synthesis found that many agencies do not clearly separate the functions of process control and acceptance. Therefore, during the development of the DB QAP, care was taken to define specific terminology and provide clear separation of project roles and responsibilities. Transportation Research Circular E-C137, Glossary of Highway Quality Assurance Terms (5) provides additional information on key definitions.

Building on the success of recent projects constructed in Texas using design-build procedures, the new TxDOT DB QAP includes provisions stating that the Design-Builder will
utilize an independent construction inspection and testing firm to test materials for acceptance purposes. The independent firm is a member of the Design-Builder’s team with approval by TxDOT. TxDOT and other local governments in the state are therefore responsible for independently verifying those test results. To accomplish this verification, TxDOT is required to perform Owner Verification (OV) testing. Information relating to validation procedures is included in FHWA Technical Advisory T6120.3 (6).

The purpose of this paper is to describe the lessons learned and key points in the development of the TxDOT DB QAP. To aid the reader, Table 1 provides key terms used throughout this paper.

Table 1: Roles and responsibilities for various project members

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
<th>Roles and Responsibilities</th>
</tr>
</thead>
</table>
| TxDOT         | Texas Department of Transportation or Agency                                | • Oversight during construction  
• Responsible for quality assurance and FHWA compliance |
| CSTM&P        | TxDOT Construction Division, Materials and Pavements Section               | • Author of DB QAP  
• IA program oversight  
• Dispute resolution  
• TxDOT’s resource on quality assurance |
| FHWA          | Federal Highway Administration                                            | • Federal oversight for Quality Assurance Program |
| DB QAP        | TxDOT Design-Build Quality Assurance Program                               | • Overarching program for quality  
• Encompasses QC, OV, and IA programs |
| CQMP          | Construction Quality Monitoring Program                                    | • Written by Design-Builder  
• Describes commitments for incorporating quality into the project |

**GENERAL**

**PROCESS CONTROL ACTIVITIES**

| Process Control | Quality Control used for Process Control                                 | • Producers, suppliers, and subcontractors working with Design-Builder  
• Responsible for process control activities under the direction of an engineer. |

**INDEPENDENT INSPECTION AND TESTING USED IN THE ACCEPTANCE DECISION**

| QC            | Quality Control testing used for Acceptance                             | • Hired by Design-Builder  
• Responsible for performing inspection and testing used as part of the acceptance decision |

**VERIFICATION SERVICES USED IN THE ACCEPTANCE DECISION**

| OV            | Owner Verification                                                       | • TxDOT or consultant that works for the Owner  
• Responsible for verification inspection and testing to validate acceptance |

**OVERSIGHT OF LABORATORY QUALIFICATION AND TECHNICIAN CERTIFICATION**

| IA            | Independent Assurance                                                   | • Managed by TxDOT or Owner  
• Oversight for laboratory qualification  
• Oversight for technician certification |
DEVELOPMENT APPROACH
Incorporating lessons learned from completed design-build projects in Texas was just one of the approaches taken in the development the TxDOT DB QAP manual. Working closely with the Texas Division of the FHWA to clearly understand the federal requirements for quality assurance was another key aspect in the development of the TxDOT DB QAP. As such, the new program clarifies requirements related to quality assurance and owner verification procedures.

Purpose of DB QAP Development
The purpose of the TxDOT DB QAP is to provide statewide consistency and a programmatic approach to quality assurance for design-build projects where the contractor’s test results are used in the acceptance decision. TxDOT now requires that the DB QAP be included (or referenced) in the procurement documents of a project. This requirement provides the quality assurance requirements up-front in the request for proposal (RFP) documents so proposers understand their commitments pertaining to quality assurance; thus minimizing future disagreements and potential change orders. This programmatic approach is consistent with the recommendations presented by Gransberg et al. during the synthesis of DOT’s design-build documents (7).

It should be noted that the content of DB QAP was developed for projects with an optional 15-year maintenance agreement so approval under FHWA Special Experimental Project 15 (SEP-15) is not required. Lastly, any modifications to the DB QAP require review and approval by TxDOT and the FHWA Division Office prior to construction.

Applicability of Program to Smaller Projects
TxDOT’s quality assurance program approach was developed for projects greater than approximately $200 million which utilize contractor results in the acceptance decision. However, many of the engineering procedures are applicable to smaller projects. The DB QAP uses a three-tiered verification approach established for larger projects with the principle of assigning resources to monitor and evaluate each analysis category based on the owner’s residual risk for failure of a particular element. This concept is universally applicable and provides for more efficiency in the validation process. For smaller projects with fewer or less frequent tests, the level of analysis or the parameters by which the analysis is performed may have to be adjusted based on project-specific conditions. These parameters can be reviewed and adjusted during a project-specific risk workshop.

DB QAP COMPONENTS
The TxDOT DB QAP is comprised of several components and the relationships between the parties and functions are shown in Figure 1 (8). The DB QAP includes requirements for development of project level process control, QC, OV and IA programs. These programs describe how project personnel will conduct business in order to meet the requirement of the DB QAP. The DB QAP requires the Design-Builder to provide a Construction Quality Management Plan (CQMP). The CQMP consists of both process control and contractor-performed testing for acceptance with respect to performance of the work and is required to be approved by TxDOT prior to implementation. The CQMP should establish a clear distinction between process control and contractor-performed QC testing activities and the persons performing each function. These components will be described in the following sections.
Process Control Program

TxDOT requires the Design-Build to be responsible for establishing a systematic approach to define the processes, methods, procedures, and documentation for delivery of process control on the project. The Design-Build must staff an on-site Process Control Manager who is a professional engineer responsible for the process control aspect of the project. Co-locating the manager on the project provides for better communication, coordination of activities, and quicker dispute resolution.

The DB QAP also requires that all subcontractors’ construction workforce are considered members of the process control staff. This promotes a unified approach to process control and an environment of quality. When repeated process control shortfalls are identified, investigations are required with corrective actions recommended. In addition, factual evidence that process control inspection and tests have been performed is required documentation by the Process Control Manager.

Although not part of the acceptance program, the process control requirements stipulated in the DB QAP provide commitments by the Design-Build that quality has been incorporated into the project prior to acceptance testing and inspection.
Acceptance Program

The DB QAP provides two types of acceptance on design-build projects. When TxDOT, or the owner agency, provides frontline acceptance testing then verification testing is not required. However, when the contractor’s test results are used in the acceptance decision, TxDOT or their designee must validate these results prior to acceptance being issued.

TxDOT-Performed Acceptance

The first type of acceptance is TxDOT-performed acceptance where acceptance testing and inspection are performed by TxDOT personnel. TxDOT routinely performs inspection and testing at vendor and/or supplier locations. Examples include offsite fabrication plants for prestressed concrete girder beams or aggregate quarries. When these offsite materials are inspected and tested at the source location prior to shipment, the acceptance decision is made by TxDOT. There are requirements for these materials to be re-inspected prior to installation to verify damage has not occurred during shipment. Aggregate materials, for instance, also require project-level testing by QC staff, although the source is pre-approved by TxDOT. The tests results performed by the QC staff must be verified by TxDOT for acceptance.

Contractor-Performed Acceptance

The second type of acceptance is contractor-performed acceptance where frontline acceptance testing and inspection are performed by the Design-Builder’s QC staff. Under the DB QAP, the Design-Builder must include the internal procedures used by QC to ensure that the work is inspected and tested to verify compliance with the plans and specifications in the CQMP. The CQMP must also demonstrate that the QC program is separate from the program used for process control activities.

Similar to the process control requirements above, the CQMP must also show that the Design-Builder met the requirement to staff an on-site QC Manager who is a professional engineer responsible for the QC aspect of the CQMP. The QC Manager acts independently as the “Engineer” in project specifications and reports jointly to the Design-Builder’s management team and TxDOT. Though not specified in the DB QAP, TxDOT’s design-build RFP documents typically afford additional protection and independence for the QC Manager by stipulating that the manager cannot be relieved of his duties without TxDOT’s approval. Co-location of resources to promote easier coordination of activities was one of lessons learned on previous design-build projects in Texas.

The QC staff provides inspection services as well as sampling and testing of materials for acceptance. The QC Manager (or his designee) is responsible for the review and approval of all mixture designs submitted by the Process Control Manager. The DB QAP requires that the QC Manager transmits all reports electronically to TxDOT within 24 hours after the work shift in a format acceptable to TxDOT.

Contractor-performed sampling and testing may be used in the acceptance decision so long as those results are statistically validated and/or verified by independent OV results.

Owner Verification Program

The DB QAP requires the development of an Owner Verification Inspection and Testing Plan (OV TIP) that describes the commitments of the owner for oversight of the Design-Builder’s work. TxDOT staff, or their designee, performs OV inspection and testing and conducts audits to verify the Design-Builder’s compliance with the approved CQMP. Careful review and
The approval of the CQMP is very important because the CQMP will serve as the “practical rule book” by which the Design-Builder’s process control and QC work will be evaluated against. With that said, the CQMP does not supersede the contract in precedence and cannot be used to change the DB QAP or other contract requirements.

In general, the OVTIP address the functions of various project personnel while performing construction-related inspections as well as sampling and testing of various materials. The QC is responsible for acceptance of inspected items and material testing results. The primary function of the OV staff is to validate or verify the QC’s inspection and tests results. As such, the majority of the procedures in the OVTIP manual should identify means to perform the validation and not necessarily detailed, step-by-step, methods of inspection and testing. The procedures should, however, provide a sufficient level of detail so that any team member can identify procedures associated with their role and how they are accomplished under different scenarios.

**Sampling and Testing Requirements**

*Sample Types*

The DB QAP provides definitions for various sample types. Sampling can be either random or fixed, depending on whether the location was selected randomly (random) or if a specific location was subjectively identified (fixed). The procedures within the CQMP and OVTIP, described earlier, will describe the methods for determining random sampling locations for QC and OV tests. Sampling is also either independent or dependent, based on whether the location was independently selected (independent) or whether is based on the location of another sample (dependent/split).

Random independent samples must be used in the statistical analysis procedures (9). Fixed samples are performed at locations were material quality is questioned or requested specifically by either the Design-Builder or TxDOT. Split samples are normally used in the independent assurance program to assure laboratory and technician test results compare favorably and to provide initial alignment of the QC and OV laboratories. However, split samples can be used throughout the project, as necessary, to investigate non-validating materials.

*Frequency of Testing*

TxDOT’s Guide Schedule of Sampling and Testing (10) provides minimum QC sampling frequencies for various construction materials. The DB QAP requires the QC Manager to track and record the quantity of materials incorporated into the project. Higher testing frequencies by the QC staff are encouraged in the preamble of the TxDOT Guide Schedule especially during start-up operations or when concerns over the material quality arise. It should be noted that only random independent tests used for acceptance should be counted in meeting minimum testing frequencies. Since a random independent QC test is required for acceptance of every lot on the project, this should be relatively easily achieved.

Frequency of testing by the OV is established in the DB QAP at the discretion of TxDOT; however the OV frequencies have been a minimum of ten percent of the QC frequencies with a higher initial testing frequency, as per the guidance of Burati and Killingsworth et al. (11, 12), and on previously completed successful projects in Texas. The higher initial testing frequency is used to establish confidence in the contractor-performed tests. TxDOT will conduct audits to verify compliance of both the QC and OV testing frequencies.
Statistical Analysis Procedures

Statistical analysis procedures are required to be used when the contractor’s tests results are used in the acceptance decision (6, 9). State Highway (SH) 130, Segments 1 through 4 in central Texas, was the first highway infrastructure project in Texas where contractor’s tests results were used as part of the acceptance decision for all project produced materials (13, 14). Owner verification was performed using the F- and t- hypothesis tests on all analysis categories (individual categories of test results that represented a unique sample population) on the project.

During the development of the DB QAP, lessons learned from SH 130 and other design-build projects in Texas were used to modify the statistical analysis procedures. One of the primary lessons learned was the level of validation effort should be based on the importance of the test method as an indicator of material performance. Key aspects of the new validation approach include:

1. The development of a three-tiered verification approach. Material properties are categorized into Levels 1, 2, and 3 as determined during a project-specific risk analysis workshop. The risk workshop will evaluate project-specific contractual framework and conditions (e.g. soil conditions, past performance of project elements in the area, etc.). During this workshop, appropriate levels of significance (α) are determined for each material category (e.g., hot-mix asphalt, embankment, hydraulic cement concrete, etc.).

2. Level 1 analysis is performed using continuous F- and t- tests. The resulting p-values are displayed and graphed over time to provide daily “real time” monitoring of validation. Tests categorized as Level 1 are directly related to performance (e.g. concrete compressive strength).

3. Level 2 analysis provides independent verification for those materials which are secondary indicators of performance (e.g., slump test for hydraulic cement concrete). This level is based on the application of engineering judgment to determine whether the contractor-performed tests used in the acceptance decision and OV test results represent the same material.

4. A Level 3 analysis provides observation verification for those materials which have a very low testing frequency or materials whose risk of failure does not affect long-term performance past the contractual maintenance obligations. For example, the acid insoluble test for fine aggregate in hydraulic cement concrete pavements has a required frequency of acceptance testing of once per project per source. The entrained air content test for non-structural (miscellaneous) concrete riprap is an example of material where risk of failure does not affect long-term performance of the facility past the contractual maintenance obligations. The OV does not perform tests but observes the QC test performance for equipment and procedural compliance with the test procedure.

Non-Validation Investigations and the use of Engineering Judgment

Guidance is provided in the DB QAP on conducting non-validation investigations. If the OV test results do not validate the QC test results, a joint investigation involving both the Design-Builder and Owner is conducted to determine the reason for not validating. Areas to be investigated include:

1. Review and verification that analysis categories were established appropriately
2. Data integrity and accuracy
3. Testing equipment and procedures
4. Sampling variability and material variability
Split samples may be performed to investigate non-validating material categories and verify or realign testing equipment and personnel. The DB QAP requires the results of non-validation investigations to be reported as described below.

In addition to statistical non-validation, the DB QAP requires an immediate investigation for individual failing test results to determine if material can be left in place or has to be removed. Procedures for determining the status of material quality requires the direct comparison of QC and OV results. How these values compare to specification limits will determine the appropriate course of action. The following four scenarios in the DB QAP provide further guidance on this topic (8).

The appropriate (QC or TxDOT) party may exercise Engineering Judgment to determine that the material will perform its intended purpose. There are four possible combinations of passing and failing results between the QC and OV test results.

1. Both the QC and OV test results pass specification limits

   Although statistical validation has not occurred, both the QC and OV test results are passing the established specification limits. Thus, material quality in question is considered acceptable.

2. QC test results fail and OV test results pass specification limits

   Material may be left in place if the QC Manager determines that Engineering Judgment may be used to accept the material or if the material is accepted through the NCR process.

3. Both the QC and OV test results fail the specification limits

   Material may be left in place if the QC Manager determines that Engineering Judgment may be used to accept the material or if the material is accepted through the NCR process. The acceptance of material is subject to one of the two scenarios below.

   a. OV test result indicates reasonable conformance with specification requirements and TxDOT exercises Engineering Judgment to concur with acceptance of material based on the QC’s Engineering Judgment or through the NCR process.

   b. OV test result does not indicate reasonable conformance with specification requirement and the QC must perform an additional test at the OV failed test location. Based on the results of QC test result and subsequent investigation discussions between TxDOT and the Design-Builder, a determination is made and documented on whether the material may be left in place.
4. QC test results pass but OV test results fail specification limits

Material may be left in place if the QC Manager determines that Engineering Judgment may be used to accept the material or if the material is accepted through the NCR process. This is subject to TxDOT response in the two scenarios below.

a. OV test result indicates reasonable conformance with specification requirements and TxDOT exercises Engineering Judgment to concur with acceptance of material based on the QC’s Engineering Judgment or through the NCR process.

b. OV test result does not indicate reasonable conformance with specification requirement and the QC must perform an additional test at the OV failed test location. Based on the results of QC test result and subsequent investigation discussions between TxDOT and the Design-Builders, a determination is made and documented on whether the material may be left in place.

**QC Engineering Judgment**

The DB QAP allows the QC Manager to exercise engineering judgment to accept materials that do not meet minimum specification limits but indicate reasonable conformance for their intended use. The use of engineering judgment must be documented and supported by sound engineering reasoning. A log of engineering decisions is generated by the QC Manager and provided to TxDOT on a monthly basis.

Some materials that do not meet minimum specification limits but are adequate for their intended use may require the review and approval of the design engineer before they are incorporated into the project. Documentation through a nonconformance record (NCR) process is required in these instances with an NCR log generated by the QC Manager.

**FHWA Reporting**

The DB QAP requires that a report be produced and submitted to the FHWA Division Office for concurrence describing TxDOT’s efforts to comply with the quality assurance commitments for each material incorporated into the project. The reporting period for specific materials is dependent on the pace of construction and the number of tests performed in each analysis category, the time period of the sampling, and the specification and quality requirements. Each report covers a period of construction not greater than three months and addresses the following areas (8):

- Statistical analysis results, to include specification requirements and status of validation process during start-up and completion of an item;
- Non-validation investigation;
- Non-conformance log;
- Engineering judgment log; and
- Construction certification

**Independent Assurance Program**

The DB QAP provides requirements for TxDOT, or their designee, to develop an Independent Assurance (IA) program. The IA program evaluates all sampling and testing procedures, personnel, and equipment used as part of an acceptance decision. This program
provides uniform statewide procedures to ensure that tests are performed by qualified personnel and that laboratory facilities and equipment are adequate to perform the required sampling and testing methods.

**Personnel Qualifications**

Sampling and testing personnel are required to obtain and keep current specific certifications tailored to TxDOT testing procedures administered through the Texas Asphalt Pavement Association (TxAPA). TxDOT has partnered with TxAPA to provide training and certifications in soils and base testing, hot-mix asphalt (HMA) testing (field and laboratory), and HMA mixture design. In addition, personnel are required to be certified in concrete-related tests administered by the American Concrete Institute (ACI). For those testing procedures not provided by the aforementioned institutions and specific to the needs of the project, the IA laboratory may qualify personnel through a written examination and performance observation. Written exams are developed by TxDOT and administered and graded by the IA staff. Performance evaluations are conducted by members of the IA staff who have selected by TxDOT as qualified assessors using forms and checklists developed by TxDOT. These forms and checklists evaluate each piece of equipment. The requirement for qualification pertains to QC, OV, and IA personnel.

**Laboratory Qualifications**

All laboratories performing QC, OV or IA testing for TxDOT under the DB QAP require accreditation by the American Association of State Highway and Transportation Officials (AASHTO) Accreditation Program (AAP). Previous guidance for AASHTO accreditation was not specifically published by TxDOT and led to some confusion over what specific test methods should be accredited. During the development of the DB QAP, guidance was established by TxDOT and is used by project personnel during the AAP assessment. Laboratories performing TxDOT test on a project are required to obtain accreditation for the AASHTO or ASTM tests as identified in the TxDOT DB QAP. For example, the minimum qualifications required for laboratories performing hydraulic cement concrete testing are shown in Table 2 (8).

In addition to AASHTO accreditation, TxDOT’s CSTM&P is responsible for the statewide laboratory accreditation program and qualifies the IA laboratory. The IA laboratory can then qualify the QC and OV laboratories.
Table 2: Example of Minimum Laboratory Qualification Requirements

<table>
<thead>
<tr>
<th>ASTM</th>
<th>AASHTO</th>
<th>TxDOT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C172</td>
<td>T141</td>
<td>TEX-407-A</td>
<td>Sampling Concrete</td>
</tr>
<tr>
<td>C143</td>
<td>T119</td>
<td>TEX-415-A</td>
<td>Slump</td>
</tr>
<tr>
<td>C231</td>
<td>T152</td>
<td>TEX-416-A</td>
<td>Air Content (Pressure)</td>
</tr>
<tr>
<td>C138</td>
<td>T121</td>
<td>TEX-417-A</td>
<td>Unit Weight, Yield</td>
</tr>
<tr>
<td>C39</td>
<td>T22</td>
<td>TEX-418-A</td>
<td>Compressive Strength (Cylinders)</td>
</tr>
<tr>
<td>C1064</td>
<td>T309</td>
<td>TEX-422-A</td>
<td>Concrete Temperature</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>TEX-423-A</td>
<td>Concrete Pavement Thickness</td>
</tr>
<tr>
<td>C31</td>
<td>T23</td>
<td>TEX-447-A</td>
<td>Making / Curing Specimens</td>
</tr>
<tr>
<td>C617</td>
<td>T231</td>
<td>TEX-450-A</td>
<td>Capping Specimens</td>
</tr>
<tr>
<td>C1231</td>
<td>---</td>
<td>TEX-450-A</td>
<td>Unbonded Caps</td>
</tr>
<tr>
<td>C1077</td>
<td>---</td>
<td>TEX-498-A</td>
<td>Min Laboratory Standards (Concrete and Aggregate)</td>
</tr>
<tr>
<td>E329</td>
<td>---</td>
<td>---</td>
<td>Standard Specification for Insp/Testing</td>
</tr>
</tbody>
</table>

Preferred test procedure for AASHTO Accreditation
Acceptable test procedure for AASHTO Accreditation
Test procedure qualified by Designated Laboratory

Annual Split/Proficiency Evaluation

The DB QAP requires each qualified technician to participate in an annual split/proficiency evaluation to maintain current qualification status. Split samples are performed between the IA laboratory and the QC and OV laboratories. Testing results are obtained and compared to the operational tolerances from the DB QAP shown in Table 3. This table indicates tolerance for Hydraulic Cement Concrete. The remaining operational tolerances for other material categories are provided in the DB QAP.

Table 3: Excerpt from Split-sample Operational Tolerances for IA Evaluation

<table>
<thead>
<tr>
<th>PROCEDURE</th>
<th>TEST METHOD</th>
<th>TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydraulic Cement Concrete Complete Mixture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slump</td>
<td>Tex-415-A</td>
<td>± 1&quot;</td>
</tr>
<tr>
<td>Entrained Air Content</td>
<td>Tex-414-A</td>
<td>± 1%</td>
</tr>
<tr>
<td></td>
<td>Tex-416-A</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>Tex-422-A</td>
<td>2°F</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>Tex-418-A</td>
<td>17% of mean * (4x8&quot;)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14% of mean * (6x12&quot;)</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>Tex-448-A</td>
<td>± 19%</td>
</tr>
</tbody>
</table>

* The difference between compared test results shall not exceed the indicated percentage of the mean of the compared test results where the mean is the average of the two test results.
Certifications for Soils and Base (SB) materials, as well as hot-mix asphalt (HMA) materials, are administered by TxDOT for all technicians that hold a current SB and HMA testing (field and laboratory) TxAPA certification. Each year, samples of materials are developed by TxDOT and distributed to each certified technician in Texas. Testing technicians are required to perform tests on these samples and return their results to TxAPA for evaluation by TxDOT. Proficiency ratings are developed with results sent to each technician. Table 4 provides those test methods that are required for split/proficiency evaluation.

Table 4: Test Methods for Split/Proficiency Evaluation

<table>
<thead>
<tr>
<th>Test Procedure</th>
<th>Proficiency Testing Procedures Description</th>
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SUMMARY AND CONCLUSIONS

The Texas Department of Transportation (TxDOT), like most agencies in the nation, has been faced with economic challenges that have required new approaches to the design and construction of transportation infrastructure. To meet these challenges, changes in Texas law have allowed new innovative funding mechanisms and recent projects have been constructed using design-build methodologies. Traditional methods of quality assurance have also been modified to allow contractor testing and acceptance with verification procedures being implemented by the owner.

The purpose of this paper is to describe the development of a new Design-Build Quality Assurance Program (DB QAP) for projects in Texas. This program provides new tools to TxDOT and prescribes commitments that must be addressed by the Design-Builder based on lessons learned from recently completed design-build projects. In addition, a new three-tiered approach to owner verification was developed that allows active materials management by TxDOT’s Materials Manager utilizing appropriate levels of testing and analysis based on the impact that the materials and their use has on the long-term performance of the project.
TxDOT will include this new DB QAP in future procurements so that proposers are well aware of the quality assurance commitment on a design-build project. With the development and implementation of this document, TxDOT has provided statewide consistency and a programmatic approach to quality assurance for design-build projects in Texas. The methodology described herein may provide guidance to other agencies in their development of a similar program.

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REFERENCES