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Construction Quality Assurance For Design-Build Highway Projects

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Introduction

A majority of State transportation agencies use the design-build (DB) contracting method to deliver some transportation projects. Documented benefits of DB include faster project delivery, improved constructability, less cost growth, early cost certainty, and fewer claims.

One area of DB contracting that requires closer examination is construction quality assurance (QA). DB is believed to provide a level of project quality equal to design-bid-build (DBB), as outlined in the Federal Highway Administration's (FHWA) *Design-Build Effectiveness Study*.⁽¹⁾ However, a recent examination of State agency DB procurement packages showed that roles and responsibilities for construction quality are not clearly defined in many instances. The paper "Does Design-Build Project Delivery Affect the Future of the Public Engineer?" examined 60 DB requests for proposals (RFPs) and found 23 cases in which assignment of responsibilities for verification and acceptance could not be determined.⁽²⁾ National Cooperative Highway Research Program (NCHRP) Synthesis 376, *Quality Assurance in Design-Build Projects*, states "With the changing quality roles found in the DB delivery method, it is imperative that quality responsibilities and the responsible parties are clearly stated in the contract documents."⁽³⁾ However, on DB projects, there is no change in the core QA functions of contractor quality control (QC) and agency acceptance. The design-builder still has a responsibility for QC, as does the contractor with DBB projects. The agency must retain its responsibility for the acceptance function, as required by Title 23, Code of Federal Regulations, Part 637 (23 CFR 637).⁽⁴⁾

One of the attributes of the DB delivery method is the single source of responsibility for design and construction issues.

When preparing the RFP and contract documents, owners must clearly define the responsibilities of the design-builder and the contracting agency. The agency performs verification tests for compliance with RFP requirements and makes progress payments under the terms of the contract. However, by doing so, the agency does not assume responsibility for any design or construction issue. The design-builder remains fully responsible for the design and the construction of the final product.

Purpose

The purpose of this TechBrief is to help clarify the roles, responsibilities, and activities related to construction QA on DB projects. The specific topics discussed include QA, QC, and acceptance. Related topics such as independent assurance (IA), dispute resolution, personnel qualification, laboratory qualification, and warranties are also discussed. Some RFP and contract documents for DB projects have incorrectly assigned responsibility for acceptance to the design-builder, which is not in accordance with 23 CFR 637. Additionally, because the DB project delivery method is often used on large, complex, fast-paced projects, it presents some unique challenges that merit discussion.

Quality Assurance

The American Association of State Highway and Transportation Officials (AASHTO) defines QA as “(1) All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service; or (2) making sure the quality of a product is what it should be.”(p. 14)⁽⁵⁾

Historically, agencies used the term QC/QA with QC referring to the contractor’s role and QA to the agency’s role. This term implied that QC and QA are separate functions; in fact, QA refers to the overall system for assuring project quality, with QC being one element of a comprehensive QA program. Therefore, the transportation industry has moved away from the term QC/QA and now uses QA.

Construction QA Programs

A construction QA program consists of the following core elements:

- Contractor QC.
- Agency acceptance.
- IA.
- Dispute resolution.
- Personnel qualification.
- Laboratory accreditation/qualification.

These core elements of QA apply regardless of the project delivery method. The agency’s responsibility for acceptance cannot be assigned to the design-builder (or to a consultant under contract to the design-builder) but, rather, remains with the agency. Each of the six core elements of a construction QA program for DB is discussed below.

Quality Control

FHWA’s *Transportation Construction Quality Assurance Reference Manual* defines QC as “The system used by a contractor party to monitor, assess, and adjust their production or placement processes to ensure that the final product will meet the specified level of quality.”(Section 2.3, p. 2–6)⁽⁶⁾

Use of QC Test Data in Acceptance Determination

While the primary purpose of QC sampling and testing is to provide timely information for the design-builder to monitor and guide each production or placement process, QC data for critical quality characteristics may also be used in the final acceptance determination. If QC test data are to be included in the agency acceptance decision, the QC data must be validated by agency verification test results. Lot and subplot sizes, sampling and testing methods, and sampling locations should be specified for each critical quality characteristic that will be verified by the agency. This information can be included directly in the DB contract documents,

or reference can be made to the agency's standard specifications or guide schedule of sampling/testing frequencies. Not all characteristics that are monitored by QC are required to be verified by the agency. Design-builders will often perform more than the minimum level of QC, including testing of material properties beyond those critical quality characteristics that will be used in the agency acceptance decision.

QC Organization

There are different approaches to QC organizational structure on DB projects. Some agencies specify that the design-builder must demonstrate, through lines of authority in the organizational chart, that QC personnel are allowed to operate independently of DB construction forces to ensure that decisions made as part of the QC process are not influenced by schedule or budget. Another approach used by some agencies (especially on large DB projects) requires the design-builder to employ an independent testing firm to conduct sampling and testing of those critical quality characteristics that will be verified by the agency as part of the acceptance decision while a separate QC team works in close coordination with the construction forces, performing sampling and testing to monitor and guide production and placement processes.

Regardless of the approach, it is important that the DB team member in charge of construction quality report to senior management of the design-builder. This will convey support for QC and minimize potential conflicts with the production staff. Senior management must realize that superior quality will not happen without the seamless interaction between the QC teams, production/placement teams, and administration. The DB contract should clearly identify requirements for the QC organization.

Use of Consultants to Perform QC

Consultant technicians and inspectors may be used to conduct QC inspection and testing on a DB project. However, responsibility for the acceptance function cannot be relinquished

to the design-builder per the requirements of 23 CFR 637.207(b).⁽⁴⁾ Use of a consultant firm hired by the design-builder for sampling, testing, and inspecting does not relieve the agency of its responsibility for verification testing.

QC Documentation and Records

The agency should specify the minimum level of QC documentation that must be provided by the design-builder as well as the timeframe and format for providing the information. This typically includes all QC test results intended for inclusion in the agency acceptance decision. QC test results that are used strictly for process control may not need to be submitted but should be available for review by the agency as part of monitoring the design-builder's QC system.

Design-Builder Quality Management Plans

It is good practice to require the design-builder to provide a comprehensive quality management plan (QMP) that outlines the overall quality system for both design and construction of the project. The construction QC section of the QMP should describe all of the QC activities that will be conducted to assure that the completed items of work will meet the specified level of quality. If a QMP is required, the DB contract should specify the format and minimum content requirements as well as the procedure for agency review and acceptance of the QMP, including any updates and changes submitted by the design-builder following initial plan acceptance. During construction, the agency and the design-builder should monitor adherence to and effectiveness of the QMP. Any weaknesses discovered in the QC system should be corrected, including revisions to the QMP. Some agencies specify that failure by the design-builder to follow the QMP will result in actions such as suspension of work or withholding of payment.

Acceptance

FHWA-NHI-08-067 defines *acceptance* as "All factors used by the Agency (i.e., sampling, testing, and inspection) to evaluate the degree

of compliance with contract requirements and to determine the corresponding value for a given product.”(Section 2.3, p. 2–9)⁽⁶⁾

Agency Responsibility for Acceptance

According to 23 CFR 637.207(b), the agency’s responsibility for acceptance does not change when using the DB delivery method.⁽⁴⁾ While the design-builder is fully responsible for design, construction, and material selection, the agency is responsible for verifying RFP compliance and making progress payments by the acceptance of the work. As stated in FHWA-NHI-08-067, “All acceptance activities must be carried out by the agency or their designated agent (i.e., consultant under direct contract with the agency), independent of the contractor.”(Section 2.3, p. 2–9)⁽⁶⁾ This does not preclude the inclusion of design-builder QC data in the acceptance decision, provided that the QC data are validated by the agency’s independently obtained verification data. It is important that the agency acceptance responsibilities be clearly defined in the DB contract documents.

Verification Sampling and Testing

23 CFR 637 defines *verification sampling and testing* as “Sampling and testing performed to validate the quality of the product.”⁽⁴⁾

The highway agency (or its designated agent) is responsible for conducting verification sampling and testing to provide an assessment of product quality that is completely independent of the design-builder’s QC process. As required in 23 CFR 637, “The verification testing shall be performed on samples that are taken independently of the quality control samples.”⁽⁴⁾ Splits of design-builder QC samples cannot be used for verification.

Verification sampling and testing may be performed at a lower frequency than the design-builder’s QC testing, particularly on DB projects where QC data are included in the acceptance determination. On some large DB projects, agencies have used frequencies of 1 verification test for every 10 or more QC tests. In order

for mathematical validation procedures to be reliable, it is suggested that a minimum of 7–10 agency verification results be obtained and used to validate the design-builder’s QC data.

It may be necessary to adjust the frequency of verification testing to reflect the estimated number of QC tests for each item of work. Rates of verification testing may also differ based on the risks involved. For example, verification testing may be more frequent for structural concrete than for embankment materials.

On some DB projects, it may be challenging to conduct verification testing at the specified rate due to the quantities of material being placed and the fast-paced nature of the work. In addition, because DB projects are typically bid as a single lump sum amount or using a small number of lump sum pay items, agency tracking of material quantities can be more difficult than on DBB projects that use standard unit price items. This can make it more difficult to schedule verification activities and determine random sample locations. Agencies should take this into consideration when determining staffing levels for DB projects so as to provide sufficient verification testing. The agency and design-builder must work cooperatively to find solutions to these issues because quality cannot be sacrificed due to large material quantities or fast-paced work.

Validation of QC Data

Agencies that have not included QC data in the acceptance decision on DBB projects may choose to do so on DB projects. As previously stated, if the design-builder’s random QC test data are to be included in the acceptance decision, the QC data must be mathematically “validated” against the agency verification test results for each lot of material. By including validated QC data in the acceptance decision, the frequency of verification testing by the agency (or its designated agent) can be reduced.

The DB contract documents should clearly outline the decisionmaking process that will be used for validation of the QC data. It is

important to specify the validation method (such as *F*- and *t*-tests), as well as actions that will be taken in the event that the design-builder QC test results are not validated by the agency verification results. There should be a well-defined process in place to resolve such an issue, including an investigation into the cause of the non-validation and increasing the rate of verification testing for the item. It is important to recognize that in some cases, even though the QC test data are not statistically validated, the material may be completely acceptable. In these cases, further investigation to determine the underlying cause of the non-validation is warranted. Also, it is necessary to specify the quality characteristics to which tests will be applied. Performing *F*- and *t*-tests on numerous quality characteristics for a particular material could make the analysis needlessly cumbersome. It is important that the agency identify the critical quality characteristics subject to the validation analysis for each material or work item.

Some materials, due to the small quantity being used, may not have a sufficient number of QC and verification tests to perform a statistical comparison. In these instances, use of an alternate method of acceptance may be necessary. To accept items requiring very few tests, it may be advisable to use only the agency's verification testing.

Quality Measures for Acceptance

Statistical quality measures used for acceptance, such as percent-within-limits (PWL), are well suited to DB projects, especially projects with work items having large quantities of materials. Agencies currently using PWL for work items on their DBB projects can easily incorporate it as the quality measure for the same items on DB projects. For agencies that do not use PWL, it may not be appropriate to utilize it on DB projects without first developing statistical specification limits that will provide a fair measure of quality. Statistical specification limits are typically developed by means of pilot projects completed over several years. Employing specification limits or procedures

developed by another agency without proper evaluation could lead to unnecessary disputes.

The acceptable quality level (AQL) applied to each work item should be specified in the DB contract documents along with requirements for appropriate corrective action (rework or replacement) when the quality level is not met. The AQL can be set at different levels for different work items based on the risk associated with lower-quality material. Since most DB projects do not utilize unit price pay items, pay adjustments for material quality are often not applied. However, some agencies do apply pay adjustments either by including a typical unit price in the DB contract for the work item being evaluated or by requiring in the RFP that proposers submit a breakdown of work items with a unit price for each item subject to pay adjustment. When pay adjustment for quality is included in the DB contract, it is important that the agency monitor and measure material quantities. For work items not suited for PWL as the quality measure, such as items with small quantities, the agency's verification test results should be evaluated against engineering limits to determine acceptance.

Inspection

Just as on DBB projects, visual inspection is a key part of agency acceptance on DB projects. Acceptance inspection must be performed by the agency or its designated agent, not the design-builder. "The State's acceptance program should provide a reasonable level of inspection to adequately assess the specific attributes which reflect the quality of the finished product. Acceptance inspection should include inspection of the component materials at the time of placement or installation, as well as the workmanship and quality of the finished product."⁽⁷⁾

Independent Assurance

23 CFR 637 defines *IA* as "Activities that are an unbiased and independent evaluation of all the sampling and testing procedures used in the acceptance program."⁽⁴⁾

The purpose of the IA system is to assure the reliability of all data used by the agency in the acceptance determination. This includes the agency's verification data and the design-builder's QC data when validated QC data are to be included in the final acceptance determination. IA is intended to confirm that the sampling and testing activities performed by the agency and the design-builder are conducted by qualified personnel using proper procedures and properly calibrated and functioning equipment. The results of IA testing should never be used to evaluate material quality.

The responsibility for IA lies with the agency. IA sampling and testing is performed by agency personnel (or by personnel of a designated agent directly contracted by the agency) that are independent of the project. IA personnel, whether employed by the agency or a designated agent, cannot perform both IA and acceptance activities. For agencies that do not routinely include QC test results in the acceptance determination, using this approach on DB projects may create new challenges for the IA system. The design-builder may not be familiar with IA requirements. The need for the design-builder QC staff to cooperate with IA personnel should be clearly stated in the DB contract. Scheduling IA activities to obtain the required level of IA evaluations is often a challenge, and keeping track of ongoing QC and verification activities and personnel on large DB projects can magnify this problem. Using the system approach to IA is an effective strategy for DB projects, since IA frequency is based on covering all active testers and equipment over a period of time, independent of the number of QC and verification tests completed on a project.

It is important that all parties involved be aware of the role that IA plays in the overall QA program and work cooperatively to assure that IA staff is kept informed of project testing schedules and personnel. Some agencies include language in the DB contract requiring the design-builder to provide the agency's project staff with updated schedules and lists of QC personnel for upcoming QC sampling and testing so that IA activities can be scheduled.

Dispute Resolution

If QC testing data will be included in the acceptance determination, agencies are required under 23 CFR 637 to have a dispute resolution system in place to resolve possible discrepancies between the design-builder's QC data and the agency's acceptance data.⁽⁴⁾ While not required on projects where agency verification results will be used exclusively to determine acceptance, a dispute resolution system is highly recommended.

The dispute resolution process should be unbiased and timely. To address testing-related disputes, use of retained splits of samples used in the acceptance decision, alternate or third party laboratories, and a well-defined decision process to determine the outcome of the dispute are advisable. When retained splits are used, it is important that the dispute resolution split samples are properly labeled and that either the agency takes immediate possession of the dispute resolution split or proper sample security techniques, such as tamper-proof containers or security seals, are used.

Personnel Qualification

All personnel performing sampling and testing for QC used in the acceptance decision, verification, or IA are required to be qualified, per 23 CFR 637.209.⁽⁴⁾ Agencies participate in State, regional, or national technician qualification or certification programs to ensure that technicians and inspectors are properly qualified. The DB contract documents should specify the minimum qualifications for DB personnel performing QC sampling, testing, and inspection. Minimum qualifications for the design-builder's quality management personnel should also be clearly stated to ensure they have a thorough understanding of QA principles and experience working under QA specifications.

Laboratory Qualification

Any laboratory used by the agency (or its designated agent) to perform verification testing and all design-builder laboratories that perform QC testing included in the acceptance

decision must be qualified, as outlined in 23 CFR 637.209.⁽⁴⁾ Laboratories that conduct QC testing only for process control are not covered by the regulation, but some agencies require these laboratories to meet a minimum standard such as approval by the agency or a certification organization. Laboratories operated by a designated agent of the agency that are used for IA or dispute resolution must be accredited by AASHTO, through a comparable program approved by FHWA, or by an accreditation body approved by the National Cooperation for Laboratory Accreditation.⁽⁸⁾

Non-Conforming Materials and Workmanship

The DB contract should describe the process for documentation and disposition of non-conforming work. Whether discovered by the design-builder or the agency, materials or workmanship that do not meet the specified level of quality should be properly documented, including the nature of the non-conformance, location, extent, and disposition (e.g., removed and replaced, reworked, accepted based on engineering judgment, etc.). The authority to approve the final disposition of non-conforming materials or workmanship cannot be assigned to the design-builder. The agency's role in approving the disposition of non-conforming work should be clearly identified in the contract.

Warranties

Some DB contracts include warranty provisions for some items of work. Contract language should specify the warranty period and the enforcement process, including a detailed description of the measures that will be used to determine warranty compliance. These measures are typically maximum levels of various distress types that, when exceeded during the warranty period, require correction by the design-builder. Some warranty provisions also include specific corrective action for each distress type. The inspection procedure for determining warranty compliance should be clearly outlined and include provisions for notification so that a design-builder representative can observe

the warranty inspections. A process for dispute of warranty inspection findings should also be included. Use of warranty provisions does not remove the need for an effective design-builder QC system; on projects where the warranty does not provide coverage for the anticipated life of the warranted product, some level of agency acceptance is still required. The requirements for warranties on DB projects are covered under 23 CFR 635.413.⁽⁹⁾

Summary

The DB project delivery system offers several documented benefits over the traditional DBB method on certain projects. While DB offers the design-builder more control over design, materials, and construction methods than DBB, the agency still has an important role in assuring quality. As agencies develop DB procurement documents, it is important that roles and responsibilities for design-builder QC and agency acceptance be clearly defined. The responsibility for acceptance by the agency (or their designated agent) is applicable regardless of the project delivery method used.

DB is often used on large, fast-paced projects, which can create challenges for conducting QA activities. Coordination and communication between the design-builder and the agency is essential for effective quality management. By working together within a well-defined QA program, the agency and design-builder can meet the goal of delivering a high quality project to the travelling public.

Further Information

The following resources provide further information on this topic:

- National Highway Institute Course 134064, "Transportation Construction Quality Assurance."
- Office of Pavement Technology. (2012). *Independent Assurance Programs*, TechBrief, Publication No. FHWA-HIF-12-001, Federal Highway Administration, Washington, DC.

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9. *Construction and Maintenance*, Code of Federal Regulations, Title 23, Part 635, U.S. Government Printing Office, Washington, DC.

Researchers—For information related to Design-Build project delivery, contact Gerald Yakowenko (contract administration team leader) at gerald.yakowenko@dot.gov. Additional information related to the Materials Quality Assurance Program can be gained by contacting the FHWA Quality Assurance Team: Michael Rafalowski (Office of Pavement Technology) at michael.rafalowski@dot.gov and Dennis Dvorak (Pavement and Materials Technical Service Team) at dennis.dvorak@dot.gov.

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