

SECTION 37 QUALITY ASSURANCE AND QUALITY CONTROL

37.1 GENERAL REQUIREMENTS

All design construction documents, reports, studies, and any other documents delivered to CDOT must comply with the minimum requirements of this BDM and the documents referenced in the Policies and Procedures. Deliverables are subject to both Quality Assurance and Quality Control (QA/QC) as described herein.

37.2 PURPOSE

All entities (CDOT and Consultants) producing deliverables for CDOT must use a rigorous QA/QC program to accomplish the following objectives, which include but are not limited to:

- Ensure safe structures for the traveling public
- Provide structures that are low maintenance for the life of the structure
- Prevent problems from occurring during construction
- Provide cost-effective solutions
- Prevent errors
- Provide consistency
- Promote ingenuity

The purpose of this section is not to supplant QA/QC programs and policy already established internally within CDOT or with individual consulting firms but rather it describes the minimum requirements that must be included in a QA/QC program applied to a CDOT project. Unless otherwise described in this BDM, specific methodologies for conducting and documenting QA/QC procedures are the prerogative of the entity executing a project. For example, an independent technical review, described in Section 37.3, is required, but the entity performing the work is responsible for determining the exact procedure and forms necessary to perform the review and to document that it has occurred.

This section defines the types of QA/QC reviews, discusses project planning, and identifies the required QA/QC reviews for each design phase in the order in which each design phase occurs.

37.3 DEFINITIONS

For definitions not included in this section, refer to the Policies and Procedures Section of this BDM.

Quality Assurance (QA): The procedure that verifies and documents that established QC procedures have been implemented during the execution of a project. QA is performed through audits as defined below.

Quality Control (QC): A systematic procedure that checks the accuracy of design calculations, construction plans, specifications, and other pertinent documents to achieve the objectives noted in Section 37.2. When properly used, QC procedures detect and correct errors and omissions before a project is constructed. QC procedures include the independent design check, independent

technical review, constructability review, and CDOT structural review on consultant projects as defined below.

Design: Design includes generation of the following:

- Structure Selection Report
- Structural design calculations that support structural elements
- Bridge geometry
- Detailing construction drawings
- Quantity calculations
- Estimates of probable costs for the Structure Selection Report (Note that final design includes only quantity calculations, not cost estimates)
- Project Special Provisions
- Structure Load Rating (Refer to the CDOT Bridge Load Rating Manual for QA/QC requirements)
- Design calculations and detailing drawings resulting from changes during construction

The Project Structural Engineer is responsible for assigning these tasks to the Structural Design Engineer(s).

Independent Design Check: The process that uses a person or party separate from those who prepared the documents to verify the contract documents. This key QC requirement involves the Independent Design Engineer verifying all design work, drawings, specifications, quantities, reports and any construction changes generated by the Structural Design Engineer to ensure structural integrity, constructability, and satisfaction of all applicable standards listed in this BDM. As such, the independent design check, combined with the initial design, results in (1) two sets of complete design and quantity calculations, both stamped by a Colorado Licensed Professional Engineer and (2) a review set of the final plans where all discrepancies between design and the independent check have been resolved. It is recommended that the Independent Design Engineer have more experience than the Structural Design Engineer. For some simple designs such as design by observation based on M&S standards, a red/yellow check may suffice in lieu of an independent design check. A red/yellow check is defined as a review of the design calculations where all assumptions and calculations are yellowed out if correct and redlined if modifications are necessary. The red/yellow check shall also be stamped by a Colorado Licensed Professional Engineer.

Independent Technical Review: The independent technical review, also known as an independent design review or a technical peer review, involves reviewing all project deliverables, including the construction plans, specifications, and estimate of probable cost. This QC review includes:

- Conformance with generally accepted best practices
- Conformance with CDOT bridge design practices
- Interdisciplinary design coordination: for example, roadway geometry correctly reflected in the structure plans

- Constructability, biddability, and inspectability issues without solely relying on the constructability review as defined below

The engineer assigned to the independent technical review (referred to as the Independent Technical Reviewer) shall be experienced, knowledgeable, and independent of the development of the project documents.

Constructability Review: The constructability review involves reviewing the construction plans and specifications to minimize scope changes, reduce design-related change orders, and ensure the structure and details are buildable. This QC review includes the following:

- Constructability, which shall consider at a minimum, phasing, sequencing, detailing, material availability, construction equipment access, and appropriate inclusion and use of specifications.
- Biddability; for example, the construction plans and specifications are consistent and contain sufficient information for a Contractor to bid on a project.
- Inspectability and safety; for example, adequate access for an inspector to determine the condition of structural elements that require inspection. Inspectability shall include details such as ladder stops on slope paving, ladder supports at inspection hatches, appropriately sized hatches, diaphragm ports, and lock protectors.

Application of constructability reviews is based on the project complexity (Category I, II, or III) as described below:

- **Category I projects** include bridges using standard construction methods that are generally one or two spans, structures that use the CDOT M&S Standards, and simple repairs such as expansion joint replacement. The Project Structural Engineer or in rare cases an outside consultant can conduct the review.
- **Category II projects** include bridges with specialty features, longer bridge lengths than Category I projects, or a project team with insufficient experience with the type of construction involved in the project. Category II bridges may include cast-in-place post-tensioned concrete, curved steel plate girders, etc. An experienced Project Structural Engineer, a construction engineer, and possibly an outside consulting firm may conduct the constructability review.
- **Category III projects** include critical or complex structures as defined by superstructure and substructure type, geometry, construction methods, height, length, or feature intersected. Category III bridges may include concrete segmental construction, curved steel box girders, viaducts, major river crossings, etc. A highly experienced Project Structural Engineer, a highly experienced construction engineer, an outside consulting firm, or possibly a contractor may conduct the constructability review.

Quality Assurance (QA) Audit: A review of the contract documents to verify that the project QC procedures have been implemented.

CDOT Structural Review: On Consultant projects, a CDOT Structural Reviewer will be assigned to review the deliverables. This review generally includes similar aspects as the independent technical review but from an oversight perspective. Thorough reviews of the preliminary design submittals (as a minimum, Structure Selection Reports and FIR plans) and final design submittals are required.

37.4 QUALITY MANAGEMENT PLAN

All CDOT projects should have a project-specific Quality Management Plan (QMP) that identifies the scope of work, project objectives, schedule, deliverables, and QA/QC procedures that will be used to achieve a successful project. A QMP may already be a requirement of a Consultant QA/QC program, which can also be used for a CDOT project.

As part of the QMP, the following meetings should be used to initiate the project and to ensure that the project is on the right path throughout the design process:

- **Project Scoping Meeting:** A project scoping meeting should be used to discuss the project objectives, design criteria, critical issues, and procedures used to mitigate risk. From a structural design point of view, the Project Structural Engineer, CDOT Structural Reviewer, and key team members should attend this meeting.
- **Structure Status Meetings:** On Consultant projects, the Project Structural Engineer shall meet periodically with the CDOT Structural Reviewer to discuss the design work. The frequency of meetings should be established at the project scoping meeting. The frequency is based on project complexity. Attendance by the Resident Engineer and, as appropriate, other design team members (e.g., geotechnical, hydraulics, roadway, and traffic) is encouraged. Holding structure status meetings for CDOT designed projects is also encouraged.

37.5 QUALITY CONTROL/QUALITY ASSURANCE PROCEDURES

Each submittal, including all portions of the submittal, is subject to the independent design check, independent technical review, constructability review, QA audit, and CDOT structural review. The following briefly describe the reviews required in each design phase:

- **Preliminary Design (FIR):** A critical period in the life of a project where the direction of a project is determined. Independent design checks of elements that make up the FIR submittal are required, such as:
 - Geometric layout
 - Confirmation of structural elements that affect the recommended structure type (e.g., span lengths, girder type, and foundation type)
 - Quantities and the cost estimate
 - Data and conclusions in the Structure Selection Report. Refer to the Structure Selection Report Checklist in Section 2, Appendix 2A. The Staff Bridge Unit Leader shall approve the Structure Selection Report.

In addition, the Structure Selection Report should undergo a technical edit for grammar, spelling, and readability to both structural and non-structural engineers.

The independent technical review, constructability review, and CDOT structural review are also required to ensure that a project is on a successful path. When critical issues are not addressed during the FIR phase, they can have a significant impact on final design.

The CDOT Structural Reviewer, in consultation with the Staff Bridge Engineer and the Resident Engineer, shall select the project category (I, II, or III) during preliminary design. This will determine the appropriate level of constructability review for the project.

- **Final Design (FOR):** The Project Structural Engineer is responsible for originating or updating tasks defined in Section 37.3. During final design, the Independent Design Engineer shall be provided a complete set of FOR construction plans without any supporting calculations from the Structural Design Engineer. Through the independent design check, a second set of calculations is produced to support all appropriate design information in the plans, including, but not limited to, the following:
 - Design criteria
 - Geometry
 - All structural elements that support load
 - Devices that accommodate structure movements
 - Quantities

The exception to the independent design check process is situations when Strut and Tie models are used. They must be shared with the design checker to obtain concurrence on the models. To avoid late changes, concurrence should be obtained for the models as they are developed, rather than at the end of the design phase.

The independent design check also involves checking the FOR specifications, which includes the following:

- Determine if the CDOT Standard Specifications for Road and Bridge Construction adequately cover all aspects of construction in the plans.
- If the Standard Specifications are not adequate, determine if the CDOT Standard Special Provisions selected for the project are appropriate.
- If neither the Standard Specifications nor the Standard Special Provisions are adequate, Project Special Provisions are required and must be checked. CDOT provides Project Special Provisions and Bridge Design Worksheets (BDW) that can be modified for a project.
- QC documents, independent technical review, constructability review, and CDOT structural review are also required for the FOR documents. When the plans are complete, the initial block on the left side of the standard CDOT border shall be completed to identify the Designer

and checker for the structural design, detailing, and quantity calculations.

- **AD Plans & Specifications (P&S):** After the FOR meeting, all comments must be addressed and incorporated as appropriate. If items change the structural design or involve new structural items, they are subject to the previously described QA/QC procedures prior to final submittal. The AD P&S submittal shall be accompanied by a Final Detail Letter (FDL) certifying that the structural plans and specifications have been prepared in accordance with standards set by CDOT.
- **Documentation of Review Comments:** All comments received from the FIR and FOR meetings shall be tracked. The documentation should include at a minimum: (1) reviewer comments, (2) reference to the location in the reviewed document (e.g., sheet number, chapter, and section) for each comment, (3) comment responses, and (4) confirmation that each comment has been incorporated into the document as appropriate.
- **Review Comment Resolution:** Comment resolution from independent design checks, independent technical reviews, and constructability reviews shall be documented. The Project Structural Engineer and/or CDOT Structural Reviewer, as appropriate, are responsible for ensuring all comments and discrepancies are resolved. He or she shall make the final determination if comments and discrepancies are unable to be resolved between the Structural Design Engineer and the Independent Design Engineer or Independent Technical Reviewer.
- **QA Audit:** A person independent from the project team (not involved in producing project-related documents) and intimately familiar with the project QA/QC requirements is assigned to perform a QA audit. This person can be someone from the organization producing the documents or another organization contracted to provide QA audits. The QA audit verifies that the QC procedures have been implemented. A QA audit should occur before each deliverable is submitted.

Below are two examples of what an auditor may do to assure that a required quality procedure has been completed correctly for a set of construction plans:

1. The independent design check process includes creating a red-line drawing that shows suggested corrections, agreement for what corrections should be made, and demonstrates incorporation of the corrections to a clean drawing. The auditor reviews the red-line drawing to see evidence of a checking procedure and verifies that the initials block identifies the Designer and checker for design, detailing, and quantities. The auditor may also compare the red-line drawing to the clean drawing, not for the purpose of determining if the change is correct, but to verify changes have been incorporated.
2. An independent technical review of drawings/documents may be conducted by filling out a comment resolution form that documents the following:
 - a. Independent Technical Reviewer (reviewer) comments

- b. Structural Design Engineer's (originator) responses
- c. Initial and final disposition of the comment, e.g., accept, delete, clarify/discuss, incorporate in the next submittal
- d. Reviewer initials placed on the form after verifying that agreed upon dispositions are addressed as discussed

In this review, an auditor will verify that there is agreement between the originator and reviewer, and that the reviewer signed the form after verifying the disposition. The auditor may also verify that the change was made to the drawing.