conference preview

QUALITY AND THE BRIDGE ENGINEER

BY SHANE R. BEABES, P.E.

Handle the increasing complexity in bridge analysis and design with a robust quality management system.

TODAY'S BRIDGES ARE becoming more complex in order to mitigate constraints like right-of-way, natural resources, maintenance of traffic and economic requirements.

Bridge span lengths are becoming longer, bridge skews are becoming sharper and roadway curvatures are becoming tighter—all of which require more in-depth analysis not only to address strength design provisions, but also predicted performance criteria such as deflections during erection and fit-up.

Couple the complexity of the analysis with more rigorous code provisions—and typically more aggressive schedules for alternative delivery projects such as design-build projects—and the bridge engineer must rely on a quality management system for confidence that the design and contract deliverables will meet the client's needs and expectations, as well as typical industry practice and standard of care.

Quality Management Systems

Requirements for a quality management system (QMS) are specified in resources such as the International Organization for Standardization (ISO) standards. The QMS in general form is outlined in ISO-9001 and may be adapted to many applications. In the context of engineering, companies often use ISO 9001 in developing a quality management system that provides the engineer a roadmap to effectively and efficiently meet the client's needs.

How is quality defined? According to BS EN ISO 9000:2005, quality is the "degree to which a set of inherent characteristics fulfills requirements." A QMS program is set up to "direct and control an organization with regard to quality." Typical terms often used in the bridge industry when it comes to quality include quality assurance and quality control. Although these terms are often used together, they each serve separate and distinct purposes in the QMS process.

Quality assurance and quality control are both integral parts of quality management and are defined in BS EN ISO 9000:2005. Quality assurance focuses on "providing confidence that quality requirements will be fulfilled" whereas quality control "focuses on fulfilling quality requirements."

A key for operating an organization, in this case an engineering firm or agency, is the implementation of a comprehensive QMS. To do this, the system must be designed for continuous improvement. Continuous improvement will increase the likelihood of both enhancing customer (client) satisfaction and meeting their desired requirements. An effective system will promote consistency in the execution of the design process—which is what bridge clients would typically desire.

Client Requirements

As mentioned earlier, a key component of quality is meeting the client's requirements. In the context of bridge engineering, typical client requirements may include safety, durability, economy, constructability and aesthetics. Due to the consequence of structural failure, defined in this instance as the collapse of a structure, safety is an overarching requirement that transcends the bridge industry. As practicing engineers, not only do we strive to meet our client's requirements, but we also must do so while recognizing industry practice and standard of care.

As engineers, we all take an oath to protect the health and welfare of the public. This is echoed in the American Society of Civil Engineers' Code of Ethics: Canon 1—"Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties."

It is important to emphasize that a QMS alone cannot protect the health and welfare of the public. The application of sound engineering judgment must be paramount in the design process. Ultimately it is the integration of a QMS

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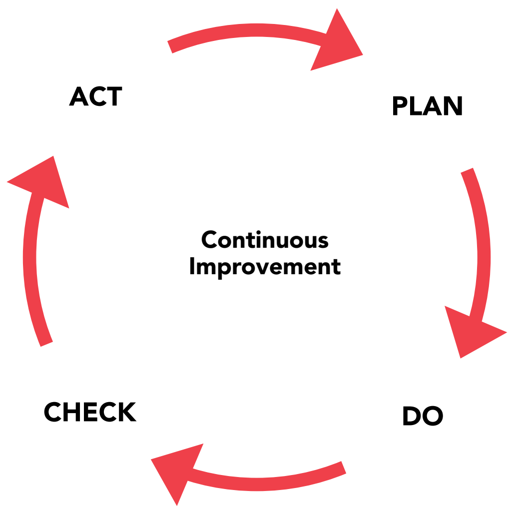
with sound engineering judgment that will provide the path to success and reliability in meeting safety requirements.

Quality Assurance and Quality Control

Quality assurance (QA) is successfully implemented as a cyclical process. This cyclical process is described in ISO 9001 as the Plan-Do-Check-Act method of performance improvement, which depicts the feedback loop between customer needs, customer satisfaction and improvement of the internal management system.



The cyclical QA process.

The first step is to document what you plan to do in writing, and then do the work in accordance with the plan while recording the work. Then, check the work that has been performed and act to improve on the process based on what has come out of the review. Essential to the QMS is continuous improvement, which is why it is important to review the work performed. In the Bridge Industry improvement is often based on lessons learned. Sometimes these lessons are taught the hard way, which makes continuous improvement the easier way.

On a project-level basis, QA should cover the process from start to finish—from project initiation through project closeout. During project initiation, the client's contract should be reviewed to understand and make sure the client's requirements are clearly defined. At the same time, staff should be assigned that have the capability to meet the specified requirements. The right staff skill sets for the project will be crucial for a successful outcome.

After review and assignment of staff, a project plan should be developed in written format for distribution to the project team outlining the client's requirements, goals of the project, staff assignments, staff responsibilities, project documentation procedures, client deliverables and intervals for review throughout the design process. In addition, and very important to meeting client requirements, the design criteria for the project should be explicitly outlined including any statutory or regulatory requirements.

The design output for a typical bridge project may include calculations, contract drawings, specifications and reports. The QC process is invoked during the development of these documents. During this process the design output is originated and then independently checked to make sure the approach and the output are technically correct. This check, however, should not be limited to just an arithmetic check of the calculations, but also must include an evaluation of the design methodology and its appropriateness to the element under design. This evaluation is invaluable in the design process and where the input from an experienced engineer is crucial.

The checking process can vary depending on the complexity of the bridge or element being designed. For simple design processes, a line-by-line check of the calculations may be adequate. In more complex bridges, such as highly curved I-girder bridges, an independent design check using a separate model may be the tool used to validate the record design model. The response of the system (interaction of the girders and cross frames) may not be intuitive and will require careful review to understand the behavior of the system. As part of the project plan, a process can be identified up front to address the anticipated complexity by requiring a technical peer review of the design output—whether it is the calculation results and/or the finished plans. Regardless of simple or complex design, the important issue is that the end product meets the client's requirements and the checking is commensurate with meeting this objective.

Inherent to the bridge industry is the use of structural analysis and design software. This can range from in-house spreadsheets with transparent limitations and assumptions to commercially available software. In all cases, these design tools must be thoroughly vetted—which should be part of the QMS.

The bridge industry relies heavily on commercially available software. Typically, the routine design software is considered industry standard or industry adopted. However, who is responsible for the accuracy of the software? In reading the disclaimer on many commercially available software packages, it is left to the user to determine the applicability of the software for use. There is also the inherent undertone that the engineer is responsible for the accuracy of the results. This is an enormous responsibility to be undertaken often under less than ideal conditions. All too often, those not engrained in the analysis and design process think this step is a "push of the button," which couldn't be further from reality. The engineer is obligated to address these challenges associated with software while adhering to industry practice and standard of care.

With the increased complexity of bridges comes the increased complexity in the analysis tools. The use of a line girder model is limited, so there is an increasing use of 2D grid/grillage models as well as 3D finite element models to address the system forces in such cases as highly skewed bridges and curved girder bridges.

The QMS may include such processes as running the software to compare results against known benchmark or published examples, when they exist, or performing hand calculations to check the results before the software is used on a project. However, the validation of the more complex 3D models, and to some degree the 2D models, is not always straightforward. There is the option to run one industry-adopted software against another to compare results, but this too often leads to even more questions. Software typically has different boundary conditions, limitations on member properties such as I-girder torsional stiffness, etc. that makes reconciling member force results and other system behavior more difficult.

The process of software validation is rarely a one-time effort. With the continuous release of new versions of software, it typically puts the engineer in the continuous mode of software validation on every project start-up. Time and effort dedicated on the last project is often lost on the next project. In the end, the process heavily relies on engineering experience and judgment.

As part of the design review, another essential process for a successful project is planning and review for constructability, which is part of the QC process and should be outlined in the project plan. A constructability review may take many forms; consider the concept of lower case "cr" and upper case "CR" to distinguish between two different levels of review. As bridge engineers, we often perform "cr" as we execute the design. This may include minimizing plate girder flange thickness changes, or it may include weld accessibility for closely spaced bearing stiffeners. "CR," on the other hand, may include where cranes can be placed for girder erection and whether these locations are feasible given the site constraints, or whether the project specifications for lane closure restrictions allow a reasonable window of time for erecting the girders. There is a great benefit to be gained in implementing a constructability review in the QC process.

The QA process must address the interface of disciplines. Typically on a bridge project, there are multiple disciplines working on the project including highway engineers, drainage engineers, utility engineers and traffic engineers. It is imperative that the process include a documented interdisciplinary review to make sure there are no issues with the interface of the different disciplines promoting both consistency and discipline integration. How many times have bridge deck elevations been completed when it is then realized that the bridge engineer does not have the latest roadway profile—or the position of a drainage scupper conflicts with a bridge girder? It is good practice to reduce the risk associated with the interface of disciplines by coupling on-going interdisciplinary coordination with formal interdisciplinary reviews at specified intervals in the project.

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Lastly, and all too often once a project is complete, the designers and managers are usually running on to the next project and its looming deadline. However, for proper project close-out, a careful review of the project and documentation of the lessons learned are critical to improving the next project and improving the ability to meet the client's expectations and needs. Documentation of the lessons learned is not enough, though. These lessons must be truly learned by the organization through use and review of them by all of the project teams prior to the start of the next project(s). The QA plan must include this process to promote continuous improvement—an essential part of a comprehensive QMS. ■

This article serves as a preview of Session B22, "Quality and the Bridge Engineer" at NASCC: The Steel Conference, taking place March 26-28 in Toronto. Learn more about the conference at ***www.aisc.org/nascc***.