Introduction

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 skewers 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 for use.
Agenda

- Quality Management System
- Client Requirements
- Quality Assurance & Quality Control
- Risk Assessment
- Computer Software Verification
- Constructability
- Technical Peer Review
- Interdisciplinary Review
- Project Closeout
- Questions

Bay Bridge Cable Walk
Quality Management System
Quality Management System

What is a Quality Management System (QMS)?

A QMS program is set up to “direct and control an organization with regard to quality.” – BS EN ISO 9000:2005

What is Quality?

Quality is the “degree to which a set of inherent characteristics fulfills requirements.” – BS EN ISO 9000:2005
Quality Management System

Which coffee cup is of higher quality?

It depends – what was the requirement to be fulfilled?
Quality Management System

A Quality Management System provides a roadmap to effectively and efficiently fulfill the requested requirements.

Fulfill the requirements while performing the Work in accordance with Industry Practice and Standard of Care.
Quality Management System

Industry Practice – “Industry Standard”

“Industry standards are a set of criteria within an industry relating to the standard functioning and carrying out of operations in their respective fields of production. In other words it is the generally accepted requirements followed by the members of an industry.”

http://definitions.uslegal.com
Quality Management System

Standard of Care

“The standard of care for all professional engineering and related services furnished by Engineer under this Agreement will be the care and skill ordinarily used by members of the subject profession practicing under similar circumstances at the same time and in the same locality.”

Engineers Joint Contract Documents Committee (EJCDEC) owner/engineer agreement
Quality Management System

• Perform the work in accordance with standard practice

• Standard practice will vary
  – do your research

• AISC Code of Standard Practice for Steel Buildings and Bridges, 2010
  – Provides a framework for acceptable standards
  – Design, purchase, fabrication and erection of structural steel
Client Requirements
Client Requirements

What are typical client requirements?

- Safety
- Durability
- Economy
- Constructability
- Aesthetics

Indian River Inlet Bridge, DE
Client Requirements

Safety – typically an overarching requirement that transcends civil engineering

ASCE 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.”
Client Requirements

What is failure?

In the context of bridge engineering, we typically think of failure in the context of a collapse; however that is the extreme case.

In terms of a client’s requirements, failure is not meeting the stated objectives defined in the Scope of Services.
Client Requirements

Failure to meet the client’s requirements from the perspective of bridge engineering:

- Safety – Perhaps the plans do not provide an adequately protected pedestrian path
- Durability – Perhaps the materials do not meet the 75-year design service life requested
- Economy – Perhaps the proposed bridge has been estimated at $5M and the client’s budget is $4M
Client Requirements

- Constructability – Perhaps the bridge supports are not accessible due to the terrain or location adjacent to a railroad.
- Aesthetics – Perhaps architectural pedestrian railing does not meet the request of the community

How do we manage the organization or a project to **consistently** meet the **client’s** requirements?

Through a robust QMS
Quality Assurance & Quality Control
Quality Assurance & Quality Control

These terms of Quality Assurance and Quality Control are often used together, however they each serve a separate and distinct purposes in the QMS process.

What is Quality Assurance (QA)?
QA focuses on “providing confidence that the quality requirements will be fulfilled” – BS EN ISO 9000:2005

What is Quality Control (QC)
QC “focuses on fulfilling quality requirements” – BS EN ISO 9000:2005
Quality Assurance & Quality Control

QA process – Plan/Do/Check/Act Loop

QA is successfully implemented as a cyclical process
Quality Assurance & Quality Control

In industry, improvement is often based on “lessons learned.” Sometimes these lessons are learned the hard way which makes the continuous improvement process under a QMS the easier and more desirable way.
Learning the hard way….The review of the probable cause of collapse led the Bridge Industry to adopt changes in the inspection, evaluation, and design of truss gusset plates – thus leading to improvement following an evaluation of the lessons learned.
Quality Assurance & Quality Control

On a project level basis, QA should cover the process from start to finish – from project initiation through project closeout

- Project Initiation – client’s contract should be reviewed to verify client’s requirements are clearly defined

- Project Resources – staff and subject matter experts should be assigned that have the capability of meeting the client’s requirements
Quality Assurance & Quality Control

- Project Plan – should be developed in written format to guide the team. It should include:
  - Client requirements
  - Project Design Criteria
  - Goals of the project
  - Project risks
  - Staff assignments & responsibilities
  - Project documentation procedures
  - Client deliverables
  - Intervals for review throughout the design process
  - Project closeout process (i.e. “lessons learned”)
Quality Assurance & Quality Control

QC process is invoked during the development of the design documents

What are typical design documents?

- Calculations
- Contract drawings
- Specifications
- Reports
- Engineer’s Estimate
Quality Assurance & Quality Control

The check is not limited to arithmetic check of the calculations…

…but also an evaluation of the design methodology and appropriateness to the element under design
Quality Assurance & Quality Control

Establish checking procedures
- Independent check
- Color coded format
  - Yellow – check
  - Blue – checker comment
  - Red – proposed changed
  - Green – back-check

Example of a check of calculations
Example of an INDEPENDENT check of plans
Quality Assurance & Quality Control

Checklists are often a tool in the QC process to make sure the process is comprehensive.

Checking process can vary depending on the complexity of the element under design.
Quality Assurance & Quality Control

For a simple design, such as a simple-span bridge, a line-by-line check of the calculations may be adequate.

In a complex bridge, such as a highly curved I-girder bridge, a design check using a separate modeling software may be warranted.

As part of the project plan, the level of risk and complexity of the design is assessed and the appropriate QC procedures identified.
Risk Assessment
Risk Assessment

- All activities involve risk – good & bad
- In a robust QMS risk is effectively managed
- Identify risk during scoping, track risk, and communicate risk with project team
Computer Software Verification
Computer Software Verification

Inherent to the industry is the use of software to help expedite the design process. This may include:

- In-house MSExcel spreadsheets
- In-house Mathcad worksheets
- Commercially available software

Regardless of the design tool, the tool must be thoroughly vetted – which shall be part of the QMS.
Computer Software Verification

“There is a growing reliance on software for the design of bridges. As this software becomes more intricate, the verification of the results is becoming increasingly difficult…with so many different paths through the logic…testing for all scenarios to ensure correctness is nearly impossible.”
Computer Software Verification

Who is responsible for the results of a commercially available software?

AASHTO LRFD Bridge Design Specifications, 6th Edition, Section 4.4 – Acceptable Methods of Structural Analysis

“The Designer shall be responsible for the implementation of computer programs used to facilitate structural analysis and for the interpretation and use of the results. The name, version, and release date of software should be indicated on the contract documents.”
Computer Software Verification

Commercially available software does have issues –

- Steel Girder Analysis Software – Errors in the computation of section properties in variable depth girders. Errors in the simple-beam reactions when the span length falls outside of the undeclared limits of the program

- Concrete Beam Software – Errors in the shear diagram

- Bridge Pier Software – Errors in the bar lap lengths, omission of secondary moment effects on the pier cap, omission of design wind overturning effects
Computer Software Verification

- Bridge Model Software (Complex 2D grid/grillage model for steel girders) – **Error** in reconciling the inputted geometry or applied loads falling outside the undeclared limits for the input.
NCHRP Report 725 – Guidelines for Analysis Methods and Construction Engineering of Curved and Skewed Girder Bridges

- Comparison of 1D and 2D Grid models against 3D (FEA)
- Scorecard to assist designers with choosing the right model
Computer Software Verification

NCHRP Report 725 – Guidelines for Analysis Methods and Construction Engineering of Curved and Skewed Girder Bridges

Curved/Skewed I-Girder Bridges

- Underestimation of I-girder torsional stiffnesses by solely using the St. Venant torsional stiffness in 2D-grid models (need to recognize warping stiffness of I-girder)
- Use of equivalent beam elements for cross-frames that do not capture beam flexure and shear deformations (Euler-Bernoulli beam theory vs. shear-deformable Timoshenko beam)
Computer Software Verification

The QMS shall address software verification

- Run the software against a benchmark or published example (when it exists)
- Perform hand calculations to check the results before the software is used on a production basis on a project

What about the more complex 2D & 3D FEM models?

- Option to run one industry-adopted software against another to compare results – however, this often leads to even more questions
Computer Software Verification

The process of software verification is rarely a one-time effort.

- Continuous release of software upgrades
- Time & effort on the last project is lost on the next

Regardless of the software verification process, nothing replaces sound engineering judgment.
Constructability
Constructability

Verifying the project details can be built

Bottom – Bearing Stiffeners

Top: Bridge Deck Closure Pour
Constructability

Verifying the bridge can be built

Scale Factor = 50x

-Bearing Line Rotations

-Girder End Twists

Don White, Georgia Tech
Bob Cisneros, High Steel Structures
Constructability

Verifying the bridge can be built

- Staged construction
- Erection sequence
- Cross-frame strength
- Cross-frame stiffness
- Two-girder systems susceptible to stability due to lateral torsional buckling during construction; requires torsional braces

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Ronnie Medlock, High Steel Structures
Constructability

Verifying the project can be built

Crane access for pier demolition?
Technical Peer Review
Technical Peer Review

• Peer review intended to result in improved project quality with less risk to all parties (engineer, owner, contractor)

• Technical Peer Review
  – Not intended to serve as a Value Engineering
  – Enhance public safety
  – Design appears conceptually correct
  – No major errors or omissions
  – Not intended to be a comprehensive check
Technical Peer Review

• Purpose is to provide greater degree of quality assurance and greater level of confidence in the final structure

• Provided the design conforms to the DESIGN CRITERIA, it is irrelevant if peer reviewer would have approached it differently

• To encompass a review of the design using independently generated calculations

• Not intended to assess constructability issues, including stability during construction, sequencing, etc.
Interdisciplinary Review
Interdisciplinary Review

One of the largest risks on a project is the interface of disciplines (highway, structures, drainage, utilities)

Requires periodic review during design process
Project Closeout
Project Closeout

Once a project is complete, the designers and managers are usually running to the next project & looming deadline

Proper project close-out requires careful review of the project and documentation of the “lessons learned” OR “Best Practices”
Project Closeout

The “lessons learned” must be learned by the organization so project teams can take what has been learned on to the next project.

A QA plan must include this process to promote continuous improvement
Questions?

Thank You
Shane R. Beabes, P.E.
District Chief Engineer – Bridges
Associate Vice President

AECOM – an ISO 9001:2008 certified company