# Quality Assurance for Structural Engineering Firms

BY CLIFFORD SCHWINGER

**Implementing an in-house quality assurance program benefits your firm, your employees, and your clients.**

**THE STRUCTURAL ENGINEERING PROFESSION** has undergone dramatic changes over the past twenty years. With fast-track construction, computerized design, complex building codes, and younger engineers taking on more responsibility earlier in their careers, the need for structural engineering firms to have a comprehensive in-house quality assurance program has never been greater. Adopting such a program will result in better design, high-quality contract documents, fewer RFIs and change orders during construction, a better product for clients, and increased profitability for engineering firms.

## The Quality Assurance Program

A quality assurance (QA) program is a defined set of procedures and standards used to facilitate design and to facilitate documentation of that design. Implementation of a QA program results in:

- ✓ Better design
- ✓ Better drawings
- ✓ A more efficient design process
- ✓ Fewer mistakes
- ✓ Fewer RFIs and change orders
- ✓ Increased client satisfaction
- ✓ Enhanced reputation
- ✓ Increased profits

Prior to 1990 the concept of formal QA programs was virtually unheard of within the profession. Quality was assured by relying on the experience, skill, continual oversight, and expertise of trained engineers, structural designers, and drafters. Structural design was a linear process and contract documents were usually not issued for bid until the design and the drawings were 100% complete. Formal QA programs, where they existed, consisted primarily of a senior engineer being assigned as the "go-to" person for answering technical questions. That engineer would also review the drawings before the project went out for bid, providing a second set of eyes on the contract documents in order to catch mistakes. Such a QA program, consisting of a "technical guru" and a single QA review, does not work today.

Today, a comprehensive QA program requires the following components:

- ✓ Training for young engineers
- ✓ Design standards
- ✓ Drafting and CAD standards
- ✓ A project delivery system
- ✓ A knowledge base
- ✓ Involvement of the QA manager and QA reviews

## Training for Young Engineers

Before computers were commonplace, young engineers working in design offices typically spent the first several years of their careers doing repetitive manual calculations. Most new engineers also spent time "on the board," learning the art of structural drafting under the guidance of experienced engineers and senior drafters. The training of a young engineer was a gradual process. As experience was gained, more responsibility was delegated: reviewing shop drawings, developing details, and eventually coordinating projects with architects and answering questions from contractors. Computers have eliminated most laborious manual calculations, and while they have greatly increased productivity, computers have also altered the informal training phase that all new engineers go through. Young engineers today are faced with the challenge of taking on much more responsibility early in their careers. Further challenging a young engineer's development in the profession are complex building codes, the details of which are usually not learned in school, and the lack of any knowledge of structural drafting, a skill which is just as valuable today as it was years ago. The ability to convey one's ideas to paper for interpretation by others will always be an essential

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skill. For moderate to large-sized engineering firms, the solution to this problem is establishment of a formal in-house training program.

Training for young engineers should consist of in-house lunchtime training seminars covering the full spectrum of structural engineering topics that are pertinent to the type of work performed by the firm. Because the goal of the training program is to pass on the combined knowledge of the senior staff, the list of topics for these seminars is long. Passing knowledge includes not just interpretation of codes, standards, and design procedures, but also a discussion of practical applications and lessons learned. These seminars are best conducted once or twice per week. While some topics can be covered in a single session, others, such as structural steel connection design, can take several sessions to fully cover.

Seminars focus on actual application of the principles discussed and are interspersed with lessons learned, discussion of common mistakes, examples of manual calculations, and tips and techniques for verifying the accuracy of computer analysis and design. Software limitations and assumptions are reviewed with a continual emphasis that computers are tools to be properly used by engineers; the creativity and solutions to structural engineering challenges come from the mind and imagination of the engineer, not the computer.

## Design Standards

Design standards are comprised of formal design procedures, design guides, and checklists.

Medium and large engineering firms must have written formal design procedures, standards, and methodologies in order to produce consistently high-quality designs and to minimize the risk of errors due to miscommunication. Office standards must be formally established so that there is no confusion regarding design procedures and methodologies. Is office policy to use ASD or LRFD design? Is the policy to show beam reactions on framing plans or to require that shear connections be designed for a percentage of the member uniform load capacity? Are connections designed by the engineer of record or is connection design delegated to the steel fabricator's engineer? Is there a minimum percentage of code wind load below which the wind tunnel wind pressures will not be used? Serious consequences could result if two engineers are working on a project, with one showing service level member reactions on the framing plans and the other showing factored reactions. The purpose of office design standards is to keep everyone on the same page and to provide a roadmap to insure uniformity of design.

Design guides are one of the ways that design procedures are set forth. Design guides delineate office policy regarding design procedures and bring together building code and design standards, textbook theory, local construction practices, practical applications, and lessons learned.

Checklists are useful tools both for engineers new to the profession, as well as for experienced engineers trying to remember the hundreds of things that go into design and documentation of a building. While major items like reviewing diaphragm strength and stiffness are well ingrained into a seasoned engineer's mind, little things like remembering to coordinate locations of fall protection tiebacks on the roof might occasionally slip by but for reminders provided on checklists.

> "While computers are indispensable tools, they will never replace the judgment of experienced engineers who have mastered the art of structural engineering."

## Drafting and CAD Standards

Structural drafting is fast becoming a lost art. Whereas mechanical drawing used to be taught to students in high school and college, many engineers now arrive in the profession with no training in a skill that is essential for communication of their design intent to others. Likewise, most structural drafters have now been replaced by CAD operators who, while proficient in use CAD software, may be lacking in the knowledge and understanding of how to lay out framing plans, draw weld symbols, or dimension details. The solution to this problem is to establish drafting and CAD standards, the components of which include:

- ✓ standardized drafting procedures
- ✓ CAD checklists
- ✓ a library of typical details
- ✓ "go-by" drawings
- ✓ a library of standard blocks

Drafting procedures include information related to rules for laying out framing plans, drawing sections and details, setting up column schedules, etc. Uniformity and consistency within the office requires that everyone draws objects consistently on the correct layers and uses the same linetypes and linetype scales. While these may seem like trivial issues having no bearing on structural design, they will improve the quality and legibility of a set of structural drawings.

Checklists include the myriad of things needed to produce complete and legible drawings. They cover things as seemingly minor as making sure north arrows are shown on the framing plans to more important items such as making sure that beam reactions are indicated.

A comprehensive structural engineering detail library will contain hundreds of typical details.

"Go-by" drawings are reference drawings that show examples of how to indicate information on framing plans, schedules, etc. While go-by framing plans may have originated from actual projects, they will usually be modified over time to include everything that can possibly occur on a framing plan. Go-by framing plans for various structural systems provide engineers and drafters a single point of reference to see how to properly draw anything they will encounter on the plans. The use of go-by drawings prevents younger engineers from using previous projects for learning how to show things on the drawings. While using other projects as a frame of reference is not necessarily a bad idea, doing so can lead to a gradual divergence of drafting standards in larger firms.

A standard block library is essential for increasing productivity and maintaining drawing uniformity. "Blocks" are pre-drawn objects such as bolts, angles, W-shapes, weld symbols, headed studs, section cuts, etc.

## Project Delivery System

The project delivery system is a library of forms, checklists, procedures, and correspondence templates used for administratively carrying a project from inception through construction. The delivery system is divided into five sections:

- ✓ project startup
- ✓ schematic design
- ✓ design development

- ✓ contract documents
- ✓ construction administration

The project startup section contains things required at the beginning of a project such as a design criteria form listing design information such as the applicable building code, design standards, loads, wind, snow and seismic design criteria, summary of the structural systems being used and fire ratings required. Correspondence templates for letters to the client regarding information needed from the geotechnical consultant and wind tunnel consultant as well as correspondence templates that summarize presumed design criteria and required "due by" dates to meet schedules, etc. are provided.

The schematic design, design development, and contract document sections contain checklists and procedures related to the deliverables in each phase of design.

The construction administration section contains meeting agenda templates for the pre-steel-detailing meeting, the pre-concrete meeting, and meetings with the inspector, as well as checklists to be used when reviewing shop drawings.

### Knowledge Base

The knowledge base (KB) is a searchable electronic database of all knowledge related to structural engineering. The KB contains the notes from training seminars, design guides, design standards, drafting and CAD standards, and information on all other topics that engineers may need to access. The primary feature of the KB is that it's a single source for answers to all questions related to structural engineering. When a question or topic comes up for which there's no answer in the KB, that information is added. When problems occur or lessons are learned, the solutions to those problems and lessons learned are added to the KB.

### Involvement of the QA Manager and QA Reviews

The QA manager is a senior level engineer who is responsible for establishing and maintaining engineering standards and for verifying that all design is done in accordance with those standards. The QA manager has the following responsibilities:

- Establishing and maintaining design and drawing standards
- Answering technical questions and getting the answers to those questions into the KB, as appropriate.
- Staff training
- Maintaining familiarity with all projects during design and providing input and suggestions, as required.
- Signing off on sections and details prior to them going to the CAD department. (A cursory review and signoff of sections and details by the QA manager is required to catch mistakes before sending sections and details to the CAD department. Such a review saves time and is informative for the engineer whose details are being critiqued.)
- Performing quality assurance reviews on all projects.

### The Quality Assurance Review

Quality assurance reviews are in-house reviews conducted to verify that all design is performed and documented in conformance with the procedures and standards mandated by the QA program.

QA reviews serve two purposes. The primary purpose of QA reviews is to provide redundancy via a second set of experienced eyes on the drawings to catch mistakes, errors, or omissions. The second purpose is to monitor the effectiveness of the QA program. If the QA program is working properly and engineers are following the procedures and utilizing the resources provided therein, then problems, mistakes, errors, and omissions caught during the review should be minor. While the QA manager is usually the one who performs the reviews, other experienced engineers can likewise perform the task.

Changes in the way contract documents are now issued have altered the way QA reviews are performed. Until ten years ago a single QA review was performed prior to the contract documents being issued for bid. Fast-track construction scheduling now requires multiple reviews at stages during design. It's not uncommon to have eight or more reviews on large projects. While the number varies from project to project, a typical QA review schedule for a steel-framed structure on pile foundations might be as follows:

1. Pile bid
2. Steel mill order
3. Foundation concrete bid
4. Steel addendum/detailing issue
5. 100% concrete
6. 100% structural steel
7. "Issued for construction" final review

Multiple reviews are also a good idea for those projects still delivered via the traditional design-bid-build process. Interim reviews will catch mistakes early, when corrections can be easily made.

There are two primary goals of QA reviews. The first and most important goal is to review the contract documents to verify that the structure was properly designed, is efficiently framed, and is constructible. The second goal is to verify that the contract documents are complete, well detailed, correct, and coordinated. The goal of issuing complete and well-detailed contract documents is not just one founded on a desire to reduce RFIs and change orders; it is one that is essential to insuring structural integrity. Finishing the drawings during construction via the RFI process is a bad idea. Not only do RFIs frequently lead to change orders, unless senior level experienced engineers are the ones answering RFIs, mistakes can slip through as well. If the drawings are complete and well detailed before construction, those details will have gone through the scrutiny of the QA review process, and the probability of engineering mistakes being made during the process of answering RFIs during construction will be greatly reduced.

A variety of tactics are employed when performing QA reviews. Those tactics are as follows:

- ✓ Look at the big picture.
- ✓ Verify load paths.
- ✓ Review framing sizes.
- ✓ Look at connection details for constructability.
- ✓ Look for mistakes.
- ✓ Look for subtleties.
- ✓ Look at the drawings for constructability.
- ✓ Review for clarity.
- ✓ Look for omissions.
- ✓ Look for "little" little things.
- ✓ Look for the "big" little things.
- ✓ Verify that the structural drawings match the architectural and MEP drawings.

### Summary and New Challenges

QA programs must be adaptable to the new challenges that continually occur. One challenge is that of recognizing the limitations and constraints of computer software and keeping up with software changes and improvements, all the while keeping in mind that while computers are indispensable tools, they will never replace the judgment of experienced engineers who have mastered the art of structural engineering. Another challenge is that of training highly motivated young engineers so that they are best equipped to be the skilled and productive professionals they enthusiastically strive to be. A comprehensive QA program can help them succeed—and everyone benefits. MSC