Quality Assurance of Structural Engineering Design
Part 2

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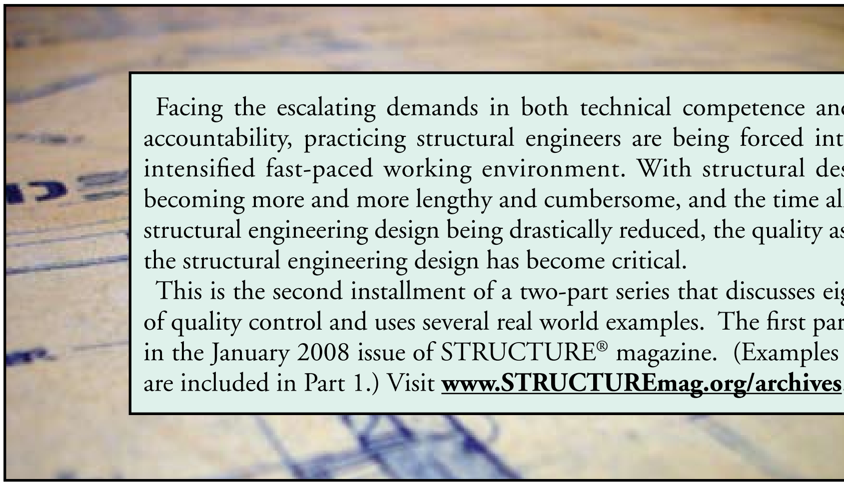

Facing the escalating demands in both technical competence and financial accountability, practicing structural engineers are being forced into an ever-intensified fast-paced working environment. With structural design codes becoming more and more lengthy and cumbersome, and the time allocated for structural engineering design being drastically reduced, the quality assurance of the structural engineering design has become critical.

This is the second installment of a two-part series that discusses eight aspects of quality control and uses several real world examples. The first part appeared in the January 2008 issue of STRUCTURE® magazine. (Examples 1, 2 and 3 are included in Part 1.) Visit **www.STRUCTUREmag.org/archives**.

Verification of Structural Design Results

Due to the complexity of structural loads, construction materials, and analysis/design methods as well as the governing codes, structural design for certain real world structures could be very demanding and involved. The whole design procedure may last for a significant length of time. Loading conditions, structural layouts, construction materials, design assumptions, code requirements, etc. may change with the progress of the project. The analysis and design of the structure could be very lengthy and fragmented. The robustness of final results of the structural design relies on the accuracy of every step of the procedure. Therefore, for a structural engineering design firm to minimize the liability risk in design, an effective yet reliable approach to verification of the design product is a vital necessity.

Since the designer of a structure is the person directly involved in all steps and all aspects of the whole design procedure, a rigorous self-checking should be the first essential verification approach. Based on a designer's experience and the scope of the subject project, a check-list of self-checking items such as:

- design codes compliance,
- loading types,
- load combinations,
- structure types,
- member properties and connections/supports,
- computer input and structural modeling,
- analysis methods,
- design criteria and assumptions, etc.

may become a routine list for easy and effective verification of each design step. For certain hand-calculation items, double checking significant equations and where the results were used should become a fundamental customary practice. A well-organized compilation of all design references and calculations will serve as an extremely useful tool for verifying design results.

The second verification approach should be a well-organized peer-review. Guidelines for peer-review shall be established to avoid viewer's negligence or error.

Interaction and Coordination with Other Design Disciplines

For a structural design to be completed on time and within the budget, an active interaction and efficient coordination between structural engineers and other design disciplines is an essential prerequisite. The lack of interaction and coordination with other design professionals involved in the project can result in misunderstanding of the project scope, design criteria, structure layout, loading conditions, client requirements, project schedule, budget, etc. Active interaction and efficient coordination with other design disciplines should also be included in the quality control and assurance measures. Active interaction means that the structural engineers shall not passively wait to be notified of project information and/or design criteria by other design disciplines. Actively requesting relevant project information and design criteria, as well as understanding client expectations, should commence at the very beginning of a project.

It is frequently observed that, especially when the schedule for the project is tight, the architectural or mechanical plans refer to some details in the structural plans; unfortunately, the structural plans may not include such referred details if the structural engineer has not been informed by the architect or mechanical engineer. These kinds of communication problems should be eliminated by efficient coordination within the project team.

Quality Control and Assurance in Producing Construction Documents

The delivery of the design results is contained in the construction plans and specifications. CAD personnel are heavily relied on for the plans.

Quality control and assurance in producing final construction plans and specifications should include at least three major categories. The first category may focus on the **accuracy of the plans and specifications**. The structural engineer should play a key role by providing accurate design results to the CAD personnel and conducting rigorous technical review of all structural members and details

Example 4

In an approval review of a commercial plaza project by a consulting firm serving as the City Engineer for a Midwest United States' jurisdiction, it was found that almost one third of the structural details in a so-called "Standard Structural Details" sheet were inconsistent with the structural members and details shown in the major structural plans. It was obvious that the "Standard Structural Details" sheet was not checked and modified by the design firm to meet the design for the particular project.

generated in the construction plans. From time to time, it has been observed that the final plans and specifications submitted for approval review contain erroneous data for structural members and details. *See Example 4*.

The second category may focus on the **completeness of the construction documents**. Both structural engineers and CAD personnel should closely work together to assure the completeness of the plans and specifications. Incomplete plans without sufficient notes, dimensions and elevations/sections of the structure have caused confusion for contractors, which can result in construction Change Orders.

The third category may focus on the efficiency of the **procedure for checking and correcting plans and specifications**. Depending on the competence level of the engineers and CAD personnel, the checking and correcting could be a harmonious procedure or a big headache. Some design firms, with less experienced CAD personnel, see the same drafting errors checked repeatedly by the engineer and marked by the drafter several times until they are fully corrected. Repetitious checking and correcting is frustrating and costly.

Interaction and Coordination with Construction Professionals

The construction phase is the final stage of quality control and validation of the structural design. This stage could also be a "touchstone" for testing the competence of the structural engineer. This is the last chance to remedy design and production errors. The interaction and coordination with construction professionals through shop drawing review, response to requests for information, providing supplemental remedial measures to correct design or coordination errors, and site visit and supervision should be effectively conducted to enhance the positives and eliminate, or minimize, the negatives of the structural design. *See Example 5*.

Example 5

There was a fast-track design project for an agriculture facility to meet the harvest season date. Before the vendor of a series of agricultural equipment had been selected, the structural engineer was requested to complete the design of a 14,000 square foot mat foundation, based on the design loads of the equipment and the facility building from a previous project with similar capacities. The foundation package was sent out for bid, and the construction contractor for the foundation was selected. When the vendor of the equipment was selected and the loads of the new equipment and building were available, the excavation and sub-grade compaction for the mat foundation had been started. By comparing the new and old equipment loads, it was found that several columns of the new equipment had much higher support reactions than those of the old equipment. Therefore, when the shop drawings of reinforcing steel for the mat foundation were submitted for the review, the structural engineer quickly re-analyzed the mat foundation with new loads and re-arranged the reinforcing steel layout. The shop drawings were marked and returned to the contractor with the new layout of the steel. The construction requirements for the new layout were communicated to the contractor in detail. Fortunately, the total amount of the reinforcing steel was kept very close to that of the original design, and no construction "Change Order" was filed.

Summary

In an effort to assure the quality of the structural design, a systematic procedure should be adhered to. As a starting point, consider the following:

1) Develop a comprehensive codes index, including the clients' local jurisdictions and the adopted general codes and special material codes.
2) Develop a check-list for the structural design guide regarding:
   • certain loads such as wind and seismic loads, and load combinations;
   • key factors in modeling of structural members, connection/supports, and loading patterns;
   • practice-oriented procedure of software input verification, design assumptions and capabilities of individual software;
   • design manuals/tables/graphics.
3) Develop a project oriented check-list of self-check items such as:
   • design codes compliance;
   • loading types;
   • load combinations;
   • structure types;
   • member properties;
   • connections/supports;
   • computer input and structural modeling, analysis methods;
   • design criteria and assumptions, etc.
4) When peer-review is conducted internally, a down-to-earth and technically rigorous review procedure can be implemented to assure the quality of the project.
5) Develop an easy-to-follow, yet technically strict, check-list in implementing the quality control

and assurance of the production of construction plans and specifications. Set up appropriate job performance thresholds, such as a maximum number of the times allowed for a checking/correcting of a plan satisfactorily to determine if a team member should go through extra training.

6) Develop a comprehensive, yet practice-oriented, guide to help structural engineers in communicating with other design disciplines and construction professionals. A check-list containing the information of other design or construction professionals and relevant project data collected during different design stages, might be included in the guide. Keep all records of communication between the structural engineer and other design/construction professionals.▪

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