

## Structural Drawings... A Perspective

By Mark K. Gilligan, S.E.

Considerable effort is spent preparing drawings, yet there is little discussion regarding the role of structural drawings and what should be included and omitted. This lack of discussion has resulted in confusion and the proliferation of poor practices.

First and foremost, structural drawings are part of the Contract Drawings and as such provide instruction to the Contractor. The Contract Documents consist of the Agreement between the Contractor and the Owner, General Conditions, Specifications and Contract Drawings along with any addenda and modifications. To the extent that we focus on this role, it is fairly simple to decide what belongs on the drawings. The problem occurs when we attempt to have these documents fulfill other secondary roles such as recording design criteria, recording information related to future structural modifications, and providing information for the building official that the Contractor does not need. The information provided in response to these secondary goals has the potential of causing confusion and exposing the engineer to unnecessary liability, while at the same time costing fee. As a result, focus should be on providing only the information needed by the Contractor to do his or her work.

Structural drawings are Contract Documents and, as with any contract, the best practice is to state only what you want, say it once, and present the information in a well organized manner. Clarity is of the utmost importance when producing drawings. We need to clearly define the size and location of all elements of the structure. The contractor may have to extract information from schedules, work out dimensions, have an engineer design members based on criteria provided, and coordinate the location and details with other systems, but the information provided must be such that there is no ambiguity. The importance of this is emphasized by the reality that, if the documents are not clear, the courts will enforce the interpretation the Contractor prefers.

Engineers often justify repeating information on drawings on the basis that this makes it easier for the Contractor, and thus saves money for the Owner. While we are obligated to spend the Owner's money wisely, we also have obligations to protect the Owner from the problems that occur as a result of mistakes. We also have an obligation to limit our exposure to risk. When information is repeated or when dimensions that can be calculated by the Contractor are added to the drawings, the likelihood of errors increases significantly. This is made worse when changes are made and we have to find all the locations that need to change. In this context, protecting the Owner from the consequences of errors takes precedence. A contractor will be much more appreciative of a well organized set of drawings where he or she can find things, than of additional dimensions, which can mean extra time resolving conflicts. Remember that contractors and their subs know how to produce shop drawings and lay out a building, so there is no need to spend time doing their job for them.

Many of the rationales for putting additional information on the drawings are based on attempts to prevent an ill-defined problem that may possibly occur at some time in the future. These are problems that we have no obligation to prevent, and 'solving' them can have negative consequences. Construction documents are most effective when they try to do just one thing. When we try to accomplish multiple objectives, such as facilitating future ill-defined modifications, we spend more time

and we create expectations that may increase our liability exposure.

Structural drawings typically define the systems that are a part of the Structural Engineer's scope of work. According to the General Conditions, no distinction is made between the structural drawings and the architectural and other drawings. This means that the Contractor is responsible for coordinating the drawings of the several disciplines; if the location of an opening edge is defined on the architectural drawings, it need not be explicitly dimensioned on the structural drawings. While this allows the engineer to not show all dimensions on the structural drawings, they must still be coordinated and compatible with the other drawings and all necessary information must be available to the Contractor. This is often accomplished by dimensioning the grid lines and other key features on the structural drawings, and controlling the location of openings, edges of slab, and other features through the use of details that define maximum or minimum dimensions. When this approach is adopted, it is appropriate to add a note in the General Notes stating that the architectural and other drawings should be referred to in order to establish missing dimensions.

### Relationship between Drawings and Specifications

According to AIA A201, *General Conditions of the Contract For Construction*, "Drawings are the graphic and pictorial portions of the Contract Documents...showing the design, location and dimensions of the Work, generally including plans elevations, sections, details, schedules and diagrams." The CSI Manual of Practice (MOP) goes on to say that "drawings indicate the relationships between elements" and for each material, assembly or product the drawings show location, identification, dimensions and sizes, details of connections, and shape and form.

Similarly, AIA A201 states that "The Specifications are that portion of the Contract Documents consisting of the written requirements for materials, equipment, construction systems, standards and workmanship for the Work, and performance of related services." The CSI MOP states that "Specifications define the qualitative requirements for products, materials, and workmanship..."



Therefore, if the information is presented in a graphical manner it belongs on the Drawings. Information designating the type, size, and location of a bolt belongs on the drawings. Information relating to the quality of the bolt, material standards, installation procedures, and testing and inspection requirements belongs in the Specifications.

The use of generic terms on the drawings should be encouraged. This allows the quality of the product or material to be easily modified without having to make extensive modifications to the drawings. This is not always feasible when specifying products such as joist hangers, where it is necessary to refer to a manufacturer's specific product designations.

Drawings and Specifications complement one another, and the names of materials and products used in the specifications should be the same as those used on the drawings. For example, referring to anchor bolts on the drawings while the specifications refer to anchor rods could cause confusion and excuse the Contractor for installing the wrong product. Typically there is no reason to place specification information on the drawings.

## General Notes

General Notes are placed on drawings to provide instructions on the organization and use of the drawings. They are also used to document loading criteria and other information required by the building code.

On small projects, where it is perceived that complete specifications are not appropriate, General Notes are often expanded to include material properties and other information that normally belongs in the specifications. It should be noted that the 2003 IBC does not require that material properties be listed on the drawings. Where other codes require material properties be placed on the drawings, provide only the minimal information to minimize conflicts with specifications. For example, in the case of concrete it would only be necessary to show  $f'c$ . Additional information is typically not required by the building official.

The practice of placing extensive General Notes on the drawings at best results in duplication of information that is already in the Specifications, and inevitably results in conflicts with the Specifications. Thus, General Notes should be kept to a minimum with every effort being made to avoid duplicating information defined elsewhere.

## The Building Code and the Building Official

Construction Documents are defined in the 2003 IBC as "Written, graphic and pictorial documents prepared or assembled for describing the design, location and physical characteristics of the elements of the project necessary for obtaining a building permit." The use of the term "construction documents" instead of drawings is important in that it allows the engineer flexibility to locate appropriate information in the Specifications.

The 2003 IBC refers to the Construction Documents in sections 106, 1603, 1802.6, and 2101.3. Section 106.1.1 is compatible with the provisions of AIA A201, and requires that the construction documents show that the work will "...conform to the provisions of this code and relevant laws, ordinances, rules and regulations..." This gives the designer significant flexibility and should cause few difficulties.

Section 1603 of the 2003 IBC additionally requires that the construction documents clearly indicate the loading criteria and address the special inspections for seismic resistance. The loading criteria are typically listed in the General Notes. While occasionally live load key plans are provided, this level of detail is typically not needed by the Contractor and therefore is not recommended. Much of the information related to the special inspection requirements will be located in the specifications, with the drawing delineating the elements that will be subject to special inspection.

Section 1802.6 requires that the construction documents show the soil classification and design load-bearing capacity. This information will typically be extracted from the Geotechnical Report and listed in the General Notes.

The provisions in section 2101.3 list specific information to be provided, and can be considered to be a clarification of the provisions in sections 106 and 1603.

Local building departments will often require additional information on the drawings. When these requirements are not compatible with the primary role of Construction Documents or where they require unnecessary duplication of information, the engineer should carefully consider strategies to minimize the problem. Extra attention to coordinating the documents can help deal with duplicate information, but conflicts still inevitably occur. When the added information is contrary to good practice and is not needed by the Contractor, consider adding a note that this information is provided for regulatory purposes only and should not be relied on.

## Contractor-Designed Components and Systems

It is not uncommon for the Contractor to be asked to design specific building components and systems. Common examples include steel connections, trusses, and the building façade. In each of these instances, the Construction Documents must provide the necessary design criteria.

AISC has done a good job of defining the information needed when an engineer working for the fabricator designs steel connections. The engineer is referred to the AISC web site ([www.aisc.org](http://www.aisc.org)) for more information.

Where trusses are designed by the Contractor, common practice is to show loading diagrams that define uniform and point loads where standard trusses are not used.

For the Contractor to design the building façade, the wind and seismic load criteria needs to be provided. Other information typically needed includes assumptions regarding how the loads from the facade will be transferred to the building structure, expected live load deflections of the building frame, and building drifts that need to be accommodated by the façade.

## Existing Construction

When adding on to or modifying existing structures, it is important to clarify what has been confirmed and what is based on existing drawings. If the Contractor relies on member sizes or dimensions based on existing drawings that differ from actual conditions, problems and claims could result. One approach is to omit showing member sizes and dimensions of existing construction on the new drawings, and provide the contractor drawings of the existing construction for reference. In general, if you have not verified the information on the original drawings either do not show it or differentiate it graphically in some way.

## Sequence of Construction

Most buildings are conventional enough that it is not necessary to say anything regarding sequence of construction, but in some instances this information must be provided. Examples include modifications to the lateral system that could temporarily weaken the building, situations where the sequence of construction will influence the forces in the members, and situations where the structure would not be stable if basement walls were backfilled prior to construction of the floor slab.

In these situations the drawings need to define construction sequence, either by the use of notes or by the use of diagrams. Alternatively, it may be appropriate to define the assumptions that the design was based on or the issue that the Contractor has to address. When the Structural

Engineer of Record (SEOR) defines the sequence of construction, he exposes himself and the Owner to added liability and limits the Contractor's options, which often increases the cost of construction. It is important to resist the temptation to define the sequence of construction just because you believe you know that they will do it a specific way, when there are other valid approaches.

The AISC Code of Standard Practice states that when a steel structure relies on structural elements other than the structural steel for stability, the SEOR needs to define the other elements that brace the steel framing. The problem is that the SEOR typically does not know how the General Contractor intends to construct the building, and failure to appreciate the subtleties of the Contractor's approach may cause problems. In such situations, the best strategy may be to require that the Contractor hire an engineer to develop, in conjunction with the steel erector, procedures that allow the building to be constructed safely. This information needs to either be provided to the Contractor, or the responsibility for addressing this issue needs to be assigned to the Contractor.

### Quality Assurance Plan

In order to implement the Quality Assurance Plans required by the IBC, the structural drawings will have to provide enough information so the Contractor and inspectors can identify the elements subject to special tests and inspections. Typically, specifications will define the testing and inspection requirements and designate the classes of members to which they apply. The structural drawings will then define which members belong to which class, and thus which tests and inspections will be performed. The drawings must use the same terminology as in the specifications so there is no confusion. In some

cases, this can be accomplished through the use of notes in typical details. However, in other cases it may be necessary to designate each member that these requirements apply to.

### Summary

The key to improving structural drawings is to recognize that they are legal instruments that give instructions to the Contractor. Drawings need to provide the Contractor with the information that he or she needs in a clear, unambiguous manner. Redundant and unnecessary information can only lead to conflicts, confusion, and an increased likelihood of claims.

### Structural Drawings: the Future

The steel industry, lead by AISC, is promoting the practice where the design and construction team (architect, structural engineer, and Contractor including and hence the steel fabricator) work within a single three-dimensional digital model of the structure. As this technology is embraced, it will fundamentally change the role of the structural engineer, his or her scope of work, fee structures, and the form and content of the structural drawings. During the transition, it is important that we not mix these two fundamentally different approaches to preparing structural documents. The recommendations offered in this article were developed in the context of the traditional scope of work and fee structure, and will have to be reformulated when adopting this new delivery system. ■

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