Coordination and Completeness in a BIM Dominated World

By David Ruby, P.E., S.E., SECB, F.ASCE

In earlier times, when computers were neither available or essential, one objective of the structural design process was to discover a computational method which was elegant, simple, and appropriately accurate. When such a process was identified, it was recorded as an expedient approach to solving a recurring structural design problem. Thus, quick "Rules of Thumb" became essential resources for the structural engineer. As computer software has proliferated, become more comprehensive, and been made very user friendly, the importance of Rules of Thumb and approximate methods has been diminished. It has been argued that, with computational speed and ease of application of computer methods, the need for approximations and Rules of Thumb no longer exists. However, equally imposing arguments can be made for the value of these quick approaches, such as:

- *The structural engineer should have tools to make on-the-spot intelligent decisions.*
- *A reasonable solution is often required as computer input.*
- *The validity of the computer output should be verified with rational approximations.*

The above paragraph is a direct quote from a February 2000 article in *Modern Steel Construction* entitled "Rules of Thumb for Steel Design."

Twenty years later, the Rules of Thumb still apply regardless of the vocabulary and modified delivery methods:

- Building Information Model
- BIM Execution Plan
- COBie (Construction Operations Building Information Exchange)
- Clash Detection
- Integrated Project Delivery (IPD)
- Level of Development
- Model Element Author
- Polygonal Modeling
- Virtual Construction

No matter the means of communication, our responsibilities have not changed: review and confirmation of the results of our analysis, transfer of the design results to construction documents, and compliance of construction documents with governing codes. Technology has allowed the design process to be completed in greater detail, moved us from 2-D to 3-D, advanced our analysis and design capabilities, and allowed today's structural engineers to achieve structural feats never dreamed of in decades past. However, we have not always viewed technology for what it is not – it is neither all-inclusive nor self-sufficient. It is only a *tool*, a tool capable of enhancing the process, but a tool that will never replace a competent structural engineer.

Kauffman Center for the Performing Arts in Kansas City, MO.

In a high-rise building design, technology often utilizes rigid diaphragms to distribute the lateral forces to the lateral force-resisting systems, complete the structural analysis, determine the structure's member forces, or, in an extreme case, will utilize the rigid diaphragm to account for the lack of a well-defined load path. However, the computations necessary to resolve those related diaphragm forces are beyond the capability of technology. They are and always will be the structural designer's responsibility to recognize and perform.

Similarly, technology analyzes the structure based on the structural engineer's assumed boundary conditions. Subsequently, the structural engineer reviews the construction documents to ensure the design concept is shown, essential elements are identified, and the scope and quality of work to be performed is communicated. The engineer must also ensure that construction details comply with the initial design assumptions and vice versa.

Twenty years later, the industry's expectations related to the quality and purpose of our construction documents have not changed. These expectations are clearly stated in CASE Document 962D, *Guideline Addressing the Coordination and Completeness of Structural Construction Documents*, initially published in 2003 and revised in 2013.

962D states that quality can be characterized as:

- *Meeting the requirement of the owner as to functional adequacy; completion on time and within budget; life-cycle costs; and operation and maintenance.*
- *Meeting the requirements of the design professional as to the provision of the well-defined scope of work; budget to assemble and use a qualified, trained, and experienced staff; budget to obtain adequate field information prior to design; provisions for timely decisions by the owner and design professional; and, contract to perform necessary work at a fair fee with adequate time allowance.*
- *Meeting the requirements of the constructor as to the provision of contract plans, specifications, and other documents prepared in sufficient detail to permit the constructor to prepare priced proposal or competitive bid; timely decisions by the owner and design professional on authorization and*

processing of change orders; fair and timely interpretation of contract requirements from field design and inspection staff; and, contract for the performance of work on a reasonable schedule which permits a reasonable profit.

- *Meeting the requirements of regulatory agencies (the public) as to public safety and health; environmental considerations; protection of public property including utilities; and conformance with applicable laws, regulations, codes, and policies.*

962D states the *Purpose of the Construction Documents*: "Documents, including building information models, drawings, and specifications, are the tools structural engineers use to communicate the elements of the design of structures to contractors. Contractors use the Documents to develop and submit bids for construction of the structure and then, if selected, to implement the design. In order for the bid to be accurate, the Documents must describe in sufficient detail the elements of the structure to be built, the quality with which it is to be built, and any special requirements governing its construction. Regardless of the format, the Documents must be developed to a sufficient level of completeness and coordination so that contractors can, within customary time constraints, develop a price, submit a bid, and, after award of the contract, build the structure in a manner consistent with their understanding of the scope of the Documents at the time of bidding. Inherent in this process are the issues of what is customary in terms of the level of detail and coordination of the Documents and the degree of scrutiny required of the bidder. For example, is a steel subcontractor able to rely solely on the structural documents, or must he also review the architectural and mechanical documents? If the contractor is required to review documents created by multiple disciplines, how much effort would it be reasonable to expect of the contractor in comprehending the totality of the design?

Inadequate communication results in budget and schedule overruns, disappointed owners, and a potential risk to the safety of building occupants and the public. Successful communication is critical for the protection of public safety, which is a structural engineer's first priority as a professional."

The three C's > Essential ingredients for successful project execution in a BIM dominated world: ***Constructability*** *through* ***Collaborative*** *design and open and shared* ***Communication***

Technology does not compensate for missing elements, such as incomplete load paths, base fixity, or member stability. Too often, design documents are developed directly from the analysis model without an intermittent review or constructability input. Load paths may go undefined, unique features of the design concept, lateral-force-resisting system, or material relationships may not be identified or communicated, and all result in contractor-initiated RFIs with an all too familiar response: "But, It Worked in the Model!" It has been suggested that Albert Einstein stated, "I fear the day that technology will surpass our human interaction. The world will have a generation of idiots."

What is evident after the author's 60 years in the industry? My Many *Rules of Thumb* still apply:

- The devil is in the details;
- The lightest structure is not always the least cost;
- Load always goes to stiffness;
- Shop time is always less costly and more efficient than field time;
- Structural steel cost is not related to pounds per square foot or based on dollars per ton. It is directly related to material choice, complexity of details, and manhours to fabricate and erect; and,
- When an ironworker offers a comment, it is time for the engineer to listen.

Cost is impacted by our design decisions related to complexity, the economy of scale, bay size, member and material selection, bolted vs. welded options, shop vs. field welding, and shop vs. field assembly. It is also impacted by truss vs. girder "do's and don'ts," lateral system, column size, and the design decisions related to strength vs. deformation vs. serviceability. All these considerations have been ignored by advanced technology.

Also, technology has led to compressed schedules and reduced budgets. This precludes the consideration of structural alternatives, material substitutions, or the development of difficult or complex connections, so they are delegated. Perhaps, in some circumstances, the better solution is to modify the framing concept. However, the owner and architect have established a fixed release date leaving no time for innovation and resulting in unanswered questions about the braced vs. moment frame lateral system; column through forces; lateral-force-resisting system description; special requirements of the design concept and/or shoring necessary to maintain the final structure's positioning.

Many elements of the design/construction process have been impacted by technology. Software has replaced manual methods, computer screens have replaced drawing boards, simple solutions may not be sufficient to check complex structures, and hand analysis is out of the question. Building models are generated directly from the analysis model, which in turn creates the construction documents through digitized printers. Even estimates are automated, and engineering team members rarely ask themselves, "How can I improve the process?"

Until the advent of Building Information Modeling, the basic process had remained virtually unchanged.

Now, however, design professionals have a limitless opportunity to expand their role within the process, create their own *Rules of Thumb*, and harness technology to improve the quality and content of their construction documents. They can do so by engaging in a collaborative environment and truly focusing on infusing construction knowledge and experience (constructability) through collaborative problem solving and design development. Such a focus on the process will make them much more than providers of information and technical solutions.

Communication within and between the design and construction communities through integrated design teams will provide answers to those unanswered questions.

Silos of influence will disappear, and jointly developed, collaborative solutions will become the order of the day.

And all stakeholders will benefit.

Remember: Communication is the goal. It is not for you to know and the contractor to find out!▪

The online version of this article contains references. Please visit **www.STRUCTUREmag.org**.

David Ruby, Chairman / Founding Principal, Ruby+Associates, Inc. authored AISC's Design Guide #23, Constructability for Structural Steel Buildings. (druby@rubyandassociates.com)

References

Building Information Modeling for the Engineer of Record, White paper prepared by Council of American Structural Engineers, July 23, 2011

Constructability of Structural Steel Buildings, American Institute of Steel Construction, Design Guide #23

Guideline Addressing Coordination and Completeness of Structural Construction Documents, Council of American Structural Engineers 2003, Revised 2013

"Rules of Thumb for Steel Design," *Modern Steel Construction*, February 2000, Socrates A Ioannides and the late John L. Ruddy, Structural Affiliates International, Inc., Nashville, TN