The Pacific Structural Steel Conference (PSSC 2013)
Singapore, 8 – 11 October 2013

Leveraging BIM for Steel Construction - Current State of Integrated Processes

Jerod J. Hoffman, PE
Principal
Meyer Borgman Johnson; 12 South Sixth Street, 810, Minneapolis, MN, USA 55304
Email:jhoffman@mbjeng.com, Website: www.mbjeng.com
Also
Structural Manager, CFO & Treasurer
TritonTek; Corner Archbishop Reyes Ave. and Mindanao Ave., Cebu, Philippines 6000

Abstract

Building Information Modelling (BIM) has changed the way many practicing structural engineers deliver their design for the built community. Starting out only as a 3D tool for visualization, BIM now allows much higher levels of collaboration and can produce significant savings in time, materials, and other economic resources. Since its adoption by the design community in the United States in the late 2000's, BIM has become the standard way of doing business in the U.S. and in many other countries. However, learning how to truly leverage BIM for significant benefits to schedule, budget, and constructability in steel construction is still something very few structural design firms embrace and implement. Learn the latest on these exciting developments and help move the steel industry forward throughout the world.

1. Background Information

Before delving into the more advanced topic of leveraging BIM in steel construction, it will be helpful to broaden perspective and look at definitions and an overview of BIM and it's history.

1.1. Definitions

Sometimes people use the same words in different ways or different words to mean the same thing. The following simplified definitions are provided at the outset to help everyone understand and relate to the concepts in this paper.

1.1.1. List of Definitions

i. BIM: "Building information modeling (BIM) is a process involving the generation and management of digital representations of physical and functional characteristics of a facility. The resulting building information models become shared knowledge resources to support decision-making about a facility from earliest conceptual stages, through design and construction, through its operational life and eventual demolition." [1]

ii. Construction Documents (CDs): The status of the design documents when they are ready to be bid upon by contractors, prior to the commencement of construction. These drawings are also referred to 'Detailed Drawings.'
iii. Detailer: In steel construction, the person or group of people that create the shop (workshop) drawings. They can be a part of the steel fabrication company or a separate company.
iv. EOR (Engineer of Record) – The engineer who oversees and takes responsibility for the design and construction documents, normally providing a stamped set of construction documents at the end of the design period. EORs typically need to be licensed to practice in the state or province where the project is located.
v. Fabricator: In this context, the company that procures, manages, fabricates and usually delivers the steel for the project. Sometimes they also hold the contract for erecting the steel.
vi. Shop Drawings: Also called 'Workshop Drawings', these documents come after CDs, and are typically produced or overseen by the subcontractor that will be performing that portion of the work.

1.2. A Short History on BIM

Although not originally called BIM, the original concepts of BIM were being developed in the early 1970's [2]. The following are key benchmark dates relative to BIM used for buildings and steel construction:

- 1987 – Graphisoft's Archicad is released
- 1993 – Tekla's predecessor (X-Steel) releases commercial version
- 1997 – Revit's predecessor begins development
- 2000 – Revit Version 1.0 (architectural platform only) is released
- 2004 – Tekla Structures launched (replaces X-Steel)
- 2005 – Revit Structure released (part of the family of Revit programs)

1.3. Current BIM Tools Dominating U.S. Building Design

There are generally two classes of BIM software within this industry; one class is primarily focused on producing design models and resulting paper contractual drawings, and the other class is primarily focused on producing 'machine readable files.' In this paper the former class is referred to as 'Design BIM' and the latter class as 'Construction BIM.'
The most proliferate Design BIM software in the U.S. are Revit, Archicad and Bentley BIM.
The most proliferate Construction BIM software in the U.S. relative to steel construction are Tekla and SDS/2 (by Design Data).

1.4. Influencing BIM Organizations and Promoters in the U.S.

The Associated General Contractors of America and the American Institute of Architects have both create standard documents to help guide uniform BIM usage in the U.S. A related international organization on interoperability, which started in the U.S., is called buildingSMART. While standard documentation has been or is just being released by these

organizations, the formal implementation of these documents on typical U.S. projects is very limited at this time. More information can be found on the following websites.

i. http://bimforum.org/lod/
ii. http://www.aia.org/contractdocs/training/bim/aias078742
iii. http://www.buildingsmart.org/openbim

2. BIM Divide: Design BIM vs. Construction BIM

Using BIM for design and construction is still relatively new and, therefore, does not have a level of uniform usage like 2D paper construction documents have had for the last several decades. Furthermore, since 2D paper documents are still the baseline contract document type for EORs on 99% of projects in the U.S., the use of BIM is mostly used non-contractually as a tool for coordination. As time goes on, the use of BIM as the contract document will increase. As such, BIM is currently fundamentally divided into two categories in its practical usage today: Design BIM and Construction BIM.

2.1. Design BIM

The main focus of design BIM is greater coordination within the design team (generally the architect, structural engineer and mechanical engineer). The final result of using Design BIM is still generally 2D contract documents. In addition to coordination with other disciplines, Design BIM enhances the efficiency of document production once the users have gained a fair amount of experience with the tool and with design documents in general.

In most cases, there is not a goal to pass the Design BIM to the general or sub-contractors so that they can rely and implement the information with 100% accuracy, as if it was the contract document. In terms of AIA nomenclature, Design BIM is at a Level of Development (LOD) of either 200 or 300. This main focus of Design BIM, plus the historical approach to creating 2D design documents, is what limits the use of Design BIM on the other side of the contract (for Construction BIM).

2.2. Construction BIM

The main focus of Construction BIM is use by contractors and fabricators for actual fabrication and construction of materials to 100% accurate dimensioning. Sometimes the files can be used as machine-readable, so the paper documents become secondary usage. In terms of AIA nomenclature, this is LOD 400.

Construction BIM is generally utilized by general and sub-contractors, not by the design team. Also, Construction BIM is usually started from the paper/pdf documents that are created by Design BIM. If Design BIM models are used for Construction BIM, then there are generally many manipulations and adjustments made (‘clean up’) in the Construction BIM before it is ready to be used for fabrication and construction.

3. Integrated BIM

Design BIM and Construction BIM both have valuable uses and are improving the overall quality and economy of construction in the U.S. However, finding ways to bring these two disciplines together can produce results that add a whole new dimension to the value of BIM. If one can effectively overlap Design BIM with Construction BIM, one develops something that can be called Integrated BIM.

Integrated BIM is a lean process that removes waste and creates additional value by reducing construction schedules, reducing construction costs, and reducing construction risk. To be effective at Integrated BIM one must understand the critical details and processes (the why's) of both Design BIM and Construction BIM. The remainder of this paper will focus on different delivery methods and processes that leverage Integrated BIM in the U.S. design and construction practice today.

4. Steel Design and Delivery Methods using Integrated BIM

There are essentially four different methods currently being used by structural engineering firms in the US relative to going beyond 2D construction documents as the contract document or as non-contractual 3D BIM models.

4.1. EOR Delivers a Member Model ('Sticks Only')

The first method for delivery is when the EOR provides a model of the accurate steel member sizes, material properties and geometry. No connections are included. The main goal for this method is accurate dimensions in plan and elevation. This model is often used for procuring the steel shapes (often called a mill order). The fabricator or independent detailer generally take over the model after the contract is established with the Member Model.

4.2. EOR Delivers a Fully Detailed Model ("Fully Connected')

The second method for delivery is when the EOR provides a model that includes the items in 4.1, but also includes all connection materials and connection geometry (angles, plates, bolts, bolt holes, copes, preps for welds and sometimes welds). The fully connected model can be created before or after a steel fabricator is contracted for the project, but it is usually best to have the fabricator's input on the connections right after Method 4.1 above. This model can be used for a full 3D in-model review process in lieu of (or conjunction with) review of paper/pdf shop drawings.

4.3. EOR Delivers Shop Drawings

The third method for delivery is when the EOR provides both items noted in 4.1 and 4.2 above, plus the paper/pdf shop drawings. In this case the EOR is acting as (or working in conjunction with) a detailer and must have experience working with steel fabricators to provide a product that is standard and provides the best economy for the fabricator. In

addition to shop drawings, digital files used for fabrication machines are a standard deliverable to the fabricator.

4.4. A BIM Consultant Provides Services between EOR and Fabricator

The fourth method for delivery is when a BIM Consultant, experienced in steel detailing, is hired by the general contractor, owner, or others to provide the benefits of integrated BIM. The BIM Consultant is usually introduced into the project during the CD phase of design and they work closely with the EOR to understand the project and deliver a model and shop drawings described in 4.3 above.

5. Integrated BIM Processes in Steel Construction

The following are specific processes that leverage Design and/or Construction BIM models in structural and light-gage steel.

5.1. Digital Procurement of Open-Web Joist

Open-web steel joists are widely used on U.S. projects because of their cost efficiency and long-span capability. One of the common challenges in procuring steel joists is the longer lead time, partially due to the shop drawing submittal process. By leveraging a BIM-enabled procurement process, the time from release of Contract Documents to final approval of shop drawings can be reduced by up to 50% [3][4].

The joist manufactures in the U.S. do their own shop drawings for their proprietary products. Within the last few years all of the large joist manufactures have created the capability to receive, translate and respond using Construction BIM models. Therefore, the process and tools are now in place to make this new digital joist procurement process standard in the industry. However, it is likely that less than 5% of current joist projects utilize this method.

5.2. Using Shop Drawings & Bill of Materials as Bid Instruments

When typical construction documents are used as the means for bidding steel contracts, there is room for interpretation and customization relative to the connections, delegated portions of the structure and miscellaneous steel components. One option to standardize bid scope is for the project team to issue a full set of approved shop drawings and associated bill of materials as the bid instruments. These items are not normally created until the steel fabricator is hired. Under this scenario, the EOR or BIM consultant with steel detailing expertise is given the expanded scope of creating shop drawings independently of the steel fabricator. This process can lead to more precise bids by fabricators as well as weeks of schedule savings.

5.3. In-model Review and Approval of Construction BIM

Even with all the digital capabilities of today's technically-advanced U.S. construction market, reviewing paper and pdf shop drawings is still the most common practice. However, some firms have pushed to the next level by leveraging Construction BIM models to assist or

be the stand-alone shop drawing/model product for review and approval. Today's tools allow reviewers to process, mark-up and save comments within the native Construction BIM. Furthermore, free BIM review tools are currently being provided by some sellers of Construction BIM software, allowing greater usage of this process. This allows better reviews and more complete transfer of review comments, making the end product (fabricated and erected steel) more reliable.

5.4. Modular Construction

Due to ever-rising labor costs and increasing safety standards, the advantages of modular construction continue to gain more value. Modular construction in steel fabrication comes in many different forms. One example is a bay of steel beams or joists connected together on the ground and hoisted as a single unit. Another example is an entire room or rooms (hotel, apartment, dormitory, portion of a condo, etc.) assembled in a warehouse, often including mechanical and electrical systems and flooring and wall finishes, which are hoisted into place in a single large module. The limiting factors on both examples are usually crane capacity and/or maximum practical transportation size. Use of these modules speed up construction, reduce safety issues with construction at high elevations, and bring cost efficiencies to the production process. Construction BIM models with multiple disciplines participating are making modular construction a reality on more and more projects.

5.5. Panelized Light-Gage Walls

For the same reasons as modular construction, Construction BIM models are being leveraged to construct large panels of light-gage steel wall systems either off-site or away from the building footprint and then hoisted in place. Full coordination with other systems, such as structural steel and mechanical and architectural systems, is being performed in the Construction BIM, allowing for the advantages of these panelized systems.

6. Concluding Statements

While both Design BIM and Construction BIM have advantages over 2D forms of construction planning and procurement, leveraging processes that join these two BIM tools can bring additional layers of benefits. The structural steel market benefits most from Integrated BIM because of its inherent tight tolerances and fabrication time. For the steel industry to benefit more broadly from Integrated BIM there needs to be more resources devoted to the development of standard practices and training so all design and construction team members can participate in these rewarding processes.

7. Citations

[1] Wikipedia (Internet). May 28, 2013
[2] Eastman, C. M., D. Fisher, et al. (1974). *An Outline of the Building Description System. Research Report No. 50*. Pittsburgh, PA.: Inst. of Physical Planning. Carnegie-Mellon Univ.
[3] Hoffman, J.J. (2011). *Building Design & Construction Magazine*. Jan. 2011, USA, pp 48-51.
[4] Hoffman, J.J. (2011). *Digital Joist Procurement, In Proceedings of AISC Steel Day Webinar*. Sept.23 2011, USA