BIM and the Structural Engineering Community

By Dan Schinler, P.E. and Erik Nelson, P.E.

Although 2D and 3D modeling software has been used for decades to analyze and design structures, over the past few years a wave of new 3D modeling tools are allowing structural engineers and designers to create models for documentation and coordination as well. As a result, more and more structural engineering firms are embracing the Building Information Modeling (BIM) movement. BIM software is based on the object-oriented programming paradigm, in which *instances* of structural members are assembled to create a building structure. Each member possesses the information and functionality that fully defines it. In other words, a beam element knows its properties (e.g. material, sectional properties…), as well as its purpose within the structure (i.e. a horizontal member on level X, spanning between column Y and girder Z). The resulting BIM model contains a wealth of information which can be useful for inter-discipline coordination as well as internal coordination.

Survey of Engineering Firms

To assist in substantiating portions of the following discussion, the authors surveyed 11 structural engineering firms across the country, some with multiple offices (17 total responses). First to gauge the use of BIM; the survey asked what percentage of their projects were done using BIM software. The average was about 50%. More importantly, the survey additionally inquired about what percentage of these projects was BIM used for the following:

- Coordination (inter-discipline)
- Documentation (producing construction drawings)
- Analysis and Design (using third party analysis links)

The survey results indicate that creating drawings (documentation) is the primary use of BIM software (to date) at about 87%, followed by coordination at about 47%, and analysis and design at about 25%. This may be attributed to the fact that documentation is the only facet of BIM that structural engineering firms have complete control over. In other words, the documentation is not dependent on analysis links nor the modeling capabilities of the other disciplines.

Coordination

The underlining factor driving the BIM movement has been the enhanced coordination tools among the design team (architect, structural and MEP engineers). In essence, the team is generating a virtual prototype of the building containing all aspects – architectural, structural and mechanical. This allows the team to coordinate and make better design decisions based on actual, accurate 3D geometries. Furthermore, the model can be used as a construction tool by contractors (construction cost estimating, scheduling and phasing) and by owners (facilities management). This downstream use is motivating owners to require BIM models to be submitted as part of the project requirements.

The use of BIM for coordination requires very conscientious modeling by the entire design team. The information can be shared either across platforms (via common file formats like IFC, CIS/2 or SDNF) or within platforms (via multi-discipline formats like Revit). The former allows for 3D coordination and clash detections, and the latter offers the additional functionality of monitoring and automating changes between the models. The result is a better building design, since many of the coordination issues are identified and resolved during design rather than propagating into construction or beyond. We know that coordination can be more time consuming than structural analysis, and BIM shows great promise to help reduce the coordination time.

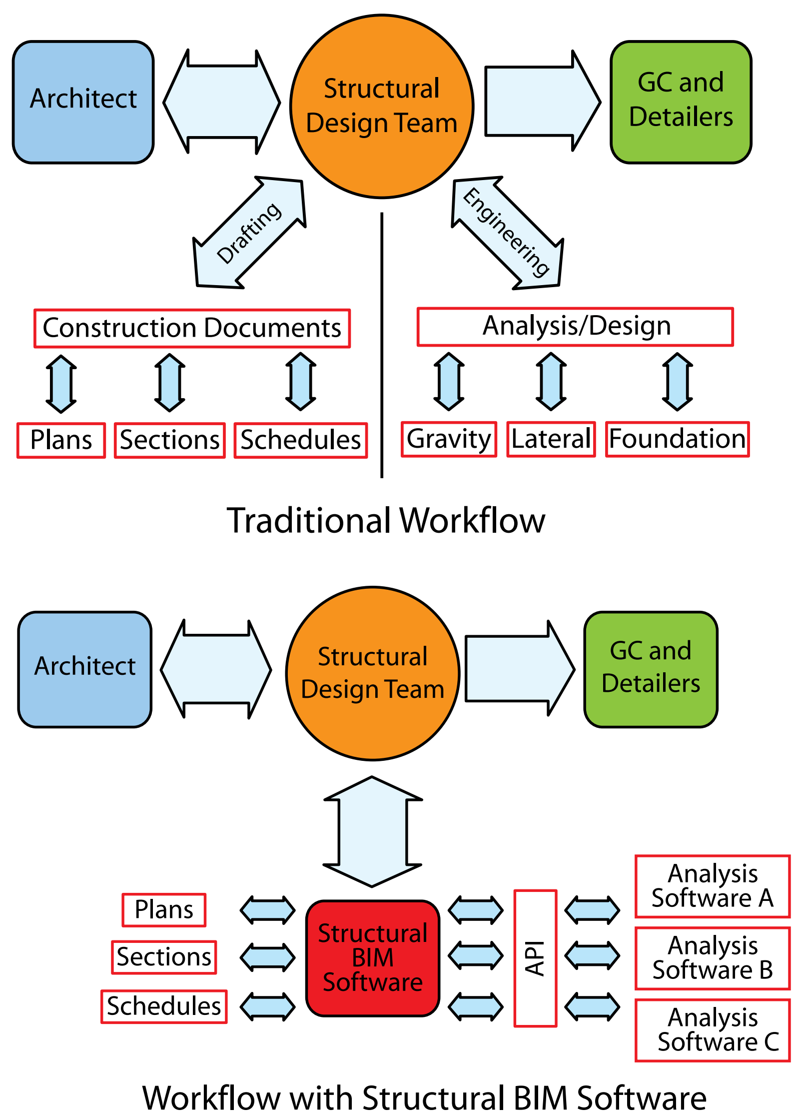

Figure 1.

It should be noted that BIM coordination tools do not replace the communication among the design team. Quite the contrary, the team needs to clearly define the use of the model and the necessary level of detail required to achieve its use. A well built structural BIM model is only as useful as the models it is linked to and coordinated with.

Structural BIM software (namely: Bentley® Structural, Autodesk® Revit Structure and Tekla Structures) aim to further leverage the model by not only using it to generate the construction documents, but also internally coordinate them with results from analysis/design software. This idea of generating and storing all the information necessary to analyze, design and document the structure is very powerful and requires a departure from the traditional workflow of a typical structural design office (*Figure 1*).

In this new workflow, drafting and engineering tasks are no longer separate, but instead integrated and shared in the same file. Since BIM has such an impact on the way we design and document, structural firms need to determine how to incorporate it into their office. Depending on their office structure, BIM may be welcomed or it may be resisted. In the case of engineers who are responsible for both design and drafting (often common for smaller firms), there is less confusion as to where BIM fits. However, in the traditional arrangement of a separate drafting department independent of the engineers, there may be some uncertainty as to who should do the modeling – drafter or engineer.

The survey asked who was doing the modeling – drafters or engineers. Based on the survey results, about 60% of the drafting staff uses BIM as opposed to 20% of the engineering staff. BIM is seen by many engineers as something not unlike drafting, and as such, should be controlled by the drafters. Other companies are restructuring the office and requiring some engineers, who are interested in this technology, to learn the BIM tools and help document and annotate a particular project. In some ways, BIM has blurred the lines between the traditional engineer/drafter dichotomy, with engineers picking up more coordination work using the BIM model. In some cases, engineers are more comfortable than drafters working within the 3 D environment because of working with finite element modeling software for many years.

The participants of the survey were given an opportunity to list three obstacles or pain points, experienced as they implement BIM software. The following is a list of key responses relating to coordination (paraphrased):

- Difficult at times to convert between different packages.
- Coordinating with architects as to ownership of elements. (Who owns the concrete columns?)
- The learning curve is very, very steep.
- Lack of documented best practices.
- Engineers are taking on more responsibility if the BIM model is transferred to the fabricator, and how is this additional liability mitigated?
- Training and defining the new modeling requirements and responsibilities for the users, and how this affects the technician/engineers relationship.
- Lack of sufficient time and resources to learn BIM software.
- BIM requires structural engineers to know too much too early, before they are ready to know it. Especially in schematic and design development, when framing plans are initially laid out with just lines representing beam locations without a final design, which will not be known for some time yet.

Documentation

Out-of-the-box structural BIM software can develop a decent set of Construction Documents. However, many firms take pride in the presentation of their drawings and have developed extensive standards that are easily conformed to using CAD tools (i.e. lines and text), but require considerable customization when working with the parametric nature of BIM elements. In some cases, the standards are just unattainable with the tools offered. However, once the limitations are identified and the alternatives are accepted, it's often for the good of the documents. Much time and effort is spent on the first pilot projects to customize the annotation and detailing tools, and in some cases "fake" in the necessary detailing to both convey the design intent and conform to the company standards. However, much of the upfront customization effort is rewarded since the integrated BIM (all the information contained in one file) will accommodate late changes to the design and propagate the changes throughout the documentation.

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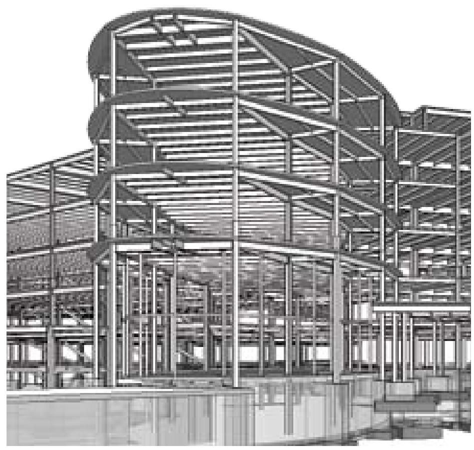
The following is a list of key responses relating to documentation pain points (paraphrased):

- Cannot produce drawings as quickly as with Cad.
- Manually modifying sections to remove unwanted graphics and adding additional graphics.
- Dealing with not being able to "fudge" anything on drawings.
- Difficult to learn. Difficult to create drawings that appear the way the firm prefers.
- The software, out of the box, is not ready for production work. Firms invest SIGNIFICANT man-hours into simply getting the BIM software to produce drawings that conform to company and industry standards.
- More difficult to annotate in BIM as opposed to CAD.
- Conversion of CAD standards to BIM is time consuming.
- Limited drafting abilities for adding additional information to plans, sections and elevations.
- Last minute design changes that are relatively easy in 2D can be tough in 3D.
- Conventional wood framed structures are difficult to model and document.
- Just when a firm gets nearly comfortable with Revit Structure, they are now having to learn Bentley BIM for a particular client.
- It is very time consuming to accurately model literally every structural element at every location it occurs. Traditionally, structural drawings are somewhat diagrammatic with a lot of typical details and symbols. To repeat a particular element several times or even a hundred times, around the building seems unwarranted when a single detail has typically sufficed.



Analysis and Design

The idea of seamless links between BIM and analysis models is great in theory but has not come to fruition in practice. To date, the links have been far from reliable and in most cases counterproductive. The software packages vary in the way they define elements, making it difficult to develop robust links that ultimately gain the confidence of the users. It is the authors' opinion that one of two things need to happen before analysis/design can be readily used with BIM: (1) the BIM software needs to become mainstream, such that analysis/design software are motivated to develop seamless links that really work; or (2) the BIM software packages need to incorporate analysis/design, thus eliminating the need to export/import and create another model. It should be said that the latter does not necessarily replace some of the leading analysis and design packages. Realistically, the BIM software only needs to address the gravity design and leave the lateral design to more sophisticated packages. The lateral design often involves generating crude models (diaphragms, walls and brace frames – often idealized significantly from the physical construction) and subjecting them to very sophisticated loading. Ultimately, the transposing of the lateral elements to the BIM model (or CAD documents) is much more cumbersome and poised for mistakes than the gravity design (beam sizes, studs and camber in the case of composite steel design), which can be integrated into the BIM software.

The following is a list of key responses relating to analysis and design pain points (paraphrased):

- Getting the analysis links to work has been very difficult. Some firms have held off on analysis links until the next versions come out to see if it is more useful.
- BIM sometimes gives the appearance of being further along than you actually are in design.
- Most of the analysis links are not good: too many mistakes during the export/import process.
- Little to no confidence in the accuracy of the links. BIM platforms need to mature before the analysis program links (for ETABS, RISA, RAM, etc.) can further develop.
- The promises of the links between BIM and analysis programs being "seamless" are a marketing fallacy. They only work well in one direction, one time.

Conclusion

Clearly, it is no longer a question of whether BIM will succeed or fail – it is already working its way onto projects. The positive attributes of BIM greatly outweigh the negatives, especially in our industry. The challenge lies in trying to utilize all that structural BIM packages have to offer – coordination, documentation, and analysis and design. The key to success is to fully define the purpose of the BIM model as it relates to the specific project and project team. By setting realistic goals and understanding the limitations of the software, overcomplicating a project by trying to do too much with a single, often unwieldy BIM model can be avoided.

Many early adopters have been mandated by their clients to produce a BIM model; however, many structural engineering firms, both large and small, still crave and seek better technology. They are willing to spend the resources to develop and nurture the latest technology, be it for competitive advantage or to reduce the fear of feeling left behind (whether a justified or not). To the extent BIM revolutionizes our industry remains to be seen, but it should be realized that BIM is simply a tool and, albeit powerful, only as good as its user.▪

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