Structural Engineering &DESIGN

The benefits of reinventing the wheel

BIM AND IPD BRING FUNDAMENTAL CHANGES TO ROLES IN A STRUCTURAL ENGINEERING FIRM

By Rick Oehmcke, S.E.

Not that many years ago, few structural engineers were aware of building information modeling (BIM) and they could not have imagined the dramatic change it would bring to the AEC industry. Today, some structural engineering firms have made impressive strides toward implementing BIM as their primary production platform while most have at least investigated how this new technology of 3D modeling of the building structure will affect their product delivery. Much has been written about the potential of BIM and how it can improve the design process, but the most profound impact on a structural engineering firm implementing BIM is on the roles and workflow of the staff.

Integrated project delivery leveraged the 3D structural model on Seattle Children's Bellevue Clinic to bring team members together for visualization and coordination.

Further expanding the benefits of BIM is the utilization of integrated project delivery (IPD) to effectively create a unified team with the owner, design team, and contractors. The advent of the IPD process will bring even more changes to workflow and roles. IPD restructures the delivery process so that all team members are on an equal footing contractually and allocates sharing the risk and reward of design and construction. The mechanism that facilitates communication, visualization, and collaboration between all team members is the shared 3D model and the power of its parametric database.

Traditional workflow and design process

The paradox of our profession is that while we conceive a structure in the 3D realm, our deliverables are normally produced as 2D paper drawings. Whether 2D CAD or ink on Mylar, the finished product for structural engineering firms has historically been a set of drawings with lines, arcs, symbols, and text that represent the original 3D concept. These drawings then serve as a contract document for a general contractor to interpret back into a 3D reality during construction. The real potential for BIM is to utilize the power of the 3D model for collaboration and visualization in as

many aspects of design and construction as possible.

The traditional workflow of a structural engineer's office has been established over the years to efficiently produce a set of high-quality structural drawings that are well coordinated with the drawings of the architectural client and fellow consultants. The process begins with principals and project managers conceptualizing the structural system and then conveying the design to project engineers who follow through with analysis and structural detailing. Analytical 3D models are often utilized for structural system design, but seldom have a direct connection to the 2D drawings. Projects are typically phased into increasingly developed design levels with 2D drawing sets acting as the deliverable product.

These drawings are produced in most offices by skilled technicians utilizing CAD software to reflect the design intent onto 2D drawings. Throughout the process, the engineers provide review and quality control, typically with colored pens and highlighters on check prints. Documents are plotted at each phase and ultimately serve as the basis of a contract set used by a general contractor to prepare his bid and construct the building. Architectural, structural, civil, and MEP drawings are manually interpreted and cross referenced to coordinate the entirety of the building's systems. This process has been honed and refined into an effective system for conveying the information necessary to construct a building.

Firm integration of BIM workflow and process

BIM necessitates a paradigm shift in the methodology and workflow of a structural engineer's office and fundamentally moves the functional deliverable from 2D drawings to a 3D model. While 2D drawings will remain the legal instrument of service for the foreseeable future, the 3D model will be the vehicle by which the structural engineering firm will convey the structural intent to the rest of the design team and ultimately to the general contractor and owner. Implementation of BIM in a structural engineering firm is challenging beyond the cost of the software, hardware upgrades, and training. In the traditional 2D workflow, roles for a firm's team members were clearly identified and time tested for efficiency and product quality. The new paradigm of using BIM blurs the line of who is most suited for creation and updating of the model. Traditional roles need to challenged and the most effective implementation requires buy-in at all levels of the firm; consider the following new roles:

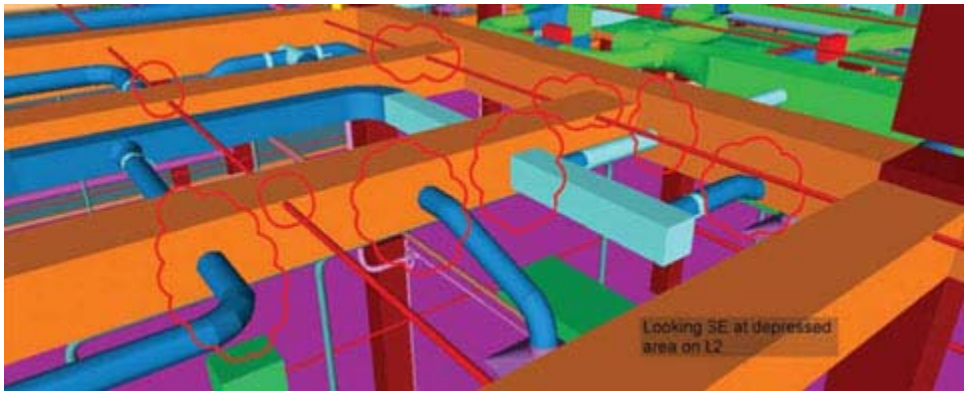
Project managers and principals may not spend a lot of time modeling, but their experience must be leveraged for the BIM process to be successful. They must be able to access the model for review, QA/QC, and be able to communicate fluently with owners and architectural clients. Maximum efficiency utilizing BIM can only be realized by working directly in the 3D model and not continuously moving back and forth between the 2D drawings extracted from the model. As the sophistication level increases with the design team's use of BIM, the 3D model becomes the actual design and coordination tool and the 2D drawings become less significant during the design process. The use of 3D screen capture of the model and electronic mark-ups should be used extensively to expedite revisions to the model.

Most design and project engineers have grown up with computers and feel at home in the 3D environment. However, *virtually* constructing a building in BIM requires the input of an experienced structural engineer who has seen many buildings go together and understands how structural systems interact with other disciplines' systems. Teaming junior and experienced engineers — while using BIM for the layout of the framing system — provides the ideal mentoring opportunity for engineering design as well as 3D model building.

Drafters in structural engineering firms have traditionally operated as production technicians who

transcribed detail sketches and “red-marked” plans from engineers into contract documents while following firm standards for drawing production. The move to BIM requires the technician to have a solid understanding of the actual construction process to be able to create a model that accurately reflects what will be built in the field. Their ability to communicate effectively to the engineer how the model is evolving and changing through each phase of the process will be instrumental in the success of the project. The need to understand the structural model as well as the requirements of the architect and other consultants increases the drafter’s role as an important project team member.

As a key part of our transition to an all-BIM production environment at PCS Structural Solutions, we have developed a BIM Abilities Matrix that analyzes team member roles, identifies the BIM skills necessary, and to what extent each member of the firm will need to be trained to utilize the model most effectively. The matrix also acts as an evaluation tool to determine how individuals are progressing toward learning their applicable BIM skills. A formalized in-house training process called PCS University addresses the needs for each level of responsibility and provides the skill sets required. These classes were set up taking advantage of numerous resources including firm-wide expertise in analysis, modeling, and detailing in BIM.



Bringing together design and contractor’s models allowed for real time clash detection — conflicts are resolved virtually prior to any work starting in the field.

BIM workflow and process in the project team

Technical limitations of the BIM software along with the structural engineering firms’ extent of understanding of the application and training will dictate to what level BIM can be utilized on a project. Interoperability with analysis and BIM software will dictate not only how the 3D model is built, but which team members will take active roles in model building during the various stages of the project. The entire team, both internal and external to the structural engineering firm, must have a clear understanding prior to starting the model of how the model will be used throughout the project. Who will use the model, what will be the desired workflow, what mechanism will be used for collaboration, and the description of the deliverables at each phase of the project need to be determined. How the model is built also has a direct impact on the intended use by all team members. Will the model be used strictly for the extraction of 2D contract documents or will the model be shared with the architectural client and other sub-consultants? Will it be used by a general contractor to facilitate the construction phase of the project and will it ultimately be used by the owner for future facilities management? How will the contractual relationship be structured between members of the design and construction team?

Using the model and technology to get the right people together at the right time fosters the collaboration necessary for a successful IPD project, as shown here in the PCS Structural Solutions technology conference room.

A checklist clarifying these issues will help establish modeling priorities and understanding between team members. The process of linking architectural, structural, and MEP 3D models can be most effectively executed when team members agree to a protocol for who will be responsible for creating the model element and maintaining it during the project. The extent of development during the project is also critical to project efficiency. The AIA recognized the importance of both of these issues and they have been addressed in the creation of a new contract addendum document, AIA E202, in which the model element author and level of development for each phase of the project are identified.

The next step for BIM — Integrated project delivery

General contractors and their sub-contractors (most notably MEP) have been leveraging the power of BIM to build 3D models for visualization, coordination between trades, and facilitation of shop fabrication, as well as for scheduling purposes and quantifying take-offs. The parametric database that is the foundation of the BIM model can be utilized by the general contractor in many ways to enhance the construction process. It is rare, however, that the 3D model used for design is also used by the general contractor. How the model is built, software incompatibilities, and traditional contractual arrangements conspire to make a worthwhile transfer of the 3D model difficult. Yet other industries such as automotive, naval, and aeronautical manufacturing have successfully relied on the same 3D models from concept to completed product as a vehicle to transfer information though all phases of design and manufacturing. One of the key elements to their success is that design and manufacturing elements are bound together by contractual relationship or corporate alliances. In the construction industry, integrated project delivery (IPD) allows this relationship to exist between owners, designers, and contractors by the use of a tri-party agreement that shares risk and reward while mandating mutual cooperation. With this arrangement, the 3D model may be freely exchanged between participants and the model's composition and structure can be negotiated for maximum benefit for everyone's use.

Case study — PCS Structural Solutions recently completed an IPD project for Seattle Children's in Bellevue, Wash., as a member of a tri-party agreement with the owner, NBBJ Architects, and Sellen Construction. The IPD process was enhanced by the use of BIM and pushed the application of the 3D model to new levels. The project consisted of an ambulatory surgery center with an attached parking garage covered by a landscaped plaza. The Revit Structural model was imported into ETABS and

ADAPT analysis software for the structural design. Architectural and structural models were linked using Revit, and the mechanical contractor used Navisworks for clash detection of their 3D HVAC and plumbing models. The models were also used for collaboration with the geotechnical engineer, civil engineer, and earthwork contractor in design and installation of a soil nailed wall. The general contractor used the structural model in conjunction with the formwork contractor's development of their shop drawings and phasing.

Throughout the project, BIM allowed various designers and trades to be able to communicate with each other by merging their individual 3D models. Teamwork was further enhanced by including subcontractors in the design meetings to review the model and comment on constructability. This ability to collaborate using the models as tools to virtually construct the building prior to starting actual construction helped to find interferences and conflicts. Minimal requests for information (RFI) and rework during the construction phase validated the efforts associated with BIM and the IPD process.

Structural engineers' role in bringing value to the process

As structural engineers, we have been involved with all types of delivery methods including negotiated bid, design-build, and team build projects, but unless true collaboration is enforced by contractual language, the process can not maximize the value to the owner. The linked 3D models and their associated parametric database can act as the key component to a successful BIM/IPD project for all team members. The building structure is often the primary coordination element for a project and this places the structural engineer in the position to act as the facilitator for collaboration. BIM and IPD allow the right people to be involved in the process at the right time to validate and buy into design decisions — this can be a significant "win" for the structural engineer.

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